THE 12TH INTERNATIONAL WORKSHOP ON APPLIED MODELING & SIMULATION

OCTOBER 30 - 31 2019

NUSS KENT RIDGE GUILD HOUSE
SINGAPORE

EDITED BY
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The 12th International Workshop on Applied Modelling and Simulation

October 30 - 31 2019

Singapore

Organized by

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WAMS 2019 Location

NUSS, Kent Ridge Guild House
9 KENT RIDGE DRIVE, 119241, Singapore

WAMS 2019 Scientific & Social Events

Wednesday, October 30th
Oct 30, 845-1200 AsiaSim & WAMS OPening, KeyNote Speeches

Oct.30, 1200-1330 AsiaSim & *WAMS Working Lunch*

Oct.30, 1400-1730 **STRATEGOS** WORKSHOP

Oct.30, 1800-1930 AsiaSim & *WAMS Welcome Cocktail*

Oct.30, 2100-2230 WAMS Night Drink at Long Bar, Raffles Hotel

Thursday, October 31st
Oct.31, 900-1200 WAMS Session 1 & 2

Oct.31, 1200-1330 AsiaSim & *WAMS Working Lunch*

Oct.31, 900-1200 WAMS Session 3 & 4

Oct.31, 1900-2200 GALA DINNER at S.E.A. Aquarium

If you are interested you can also send request to free participation to:

Friday, November 1st
Nov.1, 1400-1700 James Cook & Genoa University Workshop (optional)

Tracks and Workshop Chairs

Digital Fruition of Cultural Heritage & Architecture
Chairs: Grazia Tucci, Florence University

Serious Games
Chairs: Michael Conroy, KSC NASA, Riccardo Di Matteo, MAST

Simulation Techniques and Methodologies
Chairs: Giovanni Luca Maglione, SIM4FUTURE; Simone Youngblood, APL Johns Hopkings University, USA

Simulation for Applications
Chairs: Matteo Agresta, University of Genoa; Jen Hsien Hsu, De Montforrt University, Leeds, UK

Simulation for Emergency & Crisis Management
Chairs: Marina Massei, DIME, Italy - Terry Bossomaier, Charles Sturt University, Australia

Simulation Tools for Human Reliability Analysis Studies
Chair: Antonella Petrillo, University of Napoli, Partenope, Italy

Serious Games for Strategy
Chairs: Francesco Bellotti, Elios Lab, Italy - Gregory Zacharewicz,University of Bordeaux

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Immersive Solution for Product Design
Chairs: Letizia Nicoletti, CAL-TEK SRL

Innovative Solutions supporting Interoperability Standards
Chairs: Antonio Padovano, MSC-LES, UNICAL

Mixed Reality & Mobile Training enabling new Educational Solution
Chair: Marco Vetrano, Simulation Team

WAMS Co-Chairs' Message:

Welcome To WAMS 2019!

Dear Participants, this year we move to Singapore for the 12th edition of WAMS, after Europe and America we are exploring also Asias, therefore the event had since its beginning registered participation from all around the World.
This Singapore Edition is developed in strong Synergy with our Colleagues of ASIASIM, National University of Singapore, Nanyang Technological University and the Society of Simulation and Gaming of Singapore. Indeed 2019 Edition is co-located with ASIASIM 2019 into the wonderful structure of the NUSS at Kent Ridge Guild House.
WAMS is also hosting the STRATEGOS Workshop: A New Way to Succeed devoted to present the innovative concept of Strategic Engineering combining Modelling, Simulation, AI and Data Analytics to support Strategic Decision Making.
This year, as always, we applied a qualified peer review to guarantee High Quality of the papers to complete a valid selection that opens access to several International Journals connected to I3M & WAMS: there are 9 Journals ready to evaluate our Paper extensions.
WAMS in Singapore represents an unique opportunity to get in touch with a wide community of Scientists, Technicians, Managers from Institutions, Companies and Governmental Organizations interested in applying Modeling & Simulation in many different sectors from Shipping to Industry, from Homeland Security to Business, so we encourage you to attend the Sessions and Workshops as well as to enjoy the Beautiful Social Events such as the Gala Dinner at S.E.A. Aquarium, the ASIASIM & WAMS Welcome Cocktail at NUSS and the WAMS Night Drink at Long Bar in Raffles Hotel.
Next Year the event will be Back in Europe, therefore we are working on reinforcing connections with America and Asia and we welcome as always proposals for New Tracks and New Events from Scientists and Experts from all around the World.

Agostino G. Bruzzone


Francesco Longo


Adrano Solis


Marina Massei

ACKNOWLEDGEMENTS

The WAMS 2019 International Program Committee (IPC) has selected the papers for the Conference among many submissions; therefore, based on this effort, a very successful event is expected. The WAMS 2019 IPC would like to thank all the authors as well as the reviewers for their invaluable work.
A special thank goes to all the organizations, institutions and societies that have supported and technically sponsored the event.

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AsiaSim, WAMS & STRATEGOS & Welcome Cocktail (Included)
@ NUSS Kent Ridge Guild House, National University of Singapore, 9 Kent Ridge Drive

STRATEGOS & WAMS Night Drink (No Host)
@ Long Bar, Raffles Hotel, Raffles Arcade, 328 North Bridge Rd,

AsiaSim & WAMS Gala Dinner (Included)
@S.E.A. Aquarium, Resorts World Sentosa, 8 Sentosa Gateway, Sentosa Island

IN ADDITION WAMS ATTENDEES ARE INVITED TO THE ASIASIM & WAMS MEALS AND TEA/COFFEE BREAKS (INCLUDED) OF OCTOBER 30 AND 31 IN NUSS

JAMES COOK UNIVERSITY AND STRATEGOS

FURTHER DETAILS AVAILABLE ON: WWW.LIOPHANT.ORG/CONFERENCES/2019/WAMS

Wednesday, October 30TH

845-1200 ASIASIM & WAMS OPENING

1000-1030 Tea/Coffee Break (included)

1030-1200 KEYNOTE SPEECHES

1200-1330 ASIANSIM & WAMS Lunch (included)

1400-1730 STRATEGOS Workshop: a New Way to Succeed

1800-1930 ASIASIM & WAMS Welcome Cocktail (included)

2100-2230 Night Drink at Long Bar, Raffles Hotel (no host)

Thursday, October 31ST

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1530-1600 Tea/Coffee Break (included)

1900-2200 Gala Dinner at S.E.A. Aquarium, Resorts World Sentosa (included)

JAMES COOK UNIVERSITY AND STRATEGOS ON NOVEMBER 1ST

A SPECIAL PANEL AND STUDENT COMPETITION ON COMPLEX SYSTEM WILL BE ORGANIZED ON FRIDAY, NOVEMBER 1, 1400-1700 AT JAMES COOK UNIVERSITY, SINGAPORE, JOINTLY WITH STRATEGOS, GENOA UNIVERSITY, FOR GETTING A FREE INVITATION PLEASE CONTACT MASSEI@ITIM.UNIGE.IT FOR DETAILS.

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ADAPTIVE ALGORITHMS FOR OPTIMAL BUDGET ALLOCATION WITH AN APPLICATION TO THE EMPLOYMENT OF IMPERFECT SENSORS

Moshe Kress[(a)], Roberto Szechtman[(a)], Enver Yücesan[(b)]

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ABSTRACT
We consider sensors subject to false-positive and false-negative errors. The sensor participates at a search and rescue operation looking for search objects such as a group of persons, a survival craft or simply debris. The objects are located in a certain area of interest, which is divided into area-cells. The area-cells are defined such that each one may contain at most one search object. The task of the sensor is to determine whether an area-cell contains a search object; the objective is to minimize the expected number of incorrectly determined area-cells. Since definitive identification of a search object and subsequent rescue of that object are done by a limited number of available ground or sea units, the correct determination of an area-cell is crucial for better allocating and directing these scarce resources. We develop algorithms, rooted in the theory of large deviations and stochastic approximation, that provably lead to the optimal allocation of search effort.

Keywords: large deviations theory, hypothesis testing, ranking and selection, search and rescue

1. INTRODUCTION

Recent tragedies such as the disappearance of a civilian aircraft and the capsizing of makeshift boats carrying refugees have underlined the criticality of efficient search in search and rescue operations. Advances in sensing, unmanned aerial vehicles, sonar-equipped submersibles, and satellite technologies have vastly increased the civilian and military use of space sensors for detecting search objects such as survival craft or debris. These advanced technologies may generate powerful and effective sensors, which necessitate operational concepts in order to facilitate their efficient utilization. A typical scenario where such operational concepts are needed is related to maritime search and rescue missions where a naval task force is patrolling a certain area of interest attempting to detect search objects such as person in water, survival craft, and immigration vessel. Such search objects are relatively rare and therefore it is safe to assume that if the area of interest is divided into a grid of area-cells of size, say, five square miles, then each area-cell may contain at most one search object. The taskforce employs unmanned aerial vehicles or submersibles, equipped with electro-optical, sonar or other sensor for surveillance and search. Once a search object is detected, the taskforce dispatches an inspection unit to further investigate the object. Obviously, a false positive detection results in unnecessary deployment of the rescue unit, while a false negative detection may result in severe operational consequences such as loss of life. Arguably, the cost of a false positive detection is much smaller than the cost of false negative detection. The objective is to minimize the expected total cost through the minimization of the expected number of incorrectly determined area-cells. In particular, we address operational concepts associated with employing sensors in persistent search missions over an extended search area. Specifically, we consider the problem of efficiently allocating *adaptive* sensors across a search area of interest. The sensors are adaptive in the sense that the search plan is not set in advance, but rather is updated in real time during the search process as new information is generated by the sensor.

The theory of optimal search has a history of principal importance in both civilian and military operations. The theory has fundamental applications to search and rescue operations as well as anti-submarine warfare and counter-mine warfare. The books, Koopman (1946) and Stone (1975), are classical references in this area with Washburn (2002) a more recent addition. Search problems with discrete time and space of the type addressed in this paper are not new. Optimal whereabouts search, where we seek to maximize the probability of determining which box contains a certain object, is studied in Ahlswede and Wegener (1987) and in Kadane (1971). Chew (1967) considers an optimal search scheme with a stopping rule where all search outcomes are independent, conditional on the location of the searched object and the search policy. Wegener (1980) investigates a search process where the search time of a cell depends on the number of searches conducted so far. A minimum cost search problem is discussed in Ross (1983), where only one search mode is considered and the sensor has perfect specificity, that is, there are no false positive detections. Song and Teneketzis (2004) deals with discrete search with multiple sensors in order to maximize the probability of successful search of a single target during a specified time period. Other discrete search problems are studied in Matula (1964), Black (1965), and Wegener (1980). However, all of the aforementioned references assume that the sensor has perfect specificity. Two notable exceptions are Garcia, Campos and Li (2005) and Garcia, Lee and Pedraza (2007). Our models, which are related to (Kress, Szechtman and Jones 2008), relax this assumption. The results we obtain in this article rely on large deviations theory (Dembo and Zeitouni 1998), and on stochastic approximation theory (Kushner and Yin 2003). Like the above references, we also assume that a search area has already been designated by quantifying a number of unknowns such as the last known position, the object type, and the wind, sea state, and the currents affecting the object (Breivik and Allen 2008); the objective is then to rapidly deploy search and rescue units in the search area.

Our methodology is closely related to the adaptive approaches for feasibility determination (e.g., Szechtman and Yücesan 2016). Assume that one sensor is assigned an area of interest to search, which is partitioned into a grid of m area-cells. We assume that the area of interest can be partitioned in such a way that each area-cell i, for i=1, 2,…, m, contains at most one search object. The sensor operates in glimpses or *looks*. A look may be viewed as a nominal period of time for inspecting a certain area-cell. The sensor may spend several looks (i.e., extended inspection time) in a certain area-cell. Each look generates a cue or signal: *detection* or *no-detection*. A cue may be correct or erroneous (false positive or false negative). Suppose that the sensor has n looks that it can apply to the search, and these looks are allocated to the various area-cells dynamically as the search mission evolves.

Let $\zeta_i=1$, if area-cell i contains a search object, and $\zeta_i=0$, otherwise, leading to the hypothesis $\mathcal{H}_{i,0}:\zeta_i=1$ and $\mathcal{H}_{i,1}:\zeta_i=0$. We suppose that there is some initial intelligence about the presence of search objects, which is manifested by a prior probability, $\pi_i = P(\zeta_i=1)$, for i=1, 2,…, m. This intelligence comes from exogenous sources such as satellite imaging or some stochastic trajectory computing model (Breivik and Allen 2008). The sensor is characterized by its sensitivity and specificity: For each area-cell i, we have

a_i = P(sensor indicates detection in area cell i | $\zeta_i=1$), which is called the *sensitivity* of the sensor; the *specificity* of the sensor is 1-b_i, where

b_i = P(sensor indicates detection in area cell i | $\zeta_i=0$).

Although the a_i and b_i's may depend on the area-cell, we assume that they do not depend on the number of looks. Without loss of generality we take $a_i > b_i$, because we can reverse the cue if $a_i < b_i$. We explicitly assume that $a_i \neq b_i$, for otherwise the sensor does not provide any valuable information. We assume that the collection of search results from the various looks are independent for a given area-cell (meaning that there is no systematic bias in the sensor), and also that the results for different area-cells are independent.

The objective of this article is to characterize effort allocation schemes that employ the sensor efficiently, where the measure of effectiveness is the *expected number of correctly determined area-cells*. When the number of looks available n is small, this can be done by solving a dynamic program. However, due to the curse of dimensionality (Powell 2007), the computational cost of solving a dynamic program grows exponentially in nm, which precludes its use when the number of looks available is moderately large. This paper is therefore aimed at the settings where n is large. The optimal search effort allocation is determined in two stages: First, presuming knowledge of the true state of nature (i.e., ζ equal to 0 or 1, for i=1, 2,…, m), we use large deviations theory to characterize the optimal effort allocation; second, we use adaptive ideas to generate a search sequence that provably converges to the optimal effort allocation determined in the first stage. To the best of our knowledge, this is the first article that describes the optimal effort allocation in the context of target searching along multiple area-cells where the sensor has false positive and false negative errors, and that provides an implementable adaptive algorithm. We do not consider travel time among the area-cells because, for a large number of looks, its effect on the optimal effort allocations is not significant. This happens because the sensor could stay in the same area-cell for a large number of looks, then move to another area-cell and remain there for a long time, and so on, all the while satisfying the optimal search effort allocation. When the number of looks is relatively small one should consider resource constraints; see, for example, Sato and Royset (2010).

The remainder of this paper is organized as follows. In Section 2, we discuss what we mean by determining an area-cell, using results from the hypothesis testing literature. In Section 3, we determine the optimal search effort allocations. In Section 4, we present an adaptive algorithm that results in sampling allocations, which converge almost surely to the optimal allocations. Section 5 provides two examples that illustrate the main results. The concluding remarks appear in the last section.

2. PROBLEM FRAMEWORK

A key issue is the determination of whether or not an area-cell contains a search object. Intuitively, the average number of detections in area-cell i should approach a_i if $\zeta_i=1$ and b_i if $\zeta_i=0$. Since $a_i > b_i$, a good decision rule should conclude that an object is present if the average number of detection cues in that area-cell is close to or above a_i, and that an object is not present if the average is close to or below b_i. Hence, as each area-cell is allocated an increasing number of looks, it will become less likely to have a wrong determination. This problem has been well studied in the statistical literature; see, for example, Lehmann (1986). In this section we make precise the relevant ideas and set the stage for the main results.

Let the random variable $X_{i,j}$=1, if the j'th look into area-cell i produces a *detection* signal, and $X_{i,j}$=0, otherwise, for j=1, …, n_i, where n_i is the number of looks into area-cell i. For each area-cell i, ($X_{i,j}$: j=1, …, n_i) is a collection of independent and identically distributed random variables with Bernoulli(a_i) distribution, if there is a search object, or Bernoulli(b_i) otherwise.

A decision test $\mathcal{S}$ is a sequence of measurable maps with respect to $X_{i,1}$, …, $X_{i,ni}$ from $\{0,1\}^{n_i}$ into {0,1} such that if $\mathcal{S}_{ni}(x_{i,1}, \ldots, x_{i,ni})$=1, then $\mathcal{H}_{i,0}$ is accepted, and if $\mathcal{S}_{ni}(x_{i,1}, \ldots, x_{i,ni})$=0, then $\mathcal{H}_{i,0}$ is rejected. The error probabilities produced by the decision test $\mathcal{S}$ are:

α_{n_i} = $P_1(\mathcal{S}_{ni}$ rejects $\mathcal{H}_{i,0})$,   (Type I error probability)

and

β_{n_i}= $P_0(\mathcal{S}_{ni}$ accepts $\mathcal{H}_{i,0})$,   (Type II error probability).

Define the sample average of the sensor signals by

$$\bar{X}_i(n_i) = \frac{1}{n_i}\sum_{j=1}^{n_i} X_{i,j},$$

and let $\mathcal{S}^*_{ni}(x_{i,1}, \ldots, x_{i,ni})$ = 1 if

$$\left(\frac{a_i}{b_i}\right)^{n_i\bar{x}_i(n_i)}\left(\frac{1-a_i}{1-b_i}\right)^{n_i(1-\bar{x}_i(n_i))} > 1, \qquad (1)$$

and $\mathcal{S}^*_{ni}(x_{i,1}, \ldots, x_{i,ni})$ = 0, otherwise. In other words, $\mathcal{S}^*_{ni}(x_{i,1}, \ldots, x_{i,ni})$ = 1 if and only if the likelihood of having a search object is greater than the likelihood of not having a search object.

The Bayes probability of error is given by $\alpha_{ni}\pi_i + \beta_{ni}(1-\pi_i)$. Chernoff's bound (Dembo and Zeitouni 1998, pp. 93) asserts that if $0<\pi_i<1$, then

$$\inf \lim_{n_i\to\infty}\frac{1}{n_i}\log\left(\alpha_{n_i}\pi_i + \beta_{n_i}(1-\pi_i)\right) = -\left(\gamma_i\log\left(\frac{\gamma_i}{a_i}\right) + (1-\gamma_i)\log\left(\frac{1-\gamma_i}{1-a_i}\right)\right),$$

where the infimum is taken over all decision tests, and

$$\gamma_i = \frac{\log\left(\frac{1-b_i}{1-a_i}\right)}{\log\left(\frac{a_i}{1-a_i}\frac{1-b_i}{b_i}\right)}.$$

Several comments are in order. The infimum above is achieved by the decision test $\mathcal{S}^*_{ni}$, so that $\mathcal{S}^*_{ni}$ is optimal in the following sense: among all decision tests, it minimizes the Bayes probability of error in log scale (i.e., it is the decision test with largest exponential decay rate for the Bayes probability of error), as the number of looks $n_i\to\infty$. Hence, for the rest of this article, we deal with the decision test $\mathcal{S}^*_{ni}$ for each area-cell i=1, … , m.

By a straightforward algebraic manipulation, it can be seen that Eq. (1) holds if and only if $\bar{X}_i(n_i) > \gamma_i$. Thus, the parameters γ_i are determination thresholds, meaning that if $\bar{X}_i(n_i) \le \gamma_i$, then the sensor operator declares the area-cell to not contain a search object, and if $\bar{X}_i(n_i) > \gamma_i$, then the area-cell is declared to contain a search object.

3. MAIN RESULTS

Let θ_i be the fraction of the search budget n that is allocated to area-cell i, so that the number of looks assigned to area-cell i is $n_i = \theta_i n$. To make the mathematical proceedings less cumbersome, we work with $\bar{X}_i(\theta_i n)$, the average of the observations taken over $\theta_i n$ looks. Since our results hold for large n, they continue to be true when the integrality condition is enforced, by working with a sequence that goes to infinity.

Assume, without loss of generality, that area cells 1, …, r contain a search object, and that area cells r+1, … , m do not contain a search object. Recall the goal is to allocate the sensor in order to minimize the expected number of incorrectly determined area-cell. More precisely, the goal is to

$$\min g_n(\theta_1, \ldots, \theta_m)$$

subject to

$$\sum_{i=1}^m \theta_i \le 1,$$
$$\theta_i \ge 0, \ \ for\ i = 1, \ldots, m,$$

where

$$g_n(\theta_1, \ldots, \theta_m) = \sum_{i=1}^r P(\bar{X}_i(\theta_i n) \le \gamma_i) + \sum_{i=r+1}^m P(\bar{X}_i(\theta_i n) > \gamma_i). \qquad (2)$$

Our contribution is two-fold: (i) we characterize fractional allocations $\theta_1^*, \theta_2^*, \ldots, \theta_m^*$ that are optimal (in log scale) as $n\to\infty$, and (ii) we provide an easily implementable algorithm, rooted in stochastic approximation theory, that results in sampling allocations that provably achieve the same performance (in log scale) as the optimal allocations in the limit as $n\to\infty$.

Large deviations theory (Dembo and Zeitouni 1998) suggests that each of the summands in Eq. (2) decays roughly exponentially fast with the number of looks. The decay rate depends on the large deviations rate function, $I_i(\gamma_i) = sup_\eta(\eta\gamma_i - logEexp(\eta X))$, which, for a non-degenerate Bernoulli random variable X with mean μ_i, is given by

$$I_i(\gamma_i) = \gamma_i\log\left(\frac{\gamma_i}{\mu_i}\right) + (1-\gamma_i)\log\left(\frac{1-\gamma_i}{1-\mu_i}\right), \qquad (3)$$

for $0<\gamma_i<1$.

The next result whose proof can be found in Szechtman and Yücesan (2008) characterizes the decay rate of the expected number of wrongly determined area-cells.

Proposition 1: Suppose $a_i > b_i$ for each area-cell. Then

$$\lim_{n\to\infty}\frac{1}{n}\log g_n(\theta_1, \ldots, \theta_m) = -\min_i \theta_i I_i(\gamma_i).$$

Proposition 1 asserts that the expected number of incorrectly determined area-cells decays exponentially fast, with a rate that is equal to the smallest decay rate amongst all area-cells. This suggests that a good allocation should maximize the slowest decay rate; i.e., the minimum of $\theta_i I_i(\gamma_i)$. The next result, also from Szechtman and Yücesan (2008), shows that this approach is optimal among all feasible allocations.

Proposition 2: Suppose $a_i > b_i$ for each area-cell. Then,

$$\lim_{n\to\infty}\frac{1}{n}\log g_n(\theta_1^*, \ldots, \theta_m^*) = -\frac{1}{\sum_{k=1}^m I_k^{-1}(\gamma_k)},$$

where

$$\theta_i^* = \frac{I_i^{-1}(\gamma_i)}{\sum_{k=1}^m I_k^{-1}(\gamma_k)}. \qquad (4)$$

The elements θ_i^* are the optimal allocation scheme, meaning that no other allocation achieves a higher exponential decay rate for $g_n(\cdot)$ as the number of looks goes to infinity. Proposition 2 results in

$$\theta_i^* = \frac{\left(\gamma_i \log\left(\frac{\gamma_i}{\mu_i}\right) + (1-\gamma_i)\log\left(\frac{1-\gamma_i}{1-\mu_i}\right)\right)^{-1}}{\sum_{k=1}^{m}\left(\gamma_k \log\left(\frac{\gamma_k}{\mu_k}\right) + (1-\gamma_k)\log\left(\frac{1-\gamma_k}{1-\mu_k}\right)\right)^{-1}}, \quad (5)$$

where $\mu_i = a_i$ for i=1, …, r, and $\mu_i = b_i$ for i=r+1, …, m. It can be seen from Eq. (5) that the optimal fractional allocations tend to be large when μ_i (i.e., a_i if search object is present, or b_i otherwise) is close to the determination threshold γ_i. This happens because in that case the probability of having $\bar{X}_i(n_i)$ on “the wrong side” is relatively large, and more looks are needed to compensate for the bigger error probability.

While Proposition 2 characterizes the optimal search allocation, the fractions θ_i^* depend on knowledge about the presence/absence of the search object, which is precisely what we are trying to determine. In the next section, we present a stochastic approximation algorithm that overcomes this issue by estimating the rate function on the fly and leads to fractional allocations that converge almost surely to the optimal θ_i^* allocations.

4. STOCHASTIC APPROXIMATION ALGORITHM

We first present the algorithm and then discuss the underlying intuition. Initially, we set

$$\tilde{X}_{i,0} = \tilde{x}_i, \qquad 0 < \tilde{x}_i < 1$$

and

$$I_{i,0}(\gamma_i) = \gamma_i \log\left(\frac{\gamma_i}{\tilde{X}_{i,0}}\right) + (1-\gamma_i)\log\left(\frac{1-\gamma_i}{1-\tilde{X}_{i,0}}\right).$$

Based on prior computations, the value $\tilde{x}_i$ is our best guess of μ_i at stage 0; for instance, $\tilde{x}_i = a_i$ if $\pi_i > 0.5$ and $\tilde{x}_i = b_i$ if $\pi_i \le 0.5$. The rate functions that lead to Eq. (4) are estimated by substituting $\tilde{X}_{i,0}$ for μ_i in Eq. (5). The initial stage is n=0, and the initial sample sizes are $\lambda_{i,0}$=0.

4.1. SA Algorithm

Following initialization,

1. Generate a replicate ξ from the probability mass function, $I_{i,n}^{-1} / \sum_{k=1}^{m} I_{k,n}^{-1}$ for i=1, …, m.
2. Update sample sizes: $\lambda_{\xi,n+1} = \lambda_{\xi,n} + 1$, and $\lambda_{i,n+1} = \lambda_{i,n}$, for $i \ne \xi$.
3. Generate a look (sample) from area-cell ξ, X_{ξ,λ_ξ}.
4. Update $\tilde{X}_{\xi,n+1}$ and $I_{\xi,n+1}$:
   $$\tilde{X}_{\xi,n+1} = \tilde{X}_{\xi,n} + \frac{1}{\lambda_{\xi,n+1}}\left(X_{\xi,\lambda_\xi} - \tilde{X}_{\xi,n}\right),$$
   $$I_{\xi,n+1} = \gamma_\xi \log\left(\frac{\gamma_\xi}{\tilde{X}_{\xi,n+1}}\right) + (1-\gamma_\xi)\log\left(\frac{1-\gamma_\xi}{1-\tilde{X}_{\xi,n+1}}\right).$$
   For $i \ne \xi$, $\tilde{X}_{i,n+1} = \tilde{X}_{i,n}$ and $I_{i,n+1} = I_{i,n}$.
5. Increment $n \leftarrow n$+1 and go back to 1.

4.2. The Logic

In step 1, we decide where to look next. This is accomplished by sampling from the probability mass function $I_{i,n}^{-1} / \sum_{k=1}^{m} I_{k,n}^{-1}$, which is the best guess of the optimal allocation at stage n. In step 3, the searcher generates an observation by sampling from a Bernoulli distribution with parameter a_ξ if area-cell ξ contains a search object (i.e., $\xi \in \{1,2,\dots,r\}$), or from a Bernoulli distribution with parameter b_ξ otherwise. In step 4, we update the sample average and sample large deviations rate function of area-cell ξ.

To ensure that each area-cell is searched infinitely often, let $(\nu_n)_{n=0}^{\infty}$ be an increasing sequence such that $\nu_n \to \infty$ and $n^{-1}\sum_{k=1}^{n} J(\nu_k \le n) \to 0$, where $J(\cdot)$ is the indicator function. We search all m area-cells at iteration $\nu_1, \nu_2, \dots$, and update the parameters according to steps 2 and 4 of the algorithm.

To see why our algorithm leads to the optimal allocations, let $\theta_{i,n} = \lambda_{i,n}/n$ be the fractional allocations in stage n of the algorithm. Hence, step 2 of the algorithm can be expressed as $\theta_{i,n+1} = \theta_{i,n} + (J(\xi_n = i) - \theta_{i,n})/(n+1)$, where ξ_n is the n^{th} replicate of ξ generated in step 1 of the algorithm. The recursion for $\theta_{i,n+1}$ can then be re-written as

$$\theta_{i,n+1} = \theta_{i,n} + \frac{1}{n+1}\left(\theta_i^* - \theta_{i,n}\right) + \epsilon_n,$$

where

$$\epsilon_n = \frac{1}{n+1}\left(J(\xi_n = i) - q_{i,n}\right) + \frac{1}{n+1}\left(q_{i,n} - \theta_i^*\right),$$

and

$$q_{i,n} = I_{i,n}^{-1} / \sum_{k=1}^{m} I_{k,n}^{-1}.$$

If the error ϵ_n becomes small relative to the $\left(\theta_i^* - \theta_{i,n}\right)/(n+1)$ term, then $\theta_{i,n}$ follows, as $n \to \infty$, the path of the solution of the ordinary differential equations $\theta_i' = \theta_i^* - \theta_i$, for i=1,2, …, m, which have θ_i^* as the unique globally asymptotically stable point. This suggests that if the variability introduced by the error is sufficiently small, our algorithm provides fractional allocations that converge almost surely to the optimal allocations. The preceding argument is made rigorous in the next theorem.

Theorem 1: The stochastic approximation algorithm search allocations converge with probability one to the optimal allocations determined by Eq. (4):

$$\lambda_{i,n}/n \to \theta_i^*,$$

almost surely as $n \to \infty$.

Proof: Szechtman an Yücesan (2008). □

The next result shows that the expected number of incorrectly determined area-cells produced by the stochastic approximation algorithm approaches 0 at the best possible rate.

Theorem 2: The expected number of incorrect determinations satisfy

$$\frac{1}{n}\log\left(\sum_{i=1}^{r} P(\tilde{X}_{i,n} \le \gamma_n + \sum_{i=r+1}^{m} P(\tilde{X}_{i,n} > \gamma_n\right) \to -\frac{1}{\sum_{k=1}^{m} I_{k,n}^{-1}(\gamma_k)},$$

as $n \to \infty$.

Proof: Szechtman an Yücesan (2008). □

5. NUMERICAL ILLUSTRATIONS

We now illustrate the results of the previous sections via two small examples. In each case, we consider 4 area-cells, with only the first 2 area-cells containing a search object. The sensor parameters are a=(0.8,0.7,0.6,0.9) and b=(0.3,0.1,0.2,0.2). These parameters lead to the thresholds γ=(0.5609,0.3608,0.3869,0.5803), and to the optimal allocations θ^*=(0.2773,0.1659,0.4401,0.1167).

In the first example we portray the results of propositions 1 and 2. For each area-cell we analytically compute the exact probability of incorrect determination, given by

$$\sum_{k=0}^{\lfloor n\gamma_i\theta_i^*\rfloor} \binom{\lfloor n\theta_i^*\rfloor}{k} a_i^k(1-a_i)^{n-k}$$

for i=1, …, r and by

$$\sum_{k=\lfloor n\gamma_i\theta_i^*\rfloor+1}^{n} \binom{\lfloor n\theta_i^*\rfloor}{k} b_i^k(1-b_i)^{n-k}$$

for i=r+1, …, m. The expected number of incorrectly determined area-cells is the sum of these two expressions over all the area-cells. The algorithms have been implemented in Matlab. The results are shown in Figure 1 for three cases:

- the case of the optimal allocations θ_i^* (cf. Equations (4) and (5);
- the constant allocation case, with $\theta_i = n/m$;
- the simple allocation, where the determination thresholds are the midpoints between a_i and b_i, $(a_i+b_i)/2$. If the allocations are inversely proportional to the distance a_i - $(a_i+b_i)/2$, the allocation becomes $\theta_i = n(a_i-b_i)^{-1}/\sum_{k=1}^{m}(a_k-b_k)^{-1}$.

As expected from Proposition 1, the logarithm of the expected number of incorrect determinations for the three allocation schemes decays linearly as the number of looks increases. Also, in agreement with Proposition 2, the slope of the line corresponding to the optimal allocations is more negative (steeper) than the slope of the line corresponding to the constant and simple allocations.

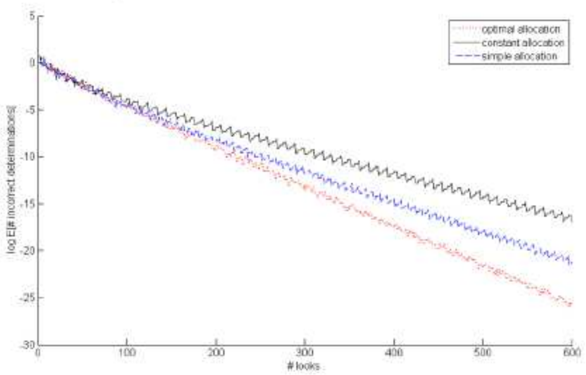

Figure 1: Exponential Decay Rate of the Expected Number of Incorrectly Determined Area-Cells for the Three Allocation Rules

Another take-away from Figure 1, which we also observed through numerical experimentation, is that the sub-exponential terms that appear when computing the expected number of incorrectly determined area-cells become unnoticeable for relatively small values of n; i.e., we get a straight line in Figure 1 even for n small. This suggests that, although all our results apply in the limit as $n\to\infty$, the transient dies out fairly quickly.

In the second example we implement the stochastic approximation algorithm, without presuming knowledge of the presence/absence of the search object in each area-cell. The goal is to illustrate Theorem 1. We generated a single replication and plotted the fractional allocations generated by the adaptive algorithm. Figure 2 illustrates how the allocations approach the optimal allocations corresponding to Equation (5).

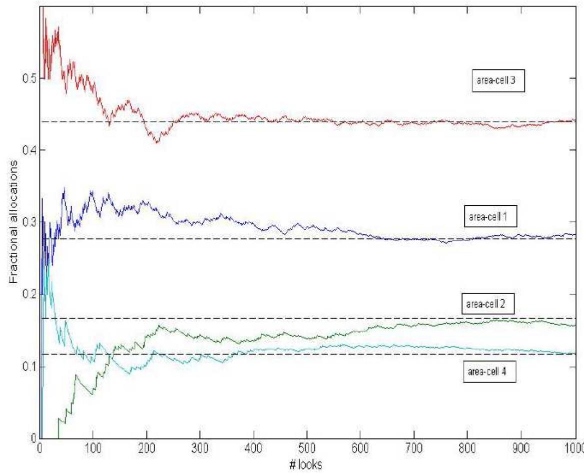

Figure 2: Sample Allocation vs Optimal Allocations

6. CONCLUSIONS

In this article, we developed a model for a single sensor that looks for search objects, when the sensor is subject to false-positive and false-negative errors. We employed large deviations theory to characterize the optimal search effort allocations, and developed a stochastic approximation algorithm. The fractions of time spent in each area-cell generated by the algorithm converge almost surely to the optimal search effort allocations. This causes the number of incorrectly determined area-cells to decay at the fastest possible exponential rate.

The stochastic approximation algorithm we introduced to obtain fractional allocations that converge almost surely to the optimal θ_i^* allocations. Unfortunately, this asymptotic approach does not provide any guarantee for the finite number of looks. It is, however, possible to construct a two-stage algorithm that bounds the expected number of incorrect determinations. In this setting, the first stage estimates the optimal allocations along with the resulting number of production samples. In the second stage, we determine feasibility based on the above sampling plan. In particular, since the optimal allocations are driven by the large deviation rate functions, we ensure that they are estimated in an accurate fashion.

The models developed in this paper may be extended in several directions, including dealing with multiple sensors and considering an arbitrary number of search objects in each area-cell or of a single search object in the area of interest among others. Some of the extensions are presented in Lee (1998).

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PROPOSAL ON NETWORK EXPLORATION TO AVOID CLOSED LOOPS

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ABSTRACT

There are a lot of enormous networks in the real world, and it is well-known that Network Exploration is important to understand structure and connectivity of the network. A random walk is one of the famous methods to explore the network. Further, a random walk is a method of randomly selecting the next node from one of several adjacent nodes and is frequently used when a walker can only get local information on the network. However, since the exploration by a random walk does not depend on the past exploration process, a walker on the network enters a loop and therefore visits the same node several times. In this paper, for improving the efficiency of network exploration, we propose an exploration algorithm in which the random walker selects a passing route as a combination of an adjacent node and a node two nodes away.

Keywords: network exploring, random walk, scale-free, complicated networks

1. INTRODUCTION

Networks in the real world are enormous and complicated such as Web, transportation network, and neural network of human. Therefore, it is not easy to investigate an indirect connection from one node to the specific node. However, it is very important to analyze these networks in order to grasp vast information (Ikeda, Kubo, Okumoto and Yamashita 2003). A random walk is one of an effective and practical method for network exploration in which the whole image is not found. A walker with random walk (random walker) explores the network using only the information on neighboring connections on the network. During the exploration, the walker moves to all adjacent nodes with equal probability because it moves completely randomly.

There are a lot of enormous networks in the real world. It has been seen that most of the enormous networks in the real world are “scale-free”. The World Wide Web (WWW) is a representative example of an enormous and complicated network. In the case of WWW, each page is node, and hyperlinks posted on the page form a network. In fact, WWW has more than 800 million nodes, and hyperlinks on WWW form a scale-free network (Barabási and Albert 1999). Then, the number of nodes connected from a node is called the degree of the node, and the connection between two nodes is called the edge. In the scale-free network, the distribution of degree (degree distribution) obeys a power-law tailed distribution (Albert and Barabási 2002).

It is well known that Network Exploration is important to understand structure and connectivity of the network. A random walk which is a method of randomly selecting the next node from one of several adjacent nodes is one of the famous and practical methods to explore the scale-free network. This means that a random walk is the exploration algorithm based on only the local information on the adjacency relation of nodes. However, since a random walk obeys a Markov process, the behavior of a random walker is determined by only the current state and is not affected by past movements. As a result, that walker during network exploration enters a loop and goes around a limited area on the network many times in the scale-free network (Yang 2005; Kim, Park and Yook 2016).

As a feature of the scale-free network, it is known that there are hub nodes with connecting to many nodes, since the degree distribution of the scale free network obeys a power-law. Although a walker at the hub node can move to a node that has not been visited before, conversely a walker may also often return to a node that has already visited. As the exploration time increases, the number of times the walker has revisited the nodes which it already visited increases. When the exploration forms such a loop, it can be said that the exploration efficiency decreases.

Therefore, in this paper, we consider an exploration algorithm for improving the efficiency of the scale-free network exploration. Then, it is necessary to construct the algorithm behaving adaptively to the scale-free network feature. Therefore, we propose a modified random walk algorithm improving the exploration efficiency through avoiding revisiting the nodes which the walker has already visited.

In our algorithm, we define nodes connected to adjacent nodes as virtual adjacent nodes. Then, in addition to the data on the adjacent node which is the information utilized in the traditional random walk, the data on the virtual node is used probabilistically according to the degree of the current node. Note that in the proposed algorithm, when the current node has a large degree, the walker is more likely to move to a node two nodes away. In this paper, we confirm that the proposed algorithm has a high exploration efficiency comparing with the algorithms which do not consider the degree of nodes including the traditional random walk algorithm.

2. NETWORKS AND RANDOM WALK MODEL

2.1. Networks

We explain networks that are the base of this paper. Networks are composed of more than one node and one or more edges which connect the nodes. The total number of nodes that compose the network is called the number of nodes *N*. Moreover, the number of edges connected each node is called the degree, and the proportion of the degree k in the whole network is called degree distribution (Albert, Jeong and Barabási 2000). There are random networks as one of network construction methods that have been studied since before. The random network is generated by repeatedly selecting two nodes from N nodes randomly and connecting the nodes with a constant probability p. Figure 1 is an example of the random network. In this figure, a circle represents a node, and its size represents the degree of the node. Generally, it is known that Poisson distribution explains the degree distribution of random networks (Barabási and Albert 1999, Albert and Barabási 2002).

Whereas, the degree distribution of the most networks in the real world is different from the random network and does not follow Poisson distribution. Concretely, the degree distribution $P(k)$ of network in the real world can be represented based on the power-law as follows:

$$P(k) \sim k^{-\gamma} \tag{2.1}$$

where γ denotes the scaling index. Then, considering the networks in the real world, we have the scaling index as $1 \leq \gamma \leq 3$ (Albert and Barabási 2002). The property that the order distribution $P(k)$ of a network is expressed by a power law is called scale-free property of the network, and the network with scale-free property is called scale-free network. Figure 2 is an example of the Scale-free network.

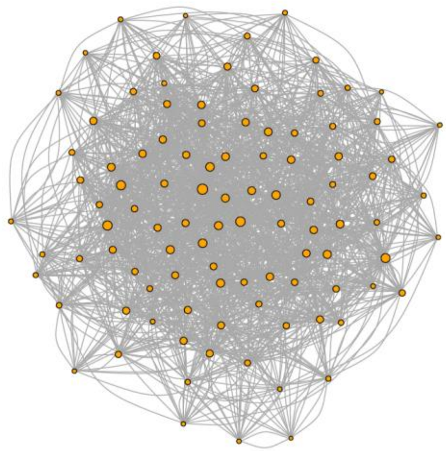

Figure 1: Random Network

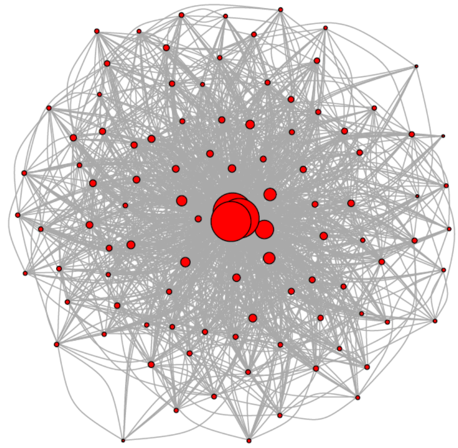

Figure 2: Scale-free Network

2.2. Random Walk

The random walk model is known as the typical and practical method to explore the path from the start to the goal on the network to understand structure and connectivity of the network (Noh and Rieger 2004). The walker in the random walk model moves to an adjacent node among all adjacent nodes with the equal probability. It is a useful method when the network connection near each node is known. The probability P_{ij} that the walker moves from node i to node j is represented as

$$P_{ij} = \begin{cases} \frac{1}{k_i}, & j \in N(k_i), \\ 0, & otherwise, \end{cases} \tag{2.2}$$

where k_i and $N(k_i)$ indicate the degree of node i and the population of the nodes adjacent to node i respectively. The walker in the random walk model moves to an adjacent node of adjacent nodes according to Eq. (2.2) one by one. It is completely random that the walker moves to which node among adjacent nodes, and even though the walker has visited a node once, the walker moves to the node with the same probability as other nodes. For this reason, a random walk has a problem that the walker tends to draw a loop especially when positioned on nodes with large degree. To improve this problem, we propose the “Skip Model” in the next section. We explore on the random network and the scale free network by using the random walk model and the proposed model and verify the effectiveness of the proposed model.

3. PROPOSAL OF SKIP MODEL

In this section, we introduce the Skip Model as a proposed model in this paper. The basic exploring method of this model is almost the same as the random walk model. However, although the walker in the random walk model moves to the adjacent nodes according to equation (2.2) basically, the Skip Model has a feature that the walker in the Skip Model sometimes moves to two nodes away node passing the adjacent nodes with the following probability Q_l specified based on the degree k_l of node l :

$$Q_l = 1 - \frac{1}{k_l}. \tag{3.1}$$

For instance, the probability P_{lmn} that the walker at node l move to two nodes away node n passing the adjacent node m is represented as follows:

$$P_{lmn} = \begin{cases} \left(1 - \frac{1}{k_l}\right)\frac{1}{k_l}\frac{1}{k_m - 1}, & m \in N(k_l)\, and\, n \in N(k_m) \\ 0, & otherwise. \end{cases} \tag{3.2}$$

Note that k_l and k_m are the degrees of node l and m respectively. In addition, note that if the node where the walker is located and the node which is two nodes away are directly connected by an edge, i.e. nodes l , m and n form a triangle, the walker does not move to node n . According to Eq. (3.1), in the event of using the Skip Model, the larger the degree of the node where the walker is located is, the higher the probability of moving to the node which is two nodes away is. In this way, it would be possible to avoid forming closed loops that increases exploring time by moving to the node which is two nodes away at the node which has large degree. We call this model of moving to the node which is two nodes away with the defined probability in Eq. (3.1) the Skip Model.

For comparisons, we prepare the Skip1 Model fixed as $Q_l = 1$ and The Skip0.5 Model fixed as $Q_l = 0.5$. It is found that the Skip1 Model is a model that always moves two by two and the Skip0.5 Model is a model that moves two with the constant probability of 1/2. Furthermore, the model becomes the traditional random walk if we set as $Q_l = 0$. Hence, we call the traditional random walk model as the Skip0 Model in this paper. We explore the network by using these four models and look for the best method among them.

4. EXPERIMENT

In this section, we analyze the exploration on the two networks explained in section 2 by using the four models introduced in section 3 while changing the scaling index and the number of nodes N . Then, we calculate the average exploring times from the obtained data, evaluate the significant difference of the result of each model, and indicate the effectiveness of the Skip Model regarding the solution ability of the problem.

4.1. Experimental Conditions

First, we explain the flow of the experiment. We generated a random network and scale-free network described in section 2 and decided the start and goal randomly. We explored 10 times each on the network with same start node and goal node by using the Skip Model, the Skip0.5 Model, the Skip1 Model, and the Skip0 Model described in section 3. We tried these processes 1000 times, found the average exploring times from the start to the goal for each model, and calculated the significant difference of performance of the Skip Model by using Mann-Whitney U-test and analysis of variance (ANOVA). However, if the walker had not reached the goal even though the walker moves 1000 times, we counted it as the number of unreached times.

Regarding generating the networks, we generated random networks by repeating the operation of selecting two nodes randomly and connecting them with probability p . Then, we set the probability $p = 1.0$. On the other hand, we generated scale-free networks according to the power law of Eq. (2.1). Concretely, the scale-free networks generated while changing the scale index γ to 1.0 and 2.0 in this experiment.

4.2. Experimental results

Most networks in the real world are scale-free. Therefore, we show the results of exploring the scale-free network, first. After that, the results of exploring the random network are shown.

4.2.1. Scale-free Networks

First, we show the exploring results for scale-free networks in Tables 1 and 2, and Figures 3 and 4. Table 1 and Figure 3 show the results of exploring the scale-free network with the scaling index $\gamma = 1.0$, and Table 2 and Figure 4 show the results with $\gamma = 2.0$. According to Table 1 and Figure 3, the Skip0 Model which is random walk always takes 1.5 times longer than the other models regardless of the value N , and it is significantly inferior. Similarly, the Skip1 Model is inferior to the Skip Model and the Skip0.5 Model regardless of the value of N . The Skip Model is the best under the conditions of $N = 100$ and $N = 200$, however inferior to the Skip0.5 Model under the condition of $N = 300$.

Table 2 and Figure 4 show that the Skip0 Model is inferior to the other models at all N values as in the case of $\gamma = 1.0$. The Skip0.5 Model is inferior to the other models under the condition of $N = 200$, and the Skip1 Model is inferior to the other models under the condition of $N = 300$. On the other hand, the Skip Model is superior to the other models at all value of N .

Table 3 shows that the number of times which the walker does not reach the goal after moving 1000 times. According to Table 3, the Skip0 Model is significantly inferior to the other models in respect to the number of unreached times as with average exploring time. Moreover, the Skip Model and the Skip1 Model have similar values for all N and γ. The Skip0.5 Model is inferior to the other models except the condition of $N = 100$ and $\gamma = 1.0$. Considering comprehensively the results in Tables 1 and 2, and Figures 3 and 4, it can be seen that the Skip Model has the superior exploration ability in comparison to the other models for all N and γ.

Table 1: The Average Exploring Times on the Scale-free Network Under condition of $\gamma = 1.0$

N	Skip	Skip0.5	Skip1	Skip0
100	79.2	86.8	86.9	150
200	149	151	154	249
300	204	194	209	307

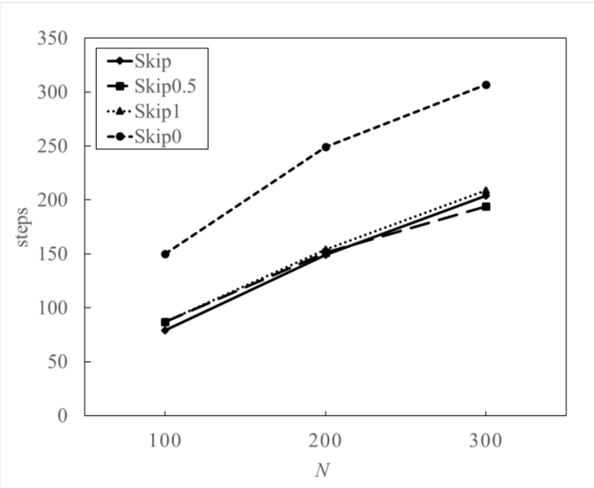

Figure 3: The Result of exploring on the Scale-free Network Under Condition of $\gamma = 1.0$

Table 2: The Average Exploring Times on the Scale-free Network Under condition of $\gamma = 2.0$

N	Skip	Skip0.5	Skip1	Skip0
100	91.5	98.0	96.4	175
200	159	171	165	260
300	204	207	218	311

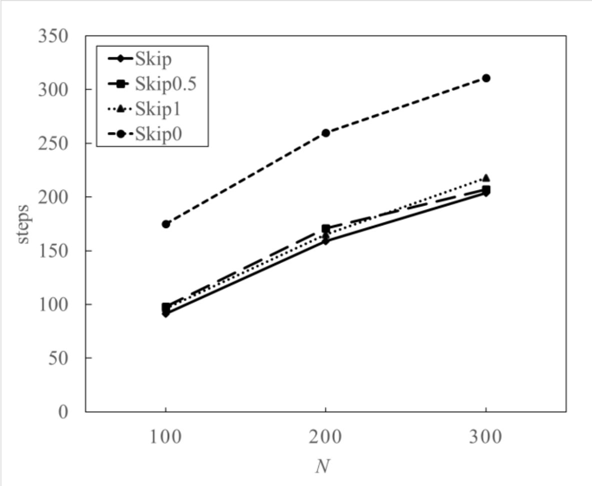

Figure 4: The Result of Exploring on the Scale-free Network Under Condition of $\gamma = 2.0$

Table 3: The Number of Unreached Times on the Scale-free Network

γ	N	Skip	Skip0.5	Skip1	Skip0
1.0	100	40	25	70	106
	200	142	234	164	757
	300	422	574	424	1466
2.0	100	53	77	70	260
	200	337	454	325	1019
	300	654	814	657	1756

4.2.2. Random Networks

Next, we show the results for exploring on the random network in Table 4 and Figure 5. The Skip0 Model which is the random walk model is inferior to the other models as with the results on the scale-free network. Although the Skip0.5 Model is slightly inferior to the Skip Model and the Skip1 Model, there is no big difference concerning these models which pass through the adjacent nodes. In addition, we show the number of unreached times for respective models in Table 5. By making a comparison between Table 3 and 5, it is obvious that the number of unreached times in the random network is less than those in the scale-free network regarding any model and value of N. The number of unreached times for each model in the random network is almost the same results for the Skip Model and the Skip1 Model, but the Skip0.5 Model is inferior to the above-referenced two models, and the Skip0 Model is inferior to the other three models.

Table 4: The Average Exploring Times on the Random Network

N	Skip	Skip0.5	Skip1	Skip0
100	74.1	76.8	73.7	124
200	130	134	129	205
300	181	184	181	259

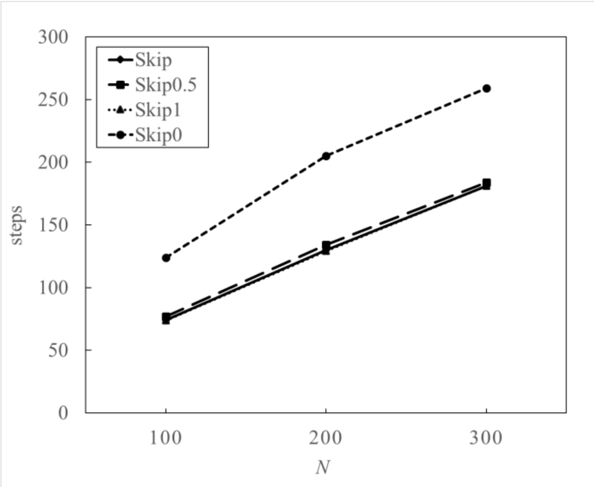

Figure 5: The Result of Exploring on the Random Network

Table 5: The Number of Unreached Times on the Random Network

N	Skip	Skip0.5	Skip1	Skip0
100	1	50	31	146
200	134	166	125	497
300	298	406	303	839

4.2.3. Statistical Processing and consideration

In the previous sections, we calculated the average exploring times on the random network and scale-free network for each model and compare them. In this section, we examine whether the obtained data have significantly different by using U-test. Moreover, we use the analysis of variance (ANOVA) to see whether the differences in models and in the value of γ affect the results. Now, the null hypothesis is that "changes in the models and the value of γ do not affect the results", and the p-value less than 0.05 is considered statistically significant. Subsequently, we consider the superiority of the proposed model based on the test in this subsection and the results of the previous subsections.

Firstly, examining whether there was a significant difference in the result by using U-test, the p-values for all the data were extremely small and close to 0. For this reason, it is found that there is a significant difference between the data. Secondly, we show the results of analysis of variance (ANOVA) under conditions of $N=100$, $N=200$, $N=300$ in Tables 6, 7, 8. Note that Df is the degree of freedom of the factor, Sum Sq is the sum of squares, Mean Sq is the square mean, and Pr (> F) is the p-value evaluated from the F distribution table. Since the p-value is much lower than 0.05 regarding both γ and models in Tables 6 and 7, the null hypothesis are rejected. In other words, both the model and γ affect the results in case of $N=100$, $N=200$. On the other hand, in Table 8, the p-value regarding γ much larger than 0.05, and the null hypothesis of "changes in the value of γ do not affect the results" cannot be rejected. However, since the p-value regarding Model is less than 0.05, the null hypothesis of "changes in the model do not affect the results" is rejected also under condition of $N=300$.

Considering the performance of each model on the scale-free network based on the above results, all models which pass through the adjacent nodes are superior to the Skip0 Model. Moreover, the Skip Model is superior to the other models in Table 1, 2 and Figure 3, 4 except under condition of $N=300$ and $\gamma=1.0$. Whereas, it turns out that we cannot always obtain a good result even if the walker moves to the node two nodes away absolutely, because the result of the Skip1 Model is inferior to the result of the Skip0.5 Model in Table 1 and Figure 3. It is presumed that this proceeds from the drawback of the model which passes through always adjacent nodes that the walker cannot break out of blind alley immediately. The feature of scale-free network is that it has a few nodes with large degree, and a lot of nodes with small degree. Therefore, scale-free network has many blind alleys (Barabási and Bonabeau 2003). Figure 6 shows an example of the exploration on the scale-free network. The walker starts from node S and must go to node G in this figure. For the walker to reach the goal, it is necessary to go to the upper node via the node M. The walker is likely to move from node S to the dead nodes A, B, and C because the walker passes through the adjacent nodes absolutely regardless the degree of the node by using the Skip1 Model. On the other hand, by using the Skip Model, the probability which the walker passes through the adjacent nodes change depending on the degree of the current node, therefore the possibility of skipping the adjacent nodes from node S with the degree is one becomes 0. Then, after the walker moves to node M, the probability of passing through the adjacent nodes and going to the goal is high because node M has a large degree. Thus, we consider that there is a difference between the results of the Skip1 Model and the Skip Model due to the difference in the probability which the walker passes through the adjacent nodes.

Now, we show the average of the number of revisits under conditions of $N=100$, $\gamma=1.0$, and the results of comparing the number of revisits between the Skip Model and other models in Table 9. Table 9 shows that there is a significant difference for all models because the p-value is extremely below than 0.05. Regarding the number of average revisit times, the Skip0 Model is overwhelmingly frequent. Subsequently, the Skip0.5 Model which has a low passing probability next to the Skip0 Model has many revisits. On the other hand, the Skip1 Model which has the highest passing probability and the Skip Model which changes the passing probability depending on the degree of the current node have fewer revisits than other models. We consider that this result is caused by the problem that the random walk is likely to form closed loops by drawing polygons as described in Section 2.1. The aim of the exploring model which passing through adjacent nodes is to improve this problem, thus we can say that the Skip0.5

Model is inferior to the Skip Model. Moreover, since the Skip0.5 Model has a lot of unreached times next to the Skip0 Model, we can infer that these two models are prone to fall into closed loops compared with the Skip model and the Skip1 Model in Figure 4.1.

On the random network, the Skip0 Model is inferior to the models which pass through adjacent nodes as with scale-free network as shown in Tables 4-8 and Figure 5. the Skip0.5 Model is inferior to the Skip Model in respect to the average exploring time and the number of unreached times, however there is no significant difference between the Skip1 Model and the Skip Model. The problem which the walker is likely to fall into closed loops also occurs on the random network, and it is improved by the model which passing through adjacent nodes. Hence, the Skip0 Model (i.e., random walk) and the Skip0.5 Model are inferior to the Skip Model and the Skip1 Model. On the other hand, we infer that there is no large difference about the result between the Skip Model and the Skip1 Model because random networks have few nodes which have small degrees compared with scale-free networks and have few blind alleys.

Summarizing the results in Tables 1, 2, 3 and Figures 3, 4 and considerations, it is concluded that the Skip Model which is proposed model is superior on the whole to the other models on the scale-free network from the viewpoint of the average exploring time, the number of unreached times, and the number of revisit times, on the whole. Regarding the random network, the Skip0 Model and the Skip0.5 Model are inferior to the other models. Further, there is no large difference between the Skip Model and the Skip1 Model. After all, it can be concluded that the Skip Model is relatively useful compared to other models.

Table 6: The Result of ANOVA on the Scale-free Network ($N = 100$)

	Df	Sum Sq	Mean Sq	F-value	Pr (>F)
γ	1	421	420.5	16.71	0.02646
Model	3	7988	2662.6	105.81	0.00153
Residual	3	75	25.2		

Table 7: The Result of ANOVA on the Scale-free Network ($N = 200$)

	Df	Sum Sq	Mean Sq	F-value	Pr (>F)
γ	1	338	338	30.73	0.011575
Model	3	13975	4658	423.47	0.000194
Residual	3	33	11		

Table 8: The Result of ANOVA on the Scale-free Network ($N = 300$)

	Df	Sum Sq	Mean Sq	F-value	Pr (>F)
γ	1	85	85	5.227	0.106325
Model	3	16095	5365	331.845	0.000279
Residual	3	48	16		

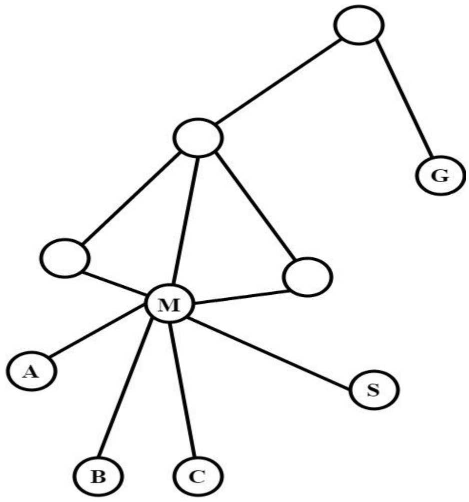

Figure 6: An Example of Exploring on the Scale-free Network

Table 9: The Number of Revisit Times on the Scale-free Network ($N = 100$, $\gamma = 1.0$)

	Skip	Skip0.5	Skip1	Skip0
p-value	-	2.20×10^{-16}	2.20×10^{-16}	2.20×10^{-16}
average	3.10	4.59	2.48	9.82

5. CONCLUSION

The random walk is one of the famous exploring methods in respect to the exploration of complex networks. However, a random walk has the problem that the walker falls into frequently closed loops and affects exploring time. To solve this problem, we proposed the Skip Model that increased or decreased the skipping probability depending on the degree of the current note considering the structure that closed loops had been formed in networks in this paper. Furthermore, we created two models with constant skip probability, and verified four exploring models including the traditional random walk model.

Consequently, the Skip Model is superior to the other models frequently regarding the average exploring times on the scale-free network. The Skip Model is the best methods for the number of nodes and scaling index verified this time because the number of unreached times is not many even under conditions where average exploring times is inferior. Focusing on the problem of forming closed loops which is our initial aim, the Skip Model has far fewer revisits than random walk, and the number of unreached times is superior to the other models. Therefore, it can be said that this model does not solve the problem completely, however improves it significantly. Meanwhile, the three models which pass through the adjacent nodes have a new problem that the walker cannot break out of blind alley immediately. The Skip1 Model which is an excellent model on the random network is affected by this problem heavily, and the results of the model on the scale-free network are not good. On the other hand, by using the Skip Model, the probability of passing through the adjacent nodes changes appropriately according to the degree of the node. Therefore, the result of the model is excellent on the scale-free network.

The Skip Model is the most effective exploring method regardless of the type of network, the number of nodes, and the value of γ under the conditions of examined in this paper. Nevertheless, networks in the real world have a lot of nodes not within the number of nodes used in this paper. Furthermore, scaling index γ changes to various values depending on the networks. To adopt the Skip Model as one of the exploring methods on complex networks, it will be necessary to verify on the networks which have a lot of nodes and consider the results.

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JOB SHOP RESCHEDULING WITH LOT SPLITTING UNDER MULTIPLE INTERRUPTIONS

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ABSTRACT
Production does not necessarily process on schedule. In fact, it is sometimes that works are stopped by some causes of machine breakdowns and so on. When these situations have occurred, rescheduling is made out to reduce bad influence. This is mostly executed by using RSS (Right-Shift-Scheduling) or metaheuristics such as GA (Genetic Algorithm). However, metaheuristics and RSS have drawbacks. In this research, we would propose a new rescheduling method using lot splitting. When the interruption happens in a factory, a time lag between machining start time at the beginning and the end of a lot exists in the following factory. We think that the time lag makes it possible to split the lot into two sublots with an appropriate ratio and the delivery into two. As a result, our proposed method is not inferior to GA and is superior to RSS under the evaluation of the number of tardy jobs.

Keywords: job shop scheduling, lot splitting, rescheduling, setup time

1. INTRODUCTION

Over the years, production scheduling has been studied in order to keep the due date, to reduce the cost and so on. Previous researches have suggested effective methods by simulating under supposing various situations. However, unexpected events such as interruptions of works or additions of new jobs may occur in actual situations. Pinedo (2008) have stated the 12 principal differences between the simulation model and the real scheduling problem:

1. New jobs constantly arrive in the system.
2. The rescheduling problem is important.
3. The job environments are more complicated.
4. The weights (priorities) of jobs change with time.
5. Job preferences in the selection of machines are important.
6. There are restrictions in machine availability according to working shift patterns or timetables.
7. Nonlinear penalty functions.
8. Several objectives are often considered.
9. Overtime work and working time assignment of workers depend on the amount of work and the time margin.
10. Processing times do not follow statistical distributions.
11. Processing times on the same machine tend to be highly positively correlated.
12. Processing time distributions may be subject to change due to learning or deterioration.

From the above, it is necessary to handle a situation that takes into consideration more realistic conditions. For example, operation stopping is often happened because of some causes of machine breakdowns and so on. Other unexpected situations such as machine failure, change in due date (changed earlier), addition of jobs, etc. may always occur. When such situations occur, the initial production schedule is reorganized, which is called Rescheduling, in order to reduce bad influence of the operation stopping. Rescheduling is a combination problem. Therefore, it is often solved with metaheuristics such as GA. Metaheuristics can get an optimal solutions or values close to them. However, in fact, it takes time to get a new schedule for the operation of renewing input data at every interruption, and it is almost difficult to trust the output of metaheuristics because of the unclear deriving method and process. Therefore, rescheduling is very likely made by RSS.
RSS is a method of shifting the initial schedule backward for the interruption time as it is. RSS has an advantage which is not to need newly considering the setup time, however, is greatly affected by interruption time. In the case that idle time is large, RSS is effective because of the interruption time is absorbed by the idle time in factory. However, idle time is usually set small because idle time is mostly dead time. So, since the work interruption time is usually much longer than the idle time, RSS cannot fully take its effectiveness.
In this research, we propose a new lot splitting method alternative to GA and RSS. Generally, a job is the set of works to make products, and the lot is a part of a job and the set of work to make products. Our proposed method is that a specific lot at an interruption is split into two sublots and the sublots are separately send to the succeeding factory, respectively. Considering the

handling of the product in the succeeding factory, there is a time lag in process start time between the start part and the end part of the original lot. Once a part of the lot has been delivered, the succeeding factory can start processing. We think that it is possible to reduce the overall due date tardiness if the time lag is used to process the first delivery lot in a succeeding factory and the undelivered part of the lot is processed by machines in an interrupted factory. Through comparing the proposed method with GA and RSS which are conventionally used, we confirm the effectiveness in rescheduling of the proposed method.

2. PREVIOUS RESEARCHS

2.1. Scheduling Environment

Production scheduling problems are roughly split into the flow shop problems and the job shop problems. The former means a problem in which all jobs are processed in the same order, and the latter means a problem in which the order of machines for processing is different for each job.

For an example in the flow shop problem, Katragjini et al. (2012) have proposed a solution for problems with different interrupting factors. The solution in Katragjini et al. (2012) is to reschedule the original schedule when some events such as a machine failure, appearance of a new job, or change at processing start time are happened in the flow shop problem. They propose ways have quality and reliability by using the IG (Iterated Greedy) (Ruiz and Stützle 2007).

On the other hand, here are some examples of the job shop problem. Sarker et al. (2016) have proposed a method of minimizing the make span by using IMA (Improves Memetic Algorithm) which is a type of GA when a new job is assigned. Jiang et al. (2016) have proposed a method to acquire production information in real time by using IoT and suppress the influence on total processing time. They use the evolved form of ACO (Ant Colony Optimization) called IACO (Improved Ant Colony Optimization) when a rescheduling is needed due to the machine failure.

Also, Vieira et al. (2003) have summarized and reported some of other rescheduling methods which were studied.

2.2. Lot Splitting

A lot is a processing unit to make products and a part of a job. The lot size can be changed to an arbitrary size as necessary, and it is possible to prevent excessive inventory and out-of-stock by appropriately controlling the lot size. Since the size of the lot very likely influence the total processing time, it is also considered in the production scheduling problem. For example, Low et al. (2003) have proposed a method to minimize the make-span by splitting a lot into several sublots. The size of all sublots were equalized and some sublots added in the paper. However, they also have stated that there are drawbacks that margin of schedule improvement decrease or costs increase if the number of sublots is increased excessively. Haase and Kimms (2000) proposed a method of rescheduling with reduced idle time by adjusting the lot size of original schedule. However, they don't consider unexpected situations such as work interruptions. On the other hand, as far as we know, there is no study that assumes splitting lots to cope with the interruption of works.

3. PROPOSED MODEL

In this research, we consider splitting lots to cope with the interruption of works. At this time, we think that flexibility in rescheduling can be secured by performing lot splitting when interruption occurred. In this research, we propose a method of performing lot splitting at the time of work interruption and performing rescheduling by applying the dispatching rule described later.

3.1. Model Setting

The model dealt with in this research is set as follows:

1. Job shop problem is treated which have 10 jobs and 10 machines.
2. The setup time of a job is given depending on each machine and the preceding job.
3. In one machine only one job is processed at a time.
4. The unit of time is minutes.
5. The workable start times of all jobs are set time 0.
6. The worktime per a day is set 480 and the planning horizon is 5 days.
7. Due date differs depending on the job, and it is generated between 1300 and 2400 with uniform random numbers.
8. All jobs are only processed once on each machine.
9. The work time of each product is set depending on each process, and they are generated between 1 and 5 with uniform random numbers.
10. One job consists of one lot.
11. The lot size which means the number of products is set depending on each job, and it is generated between 20 and 60 with uniform random numbers.
12. The slack time is between 20% and 50% of the duration from the feasible production start time of each job to the due date.
13. No more than one machine is interrupted at any time, and the interruptions are occurred with uniform random numbers.
14. Two types of interruption timing are treated. Interruption of work shall be set with uniform random numbers either at the start time of a workday or immediately at the end of a lunch break. Specifically, it is (0 or 240), (480 or 720), (960 or 1200), (1440 or 1680) and (1920 or 2160). The numbers in the parenthesis show the candidate for the timing of each interruption occurrence.

15. Each work interruption time is generated between 60 and 150 with uniform random numbers.
16. If another interruption occurs again, work is following the schedule which was created after a previous work interruption, and work is following that schedule until returning from the latest interruption. And then, at the time of interruption restoration, the new schedule is newly rescheduled by each method.

3.2. Evaluation Measure

Evaluation values are the number of tardy products, the number of tardy jobs, the average jobs tardiness, and the maximum job tardiness in all jobs. Here, each evaluation measure is defined as follows:

- The number of tardy products: The products are sum of tardy parts of tardy jobs
- The number of tardy jobs
- The average of job tardiness: The value is obtained by dividing the sum of the tardiness for all jobs by the total number of jobs.
- The maximum job tardiness in all jobs: The value is the largest job tardiness (the time difference between the final processing completion time and the due date) of all jobs.

Among them, the number of tardy products will be primary evaluated in this research because the number of products in each job is directly operated by a lot splitting and then the time criterion is considered as a secondary factor. We solve 40 numerical examples which are data generated us for experiment, and find the best method among our proposed method, GA and RSS.

4. NUMERICAL EXPERIMENT

4.1. Previous Method

We would compare the proposed method with GA and RSS which are usually used, and confirm the number of cases whose number of tardy products is the smallest in the three methods. In proposed method and GA, lot splitting is adopted, but in RSS, isn't.

4.1.1. RSS

RSS is a simple dispatching rule which shifts operations backward for the interruption time. The rule has a priority. The rule need not to consider setup time newly because new schedule is same operation order as initial schedule. So, RSS is one of the most used method to reschedule in actual. In this research, RSS dose not adopt lot splitting because job assignment of RSS is not affected by lot splitting.

4.1.2. GA

GA is one of metaheuristics. It is often used to solve combination problems. GA needs time to take solution but can get a solution close to an optimal solution. In this research, we estimate that it takes about 10 minutes to derive GA solution for rescheduling. Therefore, GA is operated so that the schedule obtained by GA is applied 10 minutes after the interruption restoration. Then, jobs are reassigned according to the result of rescheduling based on GA. Each parameter of GA is described below. In addition, parameters were set from preliminary experiments.

- Number of individuals: 100
- Number of generations: 5000
- Crossover probability: 70%
- Mutation probability: 1%
- Large mutation event: at the 1000^{th} generation
- Mutation probability in large mutation: 50%

A large mutation is to suddenly raise the mutation probability once at a specific generation. This is similar to a situation happened in nature. It refers to a significant change in the ecosystem, for example due to meteorite collision, climate change, crustal deformation, etc., when seeing the evolutionary process of living organisms from a long-term perspective. Incorporating large mutations in GA is due to prevent individuals from the loss of solution diversity, which occurs when falling into a local optimal solution at an early stage. In this research, we decided to generate a large mutation at 1000^{th} generation in order to increase the possibility of further updating the previous generated optimum solution is raised. The generation where large mutation occur is determined by confirming the convergence of the solution by several experiments. In addition, we have confirmed by several experiments that the solution became better if large mutation was taken.

There is no processing priority between the jobs because this research deals with the job shop problem. Also, gene sequence corresponds to the order of job submission. Preventing from excessively increasing of idle time of machines by the job submission order created in GA, we consider the following gene manipulation. When there is a job that can be processed by another machine, the job is submitted to the machine. Then, the gene sequence is rearranged because the job input order and gene sequence are changed. This rearranging operation is called AGM (Additional Gene Manipulation) in this research.

The flow of operation of GA is described as follows:

1. Generate initial individuals.
2. Make schedule based on the data of each individual.
3. Calculate the performance of each individual.
4. Save the best solution.
5. Selection.
6. Crossover and mutation.
7. Exit if the number of generations reaches the last generation, otherwise return to 2.

The flow of GA in the case of 5 jobs and 5 machines is shown in Table 1 and from Figure 1 to Figure 5. Table 1 shows sample data where 5 in the top left corner means that job 1 is first processed in machine 5. Figure 1 shows an example of GA solution. In Figure 1, the numbers from 1 to 5 in the sequence mean jobs which are assigned to machines in order from the left. In Figure 1, the 1st process of job 1 is assigned into the leftist locus, and then the 1st operation of job 4 is assigned into the 2nd leftist locus. The second 3 which appears in the 6th leftist locus means the 2nd operation of job 3. Figure 2 and Figure 3 show the example schedule obtained based on Table 1 and Figure 1. Figure 2 shows job assignment to each machine from leftist locus 1 to 6. Figure 3 shows that all jobs are assigned according to the locus. Figure 4 shows the gene sequence of Figure 1 rearranged by AGM. In Figure 4, for example, the 7th locus is changed from 2 to 4. In addition, the 10th, 11th, 12th, 13th, 14th, 16th, 17th, 18th, 20th and 21st loci are changed. Each evaluation measure of each individual is calculated from the solution and the best solution of the generation is saved. And the best solution is kept until a better solution being generated. In the crossover procedure, two-point crossover and mutation are executed to generate children. The flow of the two-point crossover is as follows and shows in Figure 5. Firstly, two solutions are selected as parents from the solutions, and it is determined whether to cross the parents or not according to the crossover probability. When crossover is executed, two cut points are randomly selected. Job numbers between two cut points in the selected parents are compared and the job numbers are swapped between the parents. When the number of some jobs is excess and other jobs is deficient after the crossover, the number of excess and deficient jobs is only adjusted by swapping the jobs each other from the leftist side in the swapped numbers. And then, mutation would be executed. The solution of GA is the best solution at the final generation.

Table 1: Sample Processing Data

		Operation Number				
		1st	2nd	3rd	4th	5th
Job Number	1	5	3	2	4	1
	2	1	5	4	3	2
	3	2	5	3	1	4
	4	3	5	2	1	4
	5	2	4	5	1	3

1	4	3	2	5	3	2	1	5	3	2	4	4	3	5	1	2	3	1	4	5	2	1	5	4

Figure 1: Example of an Individual

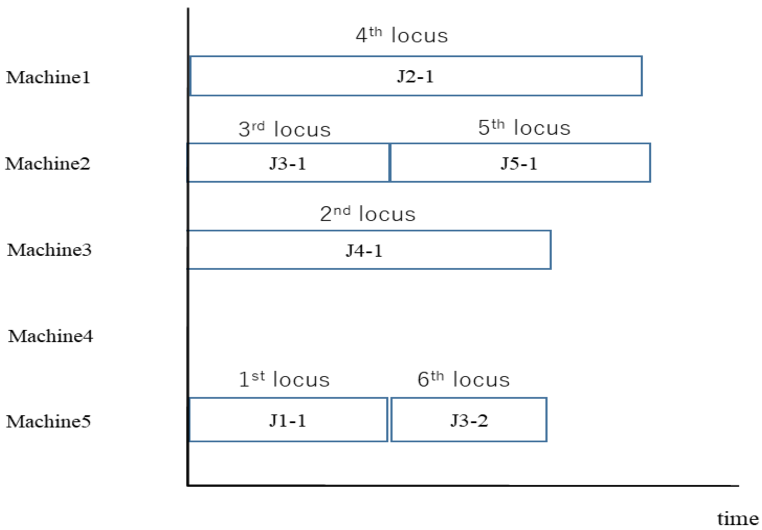

Figure 2: Example of Assigning Jobs According from 1st to 6th locus

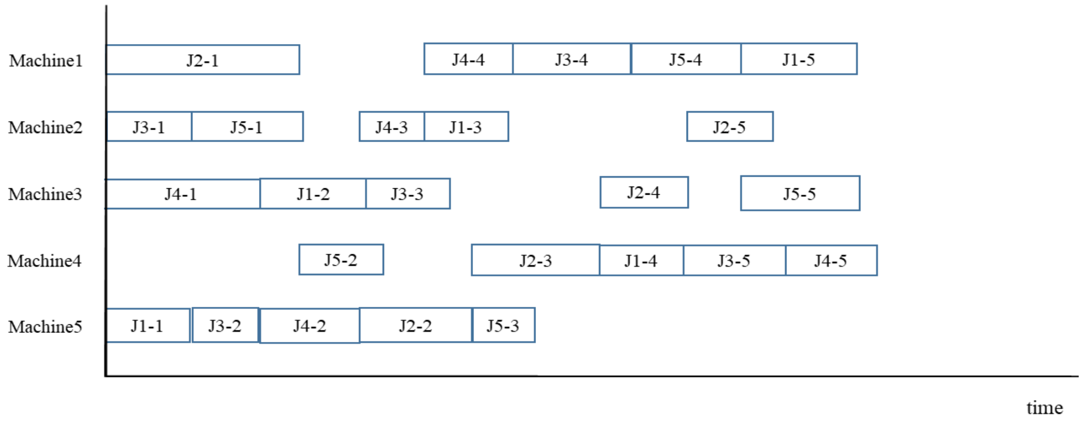

Figure 3: Example of GA Schedule

1	4	3	2	5	3	4	1	5	2	4	3	1	4	5	2	3	2	1	5	3	2	1	5	4

Figure 4: Example of Rearranged Individual by AGM

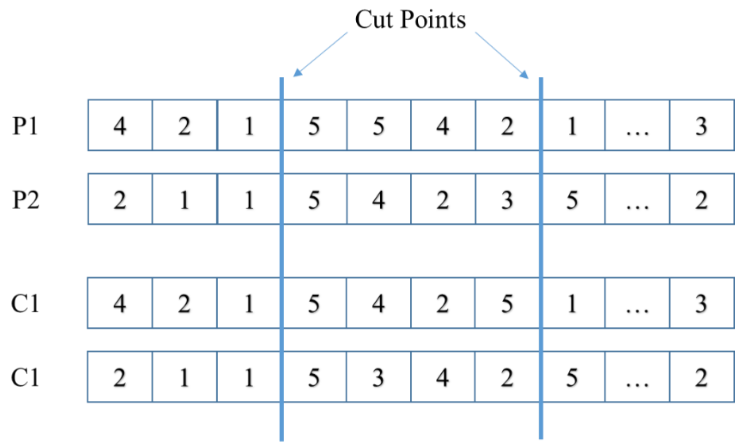

Figure 5: Two-Point Crossover

4.2. Proposed Method

It is inevitable that an interruption occurs in production activities, and how to suppress the effect of the interruption is important. In the past researches mostly focused only on the site where the interruption took place and an initial schedule is rescheduled to be able to deal with the interruption on the interrupted workstation. However, it is rare to make products from the beginning to the end within one factory. Products are made through processes in multiple companies and work sites. Therefore, if an interruption occurs in a factory, the interruption likely affects all related factories. In such a case, the succeeding factory will be negotiated about the due date and delivery of the affected products. In this research, we pay attention to the fact that the negotiation is carried out, and assume that some specific lots can be split into 2 sublots, that is, sublot 1 and sublot 2. Then, sublot 1 which is delivered at the initial due date and the other sublot 2 which is permitted delivering with a little tardiness. In this research, we will treat 3 patterns about delaying due date of sublots 2: same due date as initial lots (pattern 1), delay 10% of initial lots (pattern 2), and delay 20% of initial lots (pattern 3). Sublots 1 have processing priority to other unsplit lots and sublots 2. The simple flow of the proposed method is shown as follows:

1. Initial schedule is created by EDD (Earliest due date) or GA.
2. Select the lots to be split at the time of an interruption (details of lot splitting will be described later).
3. Split the selected lots into sublots 1 and sublots 2, respectively.
4. Apply the corresponding dispatching rule with consideration for the recovery time until the time of the interruption recovery, and perform rescheduling.
5. Repeat steps 2 to 4 when another interruption occurs.

The proposed method splits specific lots when an interruption has occurred and performs rescheduling based on the dispatching rule at the time of work restoration. When plural lots are waiting to be processed on a machine, if there are sublots 1 in the waiting lots, the sublots 1 should be preferentially processed, and if not, sublots 2 or unsplit lots are processed. At this time, if there are some sublots 1 which can be processed in the waiting lots, a sublot 1 to be processed is determined according to an applied dispatching rule. The dispatching rule to be applied at a work restoration is SLACK or SPT (Shortest-Processing-Time). SLACK is applied if a work is restored by the 4th day (1920), else SPT is applied. SLACK rule is the safe rule to reduce the problems after an interruption occurrence which are composed of the number of tardy products, the number of tardy jobs, the maximum job tardiness in all jobs, the average of job tardiness and so on. Hence, we will use SLACK from the start of the first work for a while. However, there are cases that SLACK has no jobs that can be completed by the end of the planning horizon as time goes on. Therefore, we try to reduce the processing time per process in a machine by applying the SPT from the beginning of the last half in the planning horizon and reduces the number of tardy products because SPT gives priority to processing with a shorter processing time and increases the number of processing jobs. If there are jobs that can be processed on each machine, the jobs are processed in order by decided dispatching rule. In addition, the reason why we adopt SLACK and SPT and switch them at the time after 1920 minutes from processing start time is that the combination showed the best result in some preliminary experiments.

4.3. Selection of Splitting Lot

The incompletely processed lots on a workstation are split when the interruption occurs at the workstation. However, lots already split into sublots which were never split again. In this research, in addition, once a lot is split into two sublots at an interrupted workstation then the sublots are operated without merging at all the succeeding workstations. An example of the flow of the lot splitting is shown from Figure 6 to Figure 10. In Figure 6, J3-1 on machine 4 shows the job number is three and the first step in all processing steps of Job 3. Each job has one processing step at each machine in this research. Figure 6 shows the example of an initial schedule. Figure 7 shows the process of an interruption occurred. Figure 8 shows the selection of splitting lots. Figure 9 shows before and after of lot splitting. In Figure 7, an interruption has occurred at the cross mark of the J3-1 at machine 4. As shown in Figures 7 and 8, lot splitting jobs are job number 3, 5, 1 and 2 are going to be split. And, the all processing steps of Job 3, the 4th and 5th processing steps of Job 5 and the 5th processing step of Job 1 and Job 2 are treated as split jobs. Figure 10 shows the result of rescheduling by the proposed method after interruption recovery. In Figure 10, the dispatching rule of proposed method adopted for rescheduling is SPT. If lots are available for processing even during an interruption, they will be processed based on at the latest schedule. However, sublots 2 cannot be processed unless the processing corresponding to the precedent relationship of the sublots 2 are completed. Therefore, in the case of rescheduling by GA, the following genetic manipulation is operated. If the process of sublot 2 is preceding the process of sublot 1, two loci which are the sublot 1 and sublot 2 are swapped.

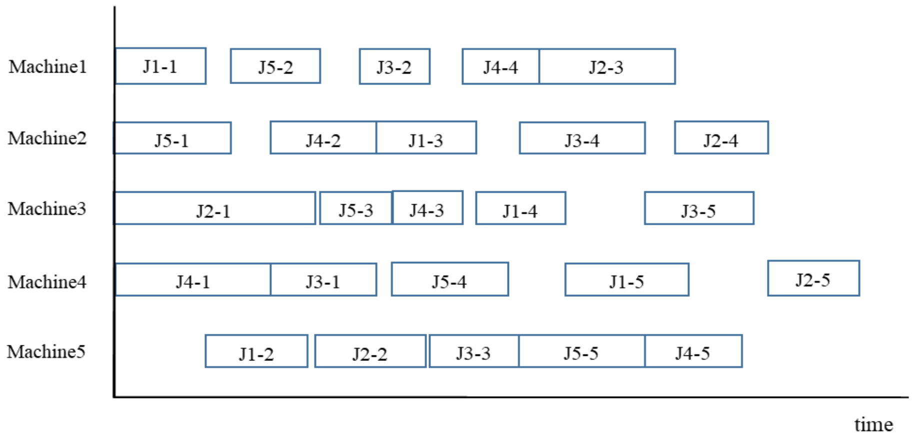

Figure 6: Example of Initial Schedule

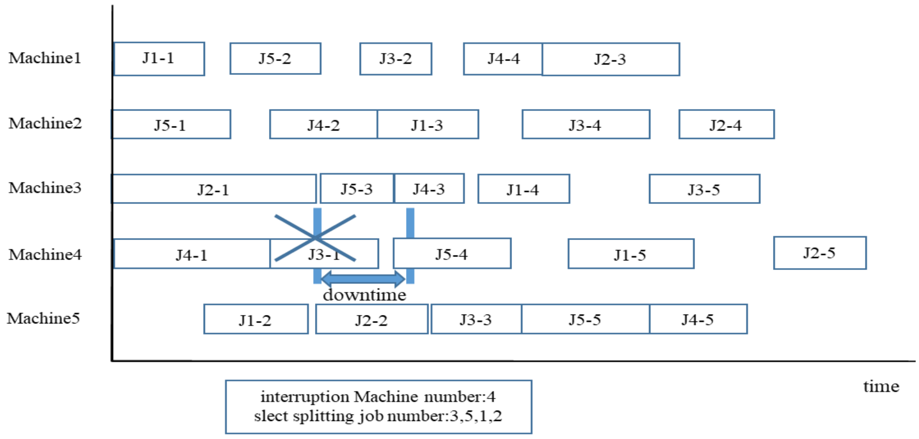

Figure 7: Interruption Occurrence

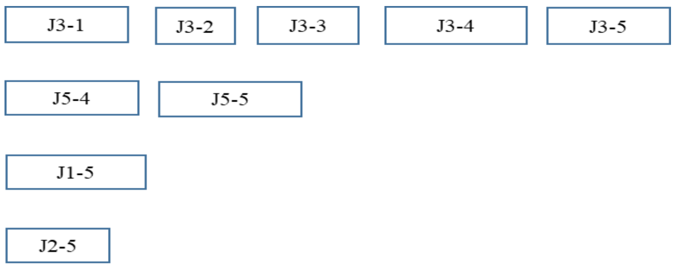

Figure 8: Selection of Splitting Lots

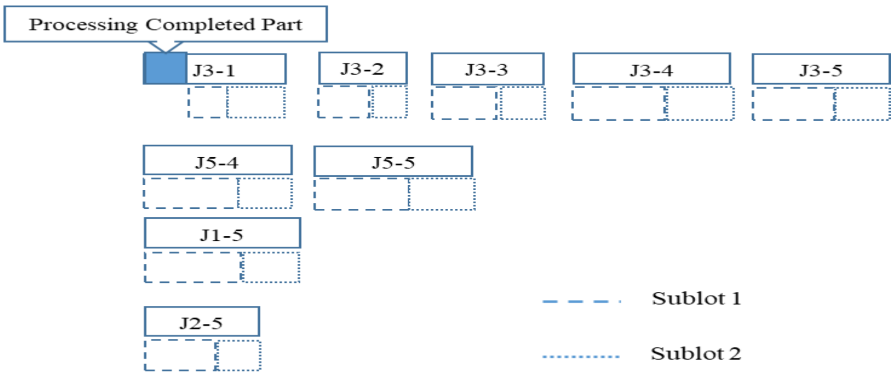

Figure 9: Lot Splitting of Selected Part

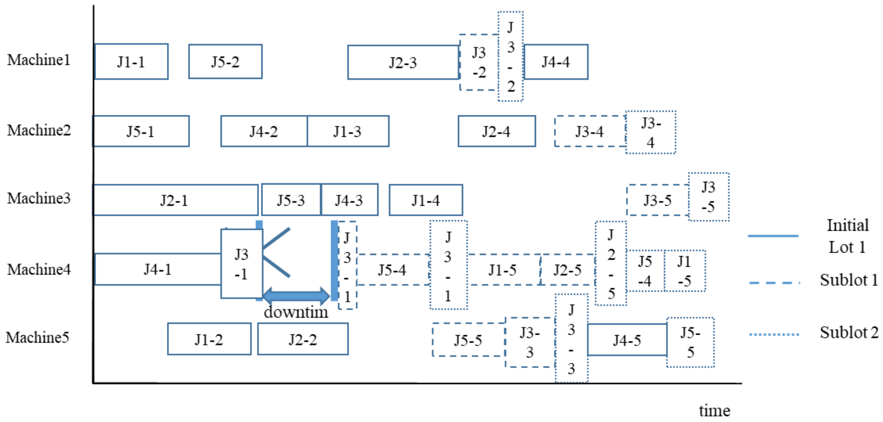

Figure 10: Example of Rescheduling by Proposed Method after Interruption Recovery

5. RESULTS OF NUMERICAL EXPERIMENTS AND CONSIDERATION

In this research, all sublots 2 in proposed method and GA are allowed to miss their initial due date, but in RSS, the due date is fixed same as initial due date. Table 2 shows the results in case of that initial schedules of proposed method and RSS are made by EDD, and Table 3 shows the results in case of that initial schedules of proposed method and RSS are made by GA. GA is superior to other two methods in most patterns from each pattern in upper parts of Table 2 and 3. In particular, GA is very excellent in pattern 1. However, the proposed method is as good as GA in pattern 2 and pattern 3. The reason is considered that GA is not able to perform fully the potential when the diversity of solutions is impaired as the progress of processes. Also, it is considered that GA is affected critically when conditions of machine processability are changed from the latest schedule because GA calculates the best or near the best schedule at each timing of rescheduling. So, scheduling by GA suffers fatal damage on the specific situations and tends to leave delayed jobs to process. On the other hand, the proposed method is considered not to be affected than GA because it schedules jobs according to rules established in advance even when the conditions are changed from the latest schedule. Although the proposed method has situations not to be treated, it can reduce serious job tardiness because of switching the dispatching rule adopted depending on the elapsed time of processing.

Then, we consider the rate of delaying the due date of sublots 2. The result of scheduling by GA is improved as delay the due date of sublots 2. However, in proposed method, it is not to say that simply delaying due date of sublots 2 is better. This is caused by that SLACK affects the results largely. In the proposed method, SLACK is applied at rescheduling executed from the start of processing to 1920 minutes (the time is the fourth day ends). The delay of the due date of sublot 2 can change the processing priority by SLACK. Therefore, if rescheduling is performed on the 3rd and 4th days, the case can occur that a job which remains only one process is delayed because SLACK gives priority to jobs with less margin of due date. This phenomenon can occur as the due date of sublot 2 is delayed more, and in the proposed method, pattern 2 is superior to pattern 3 in some cases. From the above, it is considered that the proposed method needs to change the dispatching rules to be applied according to the rate of delaying the due date of sublots 2.

As a result, the proposed method is inferior to GA from upper parts of Table 2 and 3. However, the result is not so bad from average of each evaluation measures in lower part of Table 2 and 3. And then, it can be an alternative of GA for rescheduling when time, labor on workshop and reliability from workers are taken into consideration. Moreover, the rate of delaying the due date of sublots 2 depend on the interruption time, but it is considered impractical to delay 20% of initial due date or more. Also, in this research, the due date of sublots 2 are delayed uniformly, but the limits of delaying due date of sublots 2 are actually different by each job. If the conditions are changed as described above, the results are different, so it is necessary to further experiments.

Table 2: The Results of Numerical Experiments (The Initial Schedule of Proposed Method and RSS is made by EDD)

		Pattern1			Pattern2			Pattern3		
		Proposed Method	GA	RSS	Proposed Method	GA	RSS	Proposed Method	GA	RSS
The Number of Minimum Cases in 40 Cases	The Number of Tardy Products	15	34	0	15	17	0	21	31	0
	The Number of Tardy Jobs	18	38	1	20	20	1	22	31	0
	The Average of Job Tardiness	15	32	0	14	16	0	21	31	0
	The Maximum Job Tardiness in All Jobs	22	23	2	13	16	2	22	30	0
Average Value of 40 Cases	The Number of Tardy Products	41.55	16.05	137.35	10.9	9.05	137.35	13.45	5.075	137.35
	The Number of Tardy Jobs	2.3	0.975	3.975	0.725	0.625	3.975	0.85	0.45	3.975
	The Average of Job Tardiness	40.4975	12.9175	247.8375	8.5175	4.975	247.8375	11.1275	2.3275	247.8375
	The Maximum Job Tardiness in All Jobs	169.9	151.95	482.375	62.025	73.4	482.375	69.125	45.075	482.375

Table 3: The Results of Numerical Experiments (The Initial Schedule of Proposed Method and RSS is made by GA)

		Pattern1			Pattern2			Pattern3		
		Proposed Method	GA	RSS	Proposed Method	GA	RSS	Proposed Method	GA	RSS
The Number of Minimum Cases in 40 Cases	The Number of Tardy Products	18	30	5	17	17	4	23	30	5
	The Number of Tardy Jobs	18	36	6	20	20	6	23	30	4
	The Average of Job Tardiness	17	28	5	16	16	3	22	30	4
	The Maximum Job Tardiness in All Jobs	24	20	6	15	16	3	22	30	4
Average Value of 40 Cases	The Number of Tardy Products	32	16.05	107.525	10.825	9.05	90.35	14.35	5.075	107.525
	The Number of Tardy Jobs	1.9	0.975	3.65	0.675	0.625	3.325	0.8	0.45	3.65
	The Average of Job Tardiness	29.195	12.9175	64.17	8.9825	4.975	53.475	12.3225	2.3275	64.17
	The Maximum Job Tardiness in All Jobs	144.725	151.95	318.8	57.275	73.4	313.55	87.85	45.075	318.8

6. CONCLUTION

In this research, we proposed a rescheduling method using lot splitting under the multiple work interruptions. We compare our method with GA and RSS about the number of tardy products, the number of tardy jobs, the average jobs tardiness, and the maximum job tardiness in all jobs. RSS does not split lots because the order of processing is not changed, but GA splits lots to bring the conditions closer to the proposed method. The proposed method is not so inferior to GA but greatly superior to RSS. The main reason is that proposed method is less affected than GA under multiple interruptions. In addition, the effectiveness of the proposed method increased with the ratio of delaying the due date of the sublots 2. So, the proposed method very likely have a potential to be superior to GA depending on time constraints. Also, GA has the disadvantage that extra works are required on sites and workers don't trust the solution. From the above, the proposed method is considered to be an alternative to GA etc.

As future prospects, we would like to suppose an experimental model closer to the actual situation and brush up the proposed method to exceed the results of GA.

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A NOVEL FIREFLY ALGORITHM FOR MULTIMODAL OPTIMIZATION

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ABSTRACT
Firefly Algorithm (FA) has a high ability for inquiring an optimal solution in Optimization Problem. However, FA cannot find multiple solutions including an optimal solution in Multimodal Optimization Problems. Multimodal Optimization Problem which is one of optimization problems demands finding all or most of the multiple solutions as well as the best solution. It is very important to inquire many alternatives when an optimal solution is unavailable.
Therefore, we propose New Firefly Algorithm which has new functions for Multimodal Optimization. In this model, agents realize searching solutions in multiple region and adjust parameters related to the search range of objective function regardless of the shape of the objective function. The model can have an ability for finding an optimal solution and suboptimal solutions. We applied conventional FA and proposed FA to multimodal objective functions and found that proposed FA was superior to conventional FA for Multimodal Optimization Problems.

Keywords: Firefly Algorithm, Multimodal Optimization Problem, Swarm intelligence

1. INTRODUCTION

Among evolutionary computation algorithms, Swarm intelligence such as Firefly Algorithm (FA), Particle Swarm Optimization (PSO) and Ant Colony Optimization (ACO) are inspired from the collective behavior of animal. These algorithms have powerful performance for solving Optimization Problems (Kennedy and Eberhart 1995; Dorigo 1997).
Especially, FA invented by Yang (2008) inspired from some of the flashing characteristics of fireflies (Yang 2008). Since then, several improvements of the FA have been devised (Yang 2018). The conventional FA was applied to the continuous optimization problems. Currently however, it has been applied to many other problems, for instance, the discrete optimization problems, multi-objective optimization problems and so on (Yang 2013; Marichelvam et al. 2014; Marichelvam and Geetha 2016). Therefore, the conventional FA and its extended algorithms have the potential to be applied to more various applications in the future.

In this study, we address to develop a novel FA that has an ability for finding an optimal solution and suboptimal solutions simultaneously. In the future, this study will widen the application range of the FA algorithms. Conventional FA by Xing-She Yang is basically known as a technique for searching a best solution in the search range of objective function.
On one hand, among some types of optimization problems, Multimodal Optimization Problems demand finding all or most of the multiple solutions as well as the best solution. For example, in the case of proposing a best route with car navigation, we must set alternative suboptimal route under circumstances where an optimal route cannot be used by traffic jams or accidents. Therefore, it is very important to inquire many alternatives when an optimal solution is unavailable.
However, conventional FA by Xing-She Yang is basically known as a technique for searching a best solution in the search range of objective function. Although conventional FA can occasionally obtain a few solutions in multiple region, it cannot inquire simultaneously many solutions (Yang 2008). Therefore, there is room for improvement of the performance of FA because this algorithm does not have any high performance for multimodal optimization problems.
Hence, in this paper, we propose a new FA for multimodal optimization problems. Concretely, we address to develop a novel FA that has an ability for finding an optimal solution and suboptimal solutions simultaneously. In the proposed model, agents realize searching solutions in multiple region and adjust parameters related to the search scale regardless of the shape of the objective function. As a result, the model can have an ability for finding an optimal solution and suboptimal solutions simultaneously. In the future, this study will widen the application range of the FA algorithms.

2. FIREFLY ALGORITHM

In this section, we describe Firefly Algorithm (FA) according to Yang (2008). FA obeys following three rules simplified some of the characteristics of real fireflies:

- All fireflies are unisex so that one firefly will be attracted to other fireflies regardless of their sex.

- Attractiveness of each firefly is proportional to their brightness, thus for any two flashing fireflies, the less bright one will move towards the brighter one.
- The brightness of a firefly is affected or determined by the landscape of the objective function.

In maximum optimization problems, Light intensity I_i of a firefly i is calculated as follows:

$$I_i = f(x_i), \tag{1}$$

where $f(x_i)$ is an objective function while x_i indicates the current position of firefly i.
On the other hand, in minimum optimization problems, Light intensity of a firefly i is calculated as follows in order to avoid the denominator of the function is zero:

$$I_i = \left(\left| f_{\min} - f(x_i)\right| + 1\right)^{-1}. \tag{2}$$

Parameter $f_{\min}$ represents the best solution in an objective function.
Initial position of each firefly is based on random location within the search range of an objective function. A less bright firefly will move towards the brighter one. But, the approaching distance is based on attractiveness of the brighter firefly. Attractiveness is based on the nature of light.
In general, the light obeys Beer-Lambert law and light intensity decreases exponentially by absorbing light into the air. In addition, the light intensity at the distance d from the light source is based on Inverse-square law which is inversely proportional to the square of the distance. Therefore, considering Beer-Lambert law and Inverse-square law, Light intensity I is defined as follows:

$$I(d) = I_0 \exp\left(-\gamma d^2\right). \tag{3}$$

Here, γ is light absorption coefficient and I_0 is the light intensity at a light source respectively. Parameter d represents the distance from the light source.
Therefore, attractiveness of firefly j for firefly i can be defined as follows:

$$\beta_{ij} = \beta_0 \exp\left(-\gamma r_{ij}^2\right). \tag{4}$$

Here, r_{ij} indicates the Euclidean distance between agent i and j while β_0 represents attractiveness at $r_{ij} = 0$. And r_{ij} is defined as follows:

$$r_{ij} = \left\| x_i - x_j \right\| = \sqrt{\sum_{k=1}^{D} (x_{ik} - x_{jk})^2}. \tag{5}$$

Here, D is the number of dimensions in the Euclidean space.
Based on attractiveness β_{ij} of another more attractive firefly j, the movement of a firefly i is determined by

$$x_i = x_i + \beta_{ij}(x_j - x_i) + \alpha\varepsilon_i, \tag{6}$$

Where α is randomization parameter and determines scale of random walk and ε_i means random number based on uniform distribution or Gaussian distribution. In eq.(6), second term is related to localized interactions and multiple regions of search and third term means random walk.
Pseudo code of FA is shown in Figure 1.

```
Objective function f(x), x = (x_1, ..., x_d)^T
Generate initial population of fireflies x_i (i = 1, ..., d)
Light intensity I_i at x_i is determined by f(x_i)
Define light absorption coefficient γ
while t < MaxGenaration do
  Sort fireflies in ascending order of light intensity
  for i = 1:n all n fireflies do
    for j = i:n all n fireflies do
      if I_i < I_j then
        Move firefly i towards j in d-dimension based on eq.(6)
      end if
    end for
  end for
  Find the current best
end while
Postprocess results and visualization
```

Figure 1: Pesudo code of FA

3. FISSION-FUSION FIREFLY ALGORITHM

In this section, we describe the novel Firefly Algorithm for Multimodal Optimization Problems.
This model is named Fission-Fusion Firefly Algorithm (FFFA), because of behaviors where fireflies divide from groups or gather in groups.
In addition to three rules of FA, FFFA is based on following three rules.

- While FA is a synchronous algorithm, FFFA is an asynchronous algorithm.
- The flash rate of each firefly is based on the Euclidean distance between each firefly and their N th adjacent firefly. One firefly with high flash rate does not interact with one with low flash late.
- A firefly interacts with adjacent fireflies based on the Euclidean distance or adjacent fireflies based on Light intensity by switching condition.
- The parameters related to search scale are based on distance of Nth adjacent firefly.

We explain about FFFA in detail.
It is important that FFFA is an asynchronous algorithm to affect behavior of fireflies. When FFFA is synchronous, since FA is synchronous, fireflies in FA are concentrated in one area, so localized interactions over multiple regions of search cannot be realized. Therefore, we require asynchronous update for FFFA.
The distance between a firefly and N th adjacent firefly can be regarded as a degree of the local population. The local population density names the flash rate. The flash rate which is the local population density can propagate as information if we assume that fireflies modify their flash rate based on the distance between a firefly and Nth adjacent firefly. Therefore, in FFFA, the flash rate λ_i of firefly i is based on the Euclidean distance between firefly i and N th adjacent firefly. And λ_i is defined as follows:

$$\lambda_i = \|x_i - x_N\| = \sqrt{\sum_{k=1}^{D}(x_{ik} - x_{Nk})^2}. \quad (7)$$

Here, x_N is the position of N th adjacent firefly.
The firefly i does not interact with firefly j under the following conditions:

$$if\ \lambda_i > \lambda_j \varepsilon. \quad (8)$$

Here, ε is the parameter of the flash rate.
This rule encourages fireflies to search for places that have not been searched yet.
In FFFA, there are two kinds of neighborhood based on interactions. These functions of two neighborhoods are FFFA's unique features. On the one hand, a firefly interacts with neighboring fireflies up to N th in order from the closest firefly. In this way, the topological neighborhood based on the closeness of the distance is defined as the topological neighborhood-D.
On the other hand, a firefly interacts with fireflies from the highest light intensity to the N th level in order of fireflies of closer distance. In this way, the topological neighborhood based on the light intensity is defined as the topological neighborhood-L. Fireflies based on topological neighbors-D will head towards local high-quality solution information while fireflies based on topological neighbors-L will look over the whole and will head towards good quality solutions that have not been intensively searched yet.
We describe the condition for switching these two interactions. When a firefly interacts based on the topological neighborhood-D, the firefly compares its own light intensity with light intensity of the adjacent individuals up to the $(N+\delta)$ th. If rank of its own light intensity is less than the N th-ranking, the firefly interacts based on the topological neighborhood-L. This operation is performed to mix the information of the light intensity of the neighborhood and the information of the light intensity outside the neighborhood.
Interactions with the individuals outside the neighborhood are important especially when fireflies are located in poor solutions. Therefore, depending on this switching condition, only firefly of high-ranking of light intensity interacts with neighboring fireflies, and the fireflies form a certain number of groups. On the other hand, the firefly of low-ranking interacts with fireflies that are not yet forming a group.
When a firefly i interacts, the randomization parameter α and the light absorption coefficient γ are adjusted based on the flash rate λ_i. The light absorption coefficient γ are adjusted as follows:

$$\gamma = \lambda_i^2 \gamma_s\ if\ \lambda_i \neq 1. \quad (9)$$

$$\gamma = \gamma_s\ if\ \lambda_i = 1. \quad (10)$$

Here, γ_s is the standard absorption coefficient is γ_s at $\lambda_i = 1$ .Therefore, fireflies modify the absorption coefficient based on the local population density calculated by the distance λ_i. When λ_i is small, i.e., when the local population density is relatively high, attractiveness can be strengthened.
Similarly, the randomization parameter α is adjusted as follows:

$$\alpha = \lambda_i \alpha_s\ if\ \lambda_i \neq 1. \quad (11)$$

$$\alpha = \alpha_s\ if\ \lambda_i = 1. \quad (12)$$

Here, α_s is the standard randomization parameter at $\lambda_i = 1$ .When λ_i is small, i.e., when the local population density is relatively high, they refrain from a random walk.
The movement distance of a firefly i is based on attractiveness β_{ij} and is attracted to another more attractive firefly j is determined based on eq.(6).
Pseudo code of FA is shown in Figure 2.

```
Objective function f(x), x = (x_1, ..., x_d)^T
Generate initial population of fireflies x_i (i = 1, ..., d)
Light intensity I_i at x_i is determined by f(x_i)
Define the standard randomization parameter α_s
Define the standard light absorption coefficient γ_s
Upper limit of the adjacent fireflies N
while t < MaxGenaration do
  Sort randomly fireflies i
  for i = 1 : n all n fireflies do
    Calculate the all flash rate λ_i based on eq.(7)
    A firefly can see light intensity based on eq.(8)
    Adjust the parameters α and γ based on eq.(9) and (11)
    Calculate the rank R_i of light intensity in fireflies up to the
    (N + δ) th adjacent firefly
    if N < R_i then
      for j = 1 : N sorted all N fireflies
                          in ascending order of light intensity do
        if I_i < I_j then
          Move firefly i towards j in d-dimension based on eq.(6)
          in the topological neighborhood-D
        end if
      end for
    else
      for j = i : N sorted all N fireflies
                          in ascending order of light intensity do
        if I_i < I_j then
          Move firefly i towards j in d-dimension based on eq.(6)
          in the topological neighborhood-L
        end if
      end for
    end if
  end for
  Find the current best
end while
Postprocess results and visualization
```

Figure 2: Pseudo code of FFFA

4. RESULTS

4.1. Experimental conditions

In this research, we apply FFFA to the objective function of various shapes and evaluate its performance. Formulas of the objective function are shown on eq.(10), (11) and (12).

$$F1(x_1,x_2) = e^{-(x_1-4)^2-(x_2-4)^2} x_i + e^{-(x_1+4)^2-(x_2-4)^2} + 2\left[e^{-x_1^2-x_2^2} + e^{-x_1^2-(x_2+4)^2}\right], \quad -5 \le x_1, x_2 \le 5. \qquad (13)$$

$$F2(x_1,x_2) = 80 - \left[x_1^2 + x_2^2 - 10\cos(2\pi x_1) - 10\sin(2\pi x_2) + 20\right], \quad -5.12 \le x_1, x_2 \le 5.12. \qquad (14)$$

$$F3(x_1,x_2) = \exp\left\{-2\log 2\left(\frac{x_1+4}{8}\right)^2\right\}\sin\left(\frac{x_1+5}{2}\pi\right) + \exp\left\{-2\log 2\left(\frac{x_2+4}{8}\right)^2\right\}\sin\left(\frac{x_2+5}{2}\pi\right), \quad -5 \le x_1, x_2 \le 5.$$

(15)

Shapes of the objective functions F1, F2 and F3 are shown in Figures 3, 4 and 5. In addition, the values of the solutions are shown in Tables 1, 2 and 3. We use the objective functions F1, F2 and F3 where there are multiple solutions and we know those solutions exactly. Objective functions are modified so that all search ranges are aligned to avoid tuning the parameters of FA and they can be handled as maximum optimization problems.

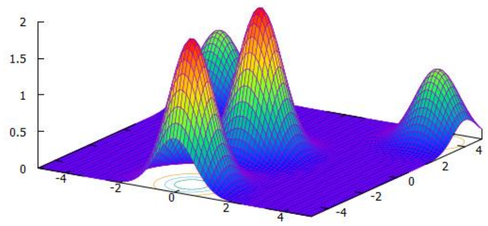


Figure 3: The shape of F1

Table 1: The values of the solutions in F1

The value of the solution	The Position	
	x_1	x_2
2.0	0.0	0.0
2.0	0.0	-4.0
1.0	4	4
1.0	-4	4

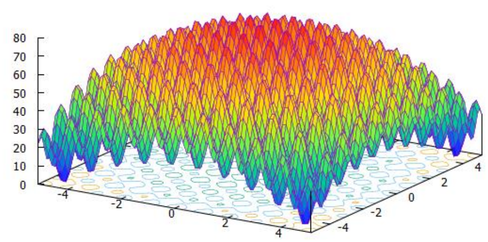


Figure 4: The shape of F2

Table 2: The values of the solutions in F2

The value of the solution	The Position	
	x_1	x_2
80.0	0.0	0.0
79.0	0.0	1.0
79.0	0.0	-1.0
79.0	1.0	0.0
79.0	-1.0	0.0
78.0	1.0	1.0
78.0	1.0	-1.0
78.0	-1.0	-1.0
78.0	-1.0	-1.0

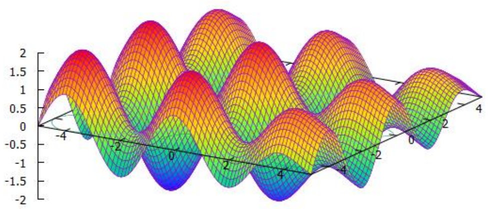


Figure 5: The shape of F3

Table 3: The values of the solutions in F3

The value of the solution	The Position	
	x_1	x_2
2.0	-4.0	-4.0

Table 4 and 5 show Parameters in FA and FFFA respectively.

Table 4: The Parameter of FA

Parameter	The set value
β_0	1.0
α	0.2
γ	1.0

Table 5: The Parameter of FFFA

Parameter	The set value
N	5
δ	3
γ_s	0.004
α_s	1.0
ε	0.25
β_0	1.0

In FA and FFFA, the number of steps is set to 500, the number of trials is set to 100, the number of agents is set to 50. We use Mersenne twister as a pseudo random number generator for random walk in the experiments (Matsumoto and Nishimura 1998).

4.2. Validation on ability for finding an optimal solution

In this section, we compare the found rate of optimal solutions of objective function in FA and FFFA. We use the multimodal objective functions (F1, F2 and F3) where there are multiple local solutions. The finding condition of the optimal solution is the time when a solution within an error of 0.005 is found from the coordinates of the point where the optimal solution is located. In each trial, Table 6 shows the results of the found rate of optimal solutions. As shown in Table 6, the found rate of the optimal solution of FFFA is higher than that of FA. Therefore, FFFA for multimodal optimization problems realizes the improvement of solving ability of optimal solution.

Table 6: The found rate of optimal solutions

Function	The found rate (%)	
	FA	FFFA
F1	100	100
F2	13	99
F3	79	100

4.3. Validation on ability for finding multiple solutions

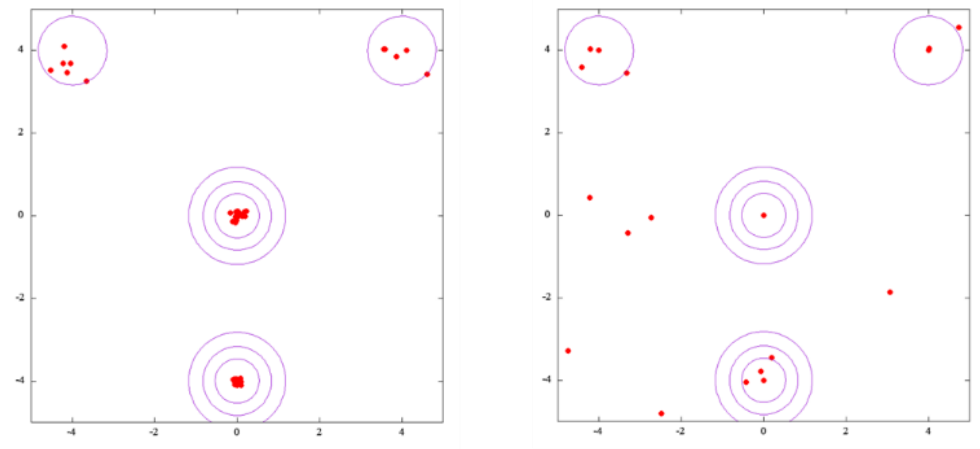
In this section, we compare the found number of the multiple solutions of the objective function in FFFA and FA. We use the multimodal objective functions (F1 and F2, where there are multiple solutions and we know those solutions exactly). The finding condition of the optimal solution is the time when a solution within an error of 0.005 is found from the coordinates of the point where the solution is located. In each trial, Table 7 shows the results of the found number of multiple solutions.

As shown in Table 7, the found number of the multiple solutions of FFFA is more than that of FA.

Table 7: The average number of finding solutions

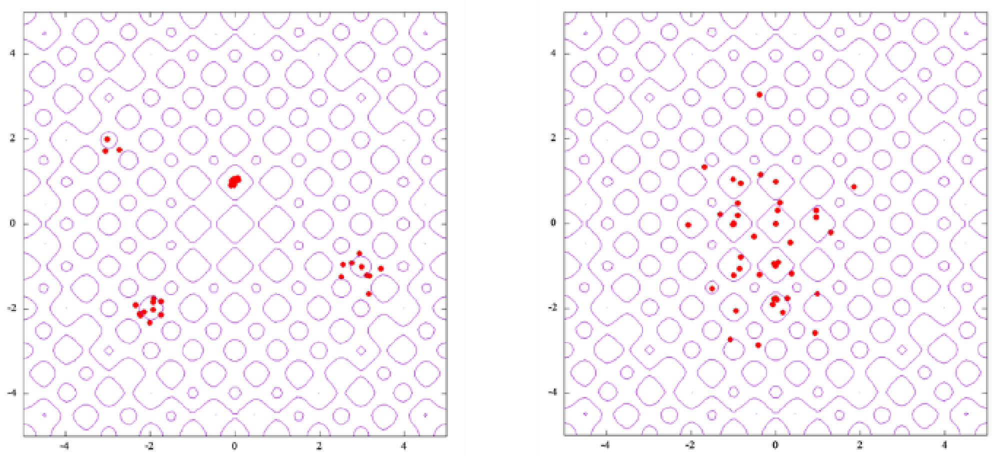
Function	Top Solutions	The average number	
		FA	FFFA
F1	4	2.42	4
F2	9	4.13	7.54

Simulations when FA and FFFA are applied to F 1 and F 2 are shown in Figures 6 and 7, respectively. At this time, (a) is the simulation of FA and (b) is the simulation of FFFA when the number of step is 300. From these results, it can be seen that the agents are more dense and more good solutions are obtained simultaneously in FFFA than in FA.



(a) (b)

Figure 6: The simulation of F1



(a) (b)

Figure 7: The simulation of F2

Therefore, FFFA for multimodal optimization problems realizes the improvement of solving ability of multiple solutions.

5. CONCLUTIONS

Firefly Algorithm (FA), which is a kind of evolutionary computation algorithm, is suitable for optimization problems. However, FA is not suitable for the multimodal optimization problem which demands finding all or most of the multiple solutions as well as best solution. It is very important to inquire many alternatives when an optimal solution is unavailable. Therefore, in this study, it is addressed to develop a novel FA that has an ability for finding an optimal solution and suboptimal solutions simultaneously. This study can be important due to the fact that it may extend the application range of FA to various problems in the future. To this end, we have proposed a new FA for the multimodal optimization problems. In the model, fireflies realize searching solutions in multiple region and adjust parameters related to the search scale regardless of the shape of the objective function. In addition, the model makes it possible for the firefly to rebuild the group at a better solution place by forming and dissolution of groups by Switching between two neighbors. The model is called Fission-Fusion Firefly Algorithm (FFFA), because of behaviors where fireflies divide from groups or gather in groups.

From the experimental results for validation on ability for finding an optimal solution and multiple solutions, the proposed model has an ability for finding an optimal solution and suboptimal solutions.

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COMPUTATIONAL INVESTIGATION ON THE EFFECT OF VARIOUS PARAMETERS OF A SPIRAL GROUND HEAT EXCHANGER

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ABSTRACT
Shallow Geothermal Energy, a Renewable Energy Source, finds application through Ground Source Heat Pumps (GSHPs) for space heating/cooling via tubes directed into the ground. Vertical Ground Heat Exchangers (GHEs) of various configurations (mainly U-tubes) extract/reject heat into the ground. Spiral type GHEs constitute an alternative to reduce the depth and hence the cost of GSHP systems. Such GHEs are used in energy piles, which are reinforced concrete foundations with helical pipes whereby heating/cooling is provided. Testing GHEs through experimental set-ups is expensive and time consuming. Hence, a computational investigation is preferred. To this end the current paper introduces a 3D mathematical model, based on the convection-diffusion equation, in COMSOL Multiphysics. The related parameters are adjusted, and the model is validated, against experimental data. The validated model is subsequently adapted to match the Cyprus moderate Mediterranean conditions. A parametric investigation of the important implications in the design of GHEs is also conducted.

Keywords: Ground Heat Exchanges, Spiral GHE, COMSOL validation

1. INTRODUCTION

Renewable Energy Systems (RES) have increased in popularity in recent years through a global effort to divert away from fossil fuels and reduction of CO2. Such a system is Ground Source Heat Pump (GSHP), which takes advantage of the Geothermal Energy stored in the sublayers of the earth. GSHP systems are used for space heating and cooling, where heat is either extracted or rejected to the earth using a network of tubes directed into the ground.

There are two main categories of Ground Heat Exchanger (GHE) types: the horizontal and the vertical types. The most commonly used ones are the vertical types, which require less space and have higher performance that the horizontal types (Aresti, Christodoulides and Florides, 2018). The main configuration of vertical types are the U-tube and double U-tube GHEs. In recent years a different configuration has become popular, namely the spiral or helical type GHE. Spiral GHEs was introduced to reduce the GHE depth and has been used in foundation piles, identified as “energy piles” (Carotenuto *et al.*, 2017). Spiral GHEs, due to their high efficiency, can be coupled with GSHP systems for heating and cooling a building. The overall aim of this configuration is to reduce the initial capital and the cost of the GSHP system and to make it more attractive for investment. In particular, energy piles are reinforced concrete foundations with helical pipes, whereby the buildings foundations are utilized to provide space heating and cooling. Typical sizing of the energy piles is considered between 20–40m depth and 0.4–1.5m diameter as reported by Brandl (2013).

Investigation of the spiral coil configuration was performed by Bezyan et al. (2015) using the FLUENT software. A validation against a U-tube configuration was achieved by the authors by comparing the outlet temperatures. The authors compared three different configuration models: the U-tube, the double U-tube (or W-shaped) and the spiral coil, with the spiral configuration providing the highest efficiency in heat transfer rate and energy output. A similar comparison was also performed by Zhao et al (2016). The authors used the COMSOL software to perform computational investigations. The results indicated that the spiral-shaped GHE was estimated to have the better thermal performance than the other GHE configurations in long-term and short-term thermal loads. Further experimental and numerical studies have been conducted by several researchers with the aim to maximize efficiency and to identify the most accurate way for effective energy piles design (e.g., Gao et al. 2008; de Moel et al. 2010; Suryatriyastuti, Mroueh and Burlon, 2012; Brandl 2013; Gashti, Uotinen and Kujala 2014; Yoon et al. 2015; Fadejev et al. 2017)

Energy piles have yet to be applied in Cyprus and, thus, a preliminary assessment considered and investigated before application would be useful. The aim of this paper is to study the effect of the different aspects on the spiral

GHE configuration using a computational modeling approach under the moderate climate conditions of Cyprus.

2. COMPUTATIONAL MODELING

To examine different parameters of a GHE, one can perform either experimental or computational investigations. In general, the sheer experimental set-up and testing of a GHE is expensive and time consuming, therefore a computational investigation is preferable. Here a numerical model using the COMSOL Multiphysics software that is based on the convection-diffusion equation is introduced. The three-dimensional conservation of the transient heat equation for an incompressible fluid is used:

$$\rho c_p \frac{\partial T}{\partial t} + \rho c_p u \cdot \nabla T + \nabla \cdot q = Q \qquad (1)$$

where ρ is density, c_p is the specific heat capacity at constant pressure, T is the temperature, t is time, u is the velocity, Q is the heat source, and q comes from the Fourier's law of heat conduction. The second term, implicating velocity is only referring to the domain where underwater flow is present and does not apply to the rest of the domains.

The three-dimensional model consists of the spiral pipe domain, the grout domain (borehole, well or pile foundation) and the ground domain.

Modeling a GHE at full scale can be challenging since there is a high scale difference between one dimension (vertical z-axis) and the other two (x- and y-axes). Due to the unbalanced dimensions, meshing the model with equilateral cells will require high computational time and memory.

Existent computational methods could overcome this issue by either applying a coordinate scaling system (Aresti, Florides and Christodoulides, 2016) or by applying parallel computational running with a simplified version (see Equation 2) on the pipes and Equation 1 on the rest of the system, as emended in the software:

$$\rho A c_p \frac{\partial T}{\partial t} + \rho A c_p u e_t \cdot \nabla_t T =$$
$$\nabla_t \cdot \left(A k \nabla_t T \right) + \frac{1}{2} f_D \frac{\rho A}{d_h} |u| u^2 + Q \qquad (2)$$

where A is the area of the pipe, ue_t is the tangential velocity, f_D is the Darcy's friction factor based on Churchill friction model and d_h is the diameter of the pipe.

Figure 1 illustrates the geometry of the model serving as a study-case, where the spiral coil can be observed as a line in a 3D environment.

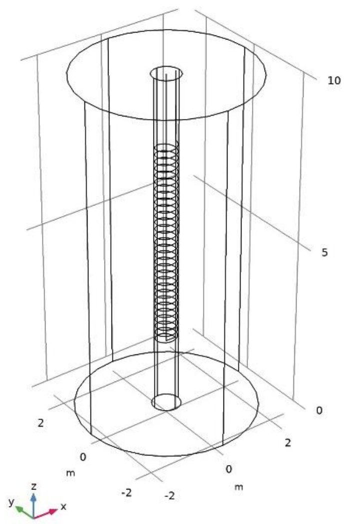

Figure 1: The geometry of the model.

3. VALIDATION AND RESULTS

The related parameters are adjusted to present actual parameters taken from experimental data by Dehghan (2017). Experimental data were obtained using a Thermal Response Test (TRT), which is the most commonly used method to determine the thermal characteristics of the ground (see, for example, Mogensen 1983; Christodoulides et al. 2016). Therefore, the computational model is validated against available experimental data, as shown in Figure 2. It can be observed that the computational results are less compatible during the first 10 hours of the model run. This can be due to the lack of detailed information from the experimental results, as only average values were provided. The rest of the graph though, indicates a very good agreement between the experimental and computational data.

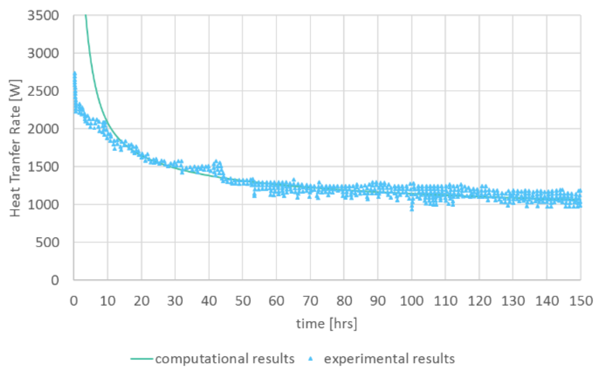

Figure 2: Experimental validation of computational model for a spiral GHE.

The model could be then modified to incorporate a theoretical case scenario of an energy pile system installed in a building in Cyprus for different climate conditions. The validated model is subsequently adapted to match the Mediterranean conditions in Cyprus. The new model is designed with a 10m depth and a 0.4m diameter. The selected model geometry (also seen in Figure 1) consists of a 10m depth pile, a 6m depth spiral coil, a 0.8m pile diameter and a 5m domain diameter. A similar configuration is described at the new public library in Limassol, Cyprus, where a spiral coil is incorporated in a well. In order to obtain more accurate and realistic results, ground temperature data were considered, as in Figure 3, where it can be observed that the temperature below a depth of 7m is constant at 22°C. The same temperatures are observed in a similar case in Limassol by Florides, Pouloupatis and Kalogirou (2011).

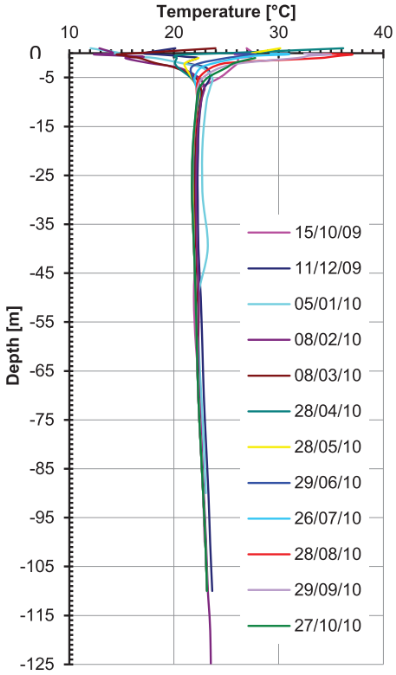

Figure 3: Recorder ground temperature at Lakatamia, Cyprus for a day from each month of a year (Pouloupatis, Florides and Tassou, 2011)

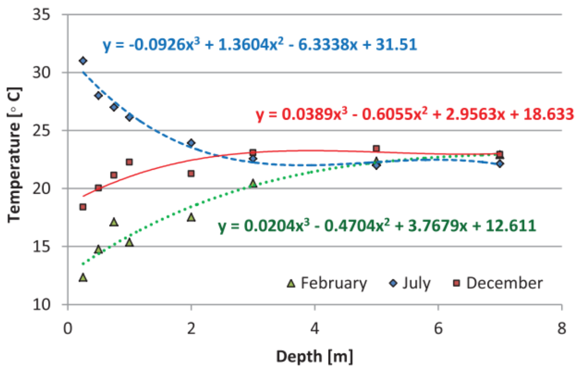

Figure 4: Recorded underground temperature at the Lakatamia shallow zone (0–7m), shown is the best-fit equation

Stylianou et al. (2019) have analyzed the data of Figure 3 and have illustrated a shallow zone temperature gradient (Figure 4) to be used in the computational model. The equation of the ground temperature is input as initial temperature in the computational model. The case of summer was examined for the month of July. Furthermore, the ground characteristics of the case study in Limassol are considered. The ground examined to consist of marl, chalk and gravel, with the complete model material properties described in Table 1.

Table 1: Material properties

Material	k $Wm^{-1}K^{-1}$	ρ $kg\ m^{-3}$	c_p $J\ Kg^{-1}\ K^{-1}$	Description
Ground	1.4	2300	950	Marl, chalk and gravel
Grout	1.628	2500	837	Reinforced concrete
Pipes	0.42	1100	1465	HDPE
Water	0.6	998.2	4182	water

The configuration of the energy pile and the dimensional characteristics are defined in Table 2.

Table 2: Model dimensional characteristics and operating parameters

Dimensional Characteristics	
Energy Pile length	10 m
Energy Pile diameter	0.8 m
Spiral coil diameter	32 mm
Pipe (coil) thickness	3 mm
Operating Parameters	
Fluid flow rate	15 l/min
Inlet temperature	60 °C

Following the model set-up, the spiral pitch was varied from 0.1m to 0.5m by 0.1m increments. With the spiral pitch changed, the length of the pipe also changed since the depth of the pile was kept the same. The results can be seen in Figure 5.

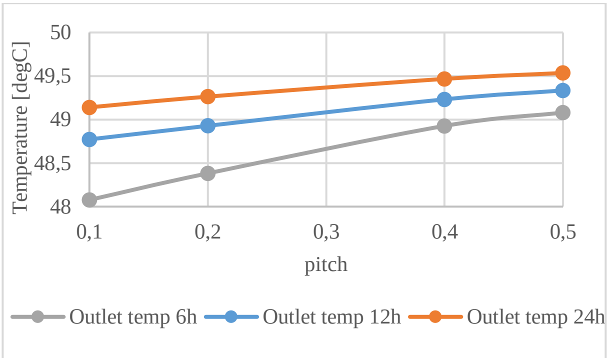

Figure 5: Spiral pitch effect on outlet temperature at different operating durations

The results obtained demonstrate that the higher the pitch, the higher the outlet temperature of the pipe. Similar results were obtained by Park et al. (2015) and Park et al. (2016).

By investigating the higher operating time duration (24h), it can be seen that the effect of the spiral pitch on the outlet temperature is decreased. This is an expected result since for long enough durations of the heat injected

into the system, the pile steady state independent of the pitch.
Further examination of the heat transfer rate can be carried out as seen in Figure 6. The heat transfer rate decreases with the increase of the pitch and it becomes almost steady with time; in this case after10 hours of continuous heat injection.

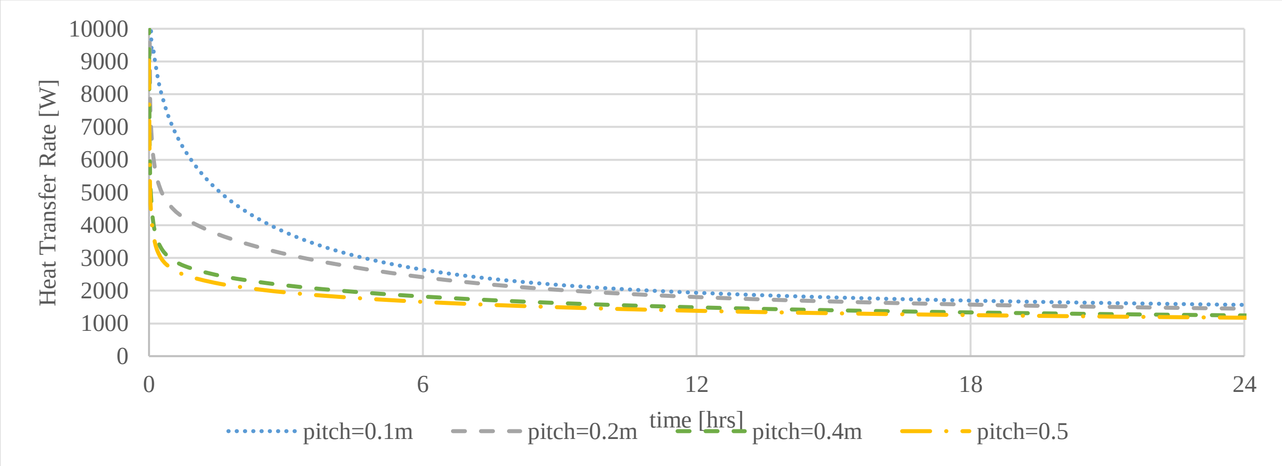

Figure 6: Heat transfer rate versus time

The results above can later be adapted to calculate the efficiency of the pump. As mentioned by Pouloupatis et al. (2017), the lower the outlet temperature of the coil (entering the pump), the higher the pump efficiency. In any design case the system engineer should try and limit the borehole numbers to reduce the initial cost. But in the case of energy piles there is a specific number of piles that can be adapted based on the civil engineer's plans. Therefore, it is important to incorporate a spiral coil in a single pile with the correct length and pitch angle.

4. CONCLUSION AND FUTURE WORK

A computational model of an energy pile with spiral coil (or helix coil) has been presented and discussed. The computational model has been validated against experimental results from the literature, before it was modified to match a close to realistic scenario of an energy pile placed in Cyprus under moderate climate. The parameters affected by the location were incorporated from the literature.
An investigation of the important implications of the design of GHEs has also been conducted. Such variables are the spiral pitch length (presented in this work), the spiral tube diameter and the coil diameter.
For future, other combinations of parameters should be investigated so as to obtain a complete understanding of the effect of the spiral parameters. The diameter and the depth of the spiral coil GHE, since utilized in the building's foundation piles, are constrained by the piles. Hence there are limitations on the actual size of the pile diameter and depth (containing an iron cage for reinforcement) as a function of the building's strength.
Further conclusions based on extended results will lead to recommendations for engineers.

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GROUND SOURCE HEAT PUMPS COST ANALYSIS IN MODERATE CLIMATE

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ABSTRACT
A debate is taken up on whether it is economically preferential to install Ground Source Heat Pumps (GSHPs), Renewable Energy Systems, instead of Air Source Heat Pumps (ASHPs). To this end, a typical house heating/cooling load for moderate climates is chosen and the thermal response of Ground Heat Exchangers (GHEs) of GSHPs and their characteristics – based on experimental data and CFD-model simulations in FlexPDE – are discussed. The results indicate that with greater difference between the inlet GSHP temperature water and the ground, a higher heat rejection is observed. The GSHP capacity over the input power operating temperature is affected by the fluid temperature entering the Heat Pump, affecting the system cost as more GHE boreholes may be needed for reducing the temperature. A cost analysis is thus presented for different-length GSHP systems and a comparison of the total energy savings is obtained versus highly competitive inverter technology ducted series ASHP systems.

Keywords: Ground Source Heat Pump Systems, GHE cost analysis in moderate climate conditions, Air Source Heat Pumps

1. INTRODUCTION

Geothermal Energy, a form of Renewable energy, has attracted attention in recent years due to the energy shortage. While the transfer of heat from a high temperature source to a low temperature one is natural, the opposite is done through HPs that are commonly used for the air-conditioning of buildings. A HP operates with electricity, using as an exchange source either the surrounding air (ASHPs) or water in the pipes of a GHE (GSHPs) that uses the Earth’s energy to gain or reject heat.

The GHEs, compared to air-to-air heat exchanger systems, exhibit significantly higher performance (Yu et al. 2013), but their installation cost is high, and they require larger spaces. Recent research has focused on the reduction of the cost (Aresti, Christodoulides and Florides 2018) and, consequently, GSHP installations that may be economically beneficial over convectional heating and cooling systems have increased over the last decade (Yang, Cui and Fang 2010). Naturally, there have been studies in the literature concerned whether it is cost beneficial to use GSHP instead of ASHPs.

Healy and Ugursal reported that between four different residential heating/cooling systems in a residential building in Nova Scotia, Canada, namely GSHP, electric resistance heat, oil-fired furnace and ASHP systems, the GSHP system was the least expensive to install-operate (Healy and Ugursal, 1997).

For similar studies conducted in Turkey, the results showed that the GSHP system is a cost-effective solution compared to electric resistance, fuel oil, liquid petrol gas, coal and diesel oil, with payback periods between 8 and 21 years (Esen, Inalli and Esen 2006), (Camdali and Tuncel 2013). Other studies include Chang et al. in China with a payback period of 7.1 years for a GSHP system versus a water-cooling machine and matching gas furnace system (Chang et al. 2017), and Badescu with a payback period of 3–10 years for a GSHP system versus convectional systems and GHEs with convectional systems (Badescu 2007).

On the other hand, Lu et al., using different economic methods from previous studies, concluded GSHP systems would provide an economic advantage compared to the ASHP systems only in the long term (40 years) (Lu et al., 2017).

In general, based on the literature, GSHP may or may not be an economic solution for heating/cooling a house, depending on many factors, such as ASHP efficiency, location of the house and climate conditions and installation cost of the GSHP (Christodoulides, Aresti and Florides 2019). The work presented below mainly aims at contributing in the study of the effectiveness and usefulness of GSHP in moderate climate conditions.

2. TYPICAL HOUSE LOAD AND MODERATE CLIMATE DESIGN

To evaluate and compare the cost effectiveness of a GSHP system, a typical house in moderate climate in Cyprus is considered. The characteristics of the residential buildings in Cyprus were presented by Panayiotou et al. (2010), where using a sample of 500 residential buildings, the authors found that most of the houses are between 51–200m^2 and a primary energy between 51–150 kWh/m^2. For the design of a GSHP system, typical house loads are required. Usually plots are built as two houses semi-detached (Figure 1(a)), or as linked-detached houses with a short distance between them (Figure 1(b)). In both cases, the only available space for drilling boreholes and use a GSHP is a 3–4 m region at the edge of the plot. Rarely, houses are detached (Figure 1(c)) having enough land space free for drilling as many boreholes as needed.

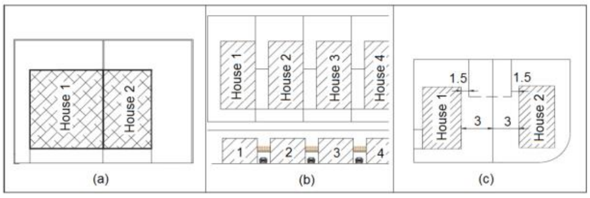

Figure 1: Typical positioning of houses in plots; (a) semi-detached, (b) linked detached, (c) detached

The selected typical house here is a 3-bedroom 2-storey house, with a total floor area of 190m², attached to another house, and with available land space of at least 4m on the other three sides. The house is made of reinforced concrete pillars and beams while the walls are made of red and sandy clay bricks. All parts of the house are thermally insulated with extruded polystyrene while double glazed aluminium framed windows are used. In a moderate climate (in the study case located at Lakatamia, Cyprus) the estimated heating/cooling loads of the typical house are shown in Table 1 (Pouloupatis et al., 2017). Peak cooling load is observed in July at 11.56kW, and peak heating load in February at 20.78kW.

Table 1: Heating/cooling loads of the typical house

Month	Cooling load (kWh)	Heating load (kWh)
January	0	2300
February	0	2450
March	0	600
April	150	0
May	500	0
June	1050	0
July	1600	0
August	1500	0
September	1000	0
October	300	0
November	0	600
December	0	1450
Total	6100	7400

3. GHE SUMMER AND WINTER MODELING

The thermal response of the GHE is examined for the maximum and the minimum load months of the year in Cyprus i.e. July and February. The equation governing the problem on convective and conductive heat transfer, under consideration here, is the following.

$$\rho c_p \frac{\partial T}{\partial t} + \rho_f c_{pf} u_{in} \cdot \nabla T + \rho_w c_{pw} u_w \cdot \nabla T + \nabla \cdot (-\lambda \nabla \mathrm{T}) = Q \quad (1)$$

where ρ is the density [kg m^{-3}], c_p the specific heat capacity [J kg^{-1} K^{-1}], t the time [s], T the temperature [K], u the velocity [m s^{-1}], λ the thermal conductivity [W m^{-1} K^{-1}], Q the power density of the heat source [W m^{-3}], while subscript f denotes fluid, w water, in inside tube and p porous media.

At the boundary between the fluid and the tubes the convective heat flux is $h\Delta T$, where h is the convective heat transfer coefficient of the process [W m^{-2} K^{-1}] and ΔT the temperature difference at the boundary. The convection heat transfer coefficient h is a function the hydraulic diameter and the Nusselt number (Stylianou et al. 2019).

A Computational Fluid Dynamics model, following the geometry of an experimental set up was developed and validated in the FlexPDE software for various input temperatures of the GHE circulating water, the reproduced model being validated. The Lakatamia GHE domain is illustrated in Figure 2.

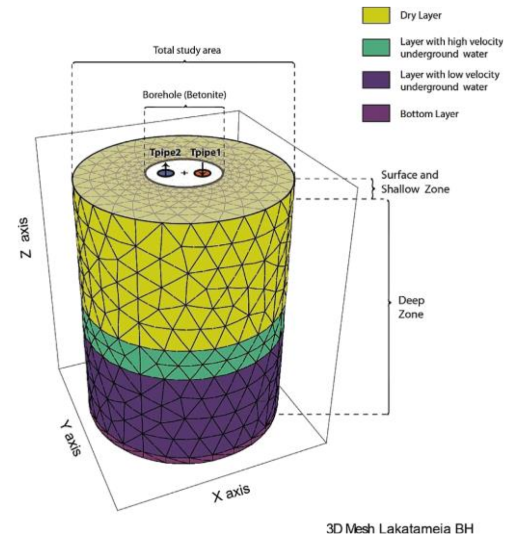

Figure 2: The FlexPDE computational model for the Lakatamia GHE. The dry well area is shown in yellow (80 m), high water velocity area is shown in green (25 m), low water velocity area is shown in blue (55 m), base area is shown in purple (5 m) (sketch not to scale) (Stylianou et al. 2019).

Calculated steady state values for summer for input temperature of 28°C, 35°C and 45°C showed that the greater the difference between the input water temperature and the ground temperature, the greater the rejected heat to the ground (Figure 3). Similarly, for winter operation with input temperature of 0°C, 9°C and 18°C showed that the greater the difference between the input water temperature and the ground temperature, the greater the absorbed heat from the ground.

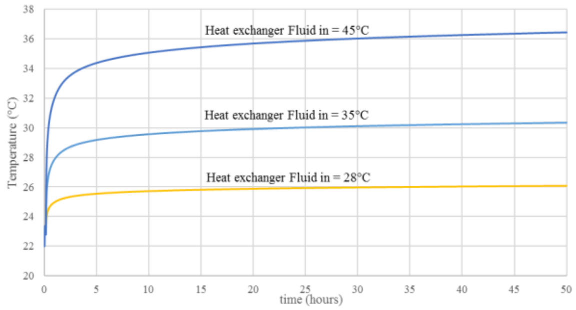

Figure 3: GHE exiting fluid temperature plotted against time for three cases of steady temperature fluid entering the GHE of 45, 35 and 28 °C (Stylianou et al. 2019).

The characteristics of such GHE/GSHP are given in Pouloupatis et al. (2017). The HP capacity over the input power is nearly doubled from a HP entering fluid temperature of 44°C to 20°C (cooling) (similarly for heating). This means that to achieve lower temperatures a bigger number of boreholes are needed and consequently the greater the initial cost will be. Therefore, the designer should consider the benefits of a greater HP efficiency against the disadvantage of greater initial cost.

4. GHE COST ANALYSIS

Robert and Gosselin demonstrated a good case of a techno-economic analysis of a GSHP system (Robert and Gosselin 2014). The total cost of any GSHP system consists of the initial capital invested and the operating costs, namely the sum of costs of the HP, mechanical room installation, drilling, piping, ground loop installation, fittings, etc., electricity consumption by the HP, the heat transfer fluid circulation pump and the backup heating/cooling system.

Hence, the difference in the cost between an ASHP and a GSHP system lays in the GHE and the associated equipment, such as the borehole extraction, U-tube GHE, grout material, ground loop installation, header-flowmeter valves, horizontal pipe circuits, and some general expenses (Christodoulides, Aresti and Florides 2019). Typical extra costs for the installation of a GHE of 400m, 600m and 800m are calculated at €12600, €18200 and €23800 respectively, based on information taken from companies based in Cyprus in 2018.

Note that, as stated by Rawlings and Sykulski, direct comparison between different countries or even regions cannot be done owing to economies of scale (Rawlings and Sykulski 1999).

Now, a specifically designed inverter technology ducted series ASHP of similar capacity, can have a ratio of Pump Capacity/Power Input of around 3.0 (cooling) and 3.7 (heating). An estimation for the electrical power needed to cover the total heating/cooling load per year is shown in Table 2.

Lu et al. discussed different methods used in the literature to examine the economic benefits of installing a GSHP system (Lu et al. 2017). It is though beyond the scope of the current study to go in detail into such methods, as the goal of comparing a single GSHP (of a vertical GHE) and a simple ASHP can be achieved through a simple methodology explained below with adequate precision.

The power savings per year for (a) the 800m GHE are 961 kWh, (b) the 600m GHE are 862 kWh and (c) the 400m GHE are 673 kWh. Considering the current price for house holdings of 0.19€/kWh would result to the following corresponding savings per year: (a) €183, (b) €164, and (c) €128. It turns out that, for all cases, the payback period would be well over 20 years.

The results show that the new specifically designed, inverter type ASHPs, have reached such a high stage of technology that can antagonize strongly GSHPs for residential use.

Table 2: Energy savings per year for the typical house

Season /GHE length /Ratio	Cooling/ Heating load (kWh)	Input electrical energy (kWh)	Savings vs ASHP (kWh)
ASHP summer /3.0	6100	2033	
ASHP winter /3.7	7400	2000	
GSHP summer /800m /4.9	6100	1245	788
GSHP summer /600m /4.7	6100	1298	735
GSHP summer /400m /4.4	6100	1386	647
GSHP winter /800m /4.05	7400	1827	173
GSHP winter /600m /3.95	7400	1873	127
GSHP winter /400m /3.75	7400	1973	27

5. CONCLUSION

The work presented here has pointed to novelty with its study of a typical house in Cyprus (moderate climate) with a GSHP system, through the analysis of its thermal response numerically. A typical residential building in Cyprus has been presented with heating/cooling loads in moderate Mediterranean climate conditions. The 3-bedroom house of 190m^2 has peak cooling/heating loads of 11.56 kW and 20.78 kW.

Moreover, the paper has offered a cost analysis of a GSHP system with different lengths as well as a cost comparison of GSHP systems with an ASHP system based on experimental data. It turned out that the payback period of using GSHP systems over ASHPs would be well over 20 years, making it not an economical solution in the specific case. This is due to comparable Pump Capacity/Power Input ratios between specifically designed inverted technology ducted series ASHPs and GSHPs.

Even using methods such as Present Worth, Annual Worth, Internal Rate of Return, External Rate of Return, Simple Payback Period, Discounted Payback Period would not alter dramatically the result (Lu et al., 2017), (Christodoulides, Aresti and Florides 2019).

Concluding, one could argue that GSHPs would be an economic and viable solution as alternatives to ASHPs if sufficiently subsidized as Renewable energy source by the State.

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SCHEDULING MULTIPLE LIFT VEHICLES IN A COMMON SHAFT IN AUTOMATED VEHICLE STORAGE AND RETRIEVAL SYSTEMS

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ABSTRACT
Automated vehicle storage and retrieval systems (AVSRSs) provide an efficient and powerful way to store small unit loads. In order to meet the increasing requirements in terms of the flexibility and throughput capacity of these systems, a new type of high-powered AVSRS can be deployed. In high-powered AVSRSs, multiple lift vehicles move in one common shaft instead of just a single vehicle, so as to further increase the throughput capacity of lifting systems and the vertical transport. In this work, we present and compare different scheduling algorithms that allow for the robust and efficient control of multiple lift vehicles. By performing simulation experiments, we show that the throughput capacity of lifting systems can be increased significantly.

Keywords: automated vehicle storage and retrieval systems, shuttle systems, discrete-event simulation, scheduling

1. INTRODUCTION
For the realization of scalable and efficient warehouses, automated vehicle storage and retrieval systems (AVSRSs) are being increasingly deployed. AVSRSs, also known as shuttle systems, are used for storing small transportation units (TUs) in order to supply picking or manufacturing areas on the basis of the goods-to-person principle. A key concept of this technology is the separation of horizontal and vertical transportation, executed by shuttle and lift vehicles, respectively. (FEM 2017)
There are different configurations of AVSRSs which have evolved over time, the most common and powerful configuration being characterized by shuttle vehicles restricted to a single storage aisle and tier (Lienert and Fottner 2017). At each tier, a shuttle vehicle transports TUs in a horizontal direction from and to the storage locations. In this type of AVSRS, a number of lifting systems, each with a vertically operating lift vehicle, enable vertical movement of TUs from and to the tiers. As lifting systems often limit the throughput capacity of AVSRSs (Lerher et al. 2015), more than one lift vehicle could be deployed in these systems (see figure 1).
As a consequence, the overall throughput capacity of AVSRSs could be increased by adding more lift vehicles to the lifting systems. In this way, the throughput capacity of already existing AVSRSs could be increased as well, and thus transformed into high-powered AVSRSs.

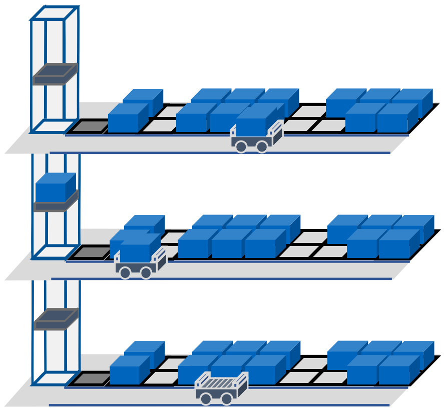

Figure 1: Several lift vehicles moving in a common shaft in an aisle of a high-powered AVSRS

The remainder of the paper is organized as follows. In the second section, a literature review of the respective areas is presented. In section 3, a description of the algorithms developed for scheduling multiple lift vehicles is given. In section 4, the simulation model as well as the model validation is described. In section 5, the simulation results of the different scheduling algorithms are presented. Finally, section 6 provides a conclusion and outlook.

2. LITERATURE REVIEW
In the following section, we give a review of related work in the field of throughput analysis and of the control algorithms of AVSRSs. Finally, we present existing scheduling problems in other applications.

2.1. Throughput Analysis of Automated Vehicle Storage and Retrieval Systems
When it comes to the dimensioning of AVSRSs, the throughput analysis of these systems is of high relevance. In order to determine the throughput of AVSRS, two fundamental approaches exist. Analytical models, e.g. based on queuing theory (Marchet et al. 2012; Eder and

Kartnig 2016), can be used to analyze the performance of less complex systems.
However, especially when a variety of configurations or complex systems have to be investigated, throughput analysis is generally performed by using simulation. Lerher et al. (2015) conduct a simulation study in order to analyze the effect of different parameters on throughput. Zhao et al. (2016) present a simulation model for investigating various rack configurations with multiple lifting systems, in order to identify the ideal configuration in a short space of time.

2.2. Control Algorithms of Automated Vehicle Storage and Retrieval Systems

Controlling strategies in conventional AVSRSs are often limited to simple priority rules, since the transport processes do not require sophisticated algorithms. However, when deploying high-powered AVSRSs with multiple lift vehicles operating in a common shaft and lifting system as well as multiple shuttle vehicles moving along the same rail, scheduling algorithms need to be applied in order to prevent collisions and to ensure efficient transport processes. By introducing the shuttle-vehicle scheduling problem, Habl et al. (2019) present a control algorithm to schedule multiple shuttle vehicles moving on a common rail. In line with this, the lift-vehicle scheduling problem occurs in lifting systems of high-powered AVSRSs.
The paper most closely related to the lift-vehicle scheduling problem is presented in (Carlo and Vis 2012), with the scheduling of two non-passing lift vehicles mounted along a common shaft. This was enhanced in (Zhao et al. 2018) by considering the acceleration and deceleration of the lift vehicles. However, the number of lift vehicles was limited to two vehicles, whereas in high-powered AVSRSs there can be more than two lift vehicles moving in a common shaft and lifting system.

2.3. Scheduling Algorithms in Other Applications

In order to prevent collisions between and blockings of the vehicles, efficient strategies for scheduling the transportation tasks need to be applied to each lifting system. However, we can find similar scheduling problems with non-crossing constraints in other logistics applications, for example port cranes, factory cranes, elevators, and industrial robots.
Kress et al. (2019) present a dynamic programming algorithm and a related beam search heuristic to schedule two gantry cranes moving along one rail while avoiding interferences. Peterson et al. (2014) present a heuristic algorithm to schedule several factory cranes on a common track by using a block-sequencing method. Takahashi et al. (2003) present an optimized zoning strategy for controlling two elevator cars in one shaft by using a genetic algorithm to determine optimal zoning. Erdoğan et al. (2014) present exact and heuristic algorithms to schedule two robots operating on a common line.
In this work, we leverage these existing concepts in order to address the lift vehicle scheduling problem described above. In doing so, we develop and apply three scheduling algorithms in order to control multiple lift vehicles in a common shaft.
Since we consider different configurations of lifting systems, we evaluate the performance and robustness of the developed scheduling algorithms by using the simulation-based approach.

3. SCHEDULING ALGORITHMS

When deploying multiple lift vehicles in a common shaft, the vehicles need to be coordinated in order to prevent blockages and collisions between them, and to minimize empty driving times and waiting times. In this section, we present the control algorithms for the robust and efficient scheduling of multiple lift vehicles.

3.1. Rigid and Rolling Block-sequencing Algorithm

Our first approach towards scheduling multiple lift vehicles with non-crossing constraints relies on the algorithm for scheduling several factory cranes on a common track by using a rigid block-sequencing method, as presented in (Peterson et al. 2014). The algorithm was already adapted in (Habl et al. 2019) to shuttle vehicles which perform horizontal transportations in high-powered AVSRSs, and further improved in (Habl et al. 2019) so as to apply the algorithm in multi-deep storage. In this work, the algorithm is adapted to lift vehicles for optimizing vertical transport in high-powered AVSRSs.
The algorithm successively extracts a selected number of jobs from the job list for processing and creates a decision tree of possible states (partial and complete schedules). Thereafter, the extracted jobs are assigned to the lift vehicles according to the selected schedule with the lowest completion time. Due to the exponential growth of the decision tree, the algorithm's computation time is reduced by the heuristic developed in (Peterson et al. 2014). This includes the pruning of inferior partial schedules (dominance check) as well as chopping partial schedules when the heuristic threshold is passed.
However, since every block of jobs needs to be fully completed by the vehicles, it emerges that some of the faster vehicles are subject to waiting times. In order to further optimize this scheduling process, we combine rolling scheduling to the block-sequencing method to obtain a more dynamic version of the existing algorithm. This means that instead of starting the next block iteration after the last job of the block has been finished, new jobs are added to the schedule when the first vehicle has completed its jobs (see figure 2).

3.2. Cluster-sequencing Algorithm

The second approach for scheduling multiple lift vehicles in a common shaft is based on the algorithm for controlling multiple stacker cranes on a common rail, as given in (Kung et al. 2014). The algorithm combines several transport jobs into a cluster and uses dynamic programming to obtain the optimum sequence. The size of a cluster corresponds to the number of vehicles.

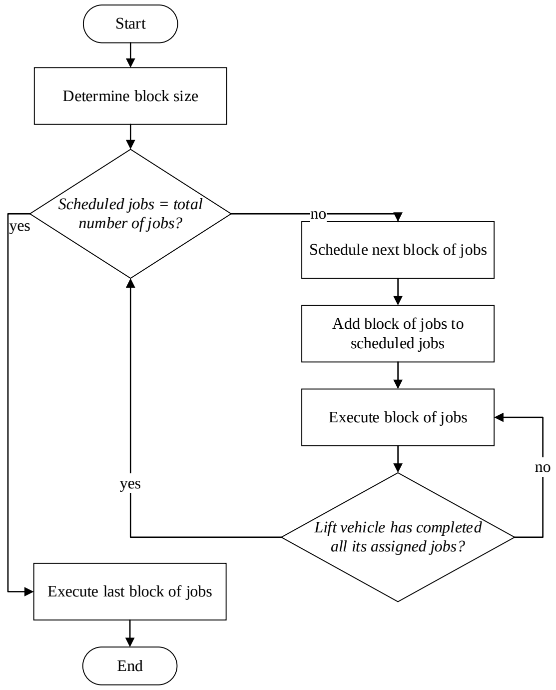

Figure 2: Block-sequencing algorithm combined with rolling scheduling (rolling block-sequencing algorithm)

Each job in the cluster is scheduled according to an initially assigned priority and under the premise that every job can be executed without interruption (see figure 3). Afterwards, the priorities are changed and the jobs are rescheduled as long as every combination is considered. In order to optimize the sequence of several clusters, the transition times, i.e. the travel times of the lift vehicles to the next cluster, need to be considered. For that reason, several clusters are combined into a cluster block, which is further processed. In order to get the cluster combination with the shortest completion time, a list of combinations (states) is created and searched using a breadth-first search. Finally, the cluster block is forwarded for execution by the lift vehicles. The scheduling and execution process is repeated until all jobs are accomplished by the vehicles (see figure 4).

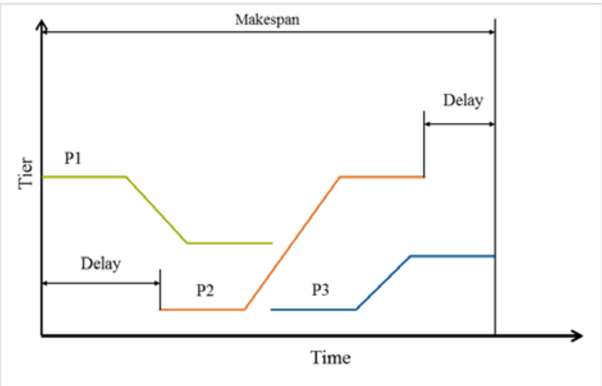

Figure 3: Cluster version with three lift vehicles and three priorities (P1, P2, P3)

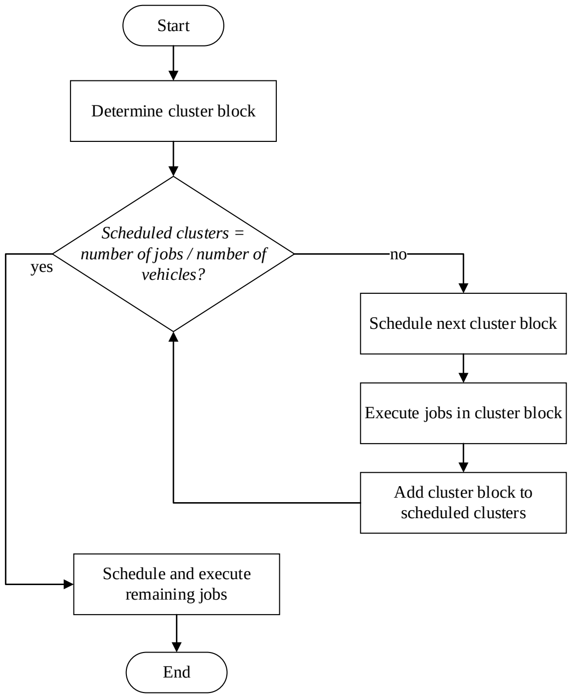

Figure 4: Cluster-sequencing algorithm

4. SIMULATION MODEL

For the purpose of the analysis and comparison of the scheduling algorithms described in the section above, the algorithms are implemented in a simulation model. In the following, the model as well as its validation is presented.

4.1. Model and Parameters

A simulation model was created by using the discrete-event simulation environment *Tecnomatix Plant Simulation*. It represents a lifting system with several lift vehicles, transporting TUs vertically from the input/output (I/O) point to the transfer buffer of the respective tier of an aisle in an AVSRS and vice versa. Since we focused on the lifting system, TUs at I/O point and at transfer buffers are immediately available for pick-up or drop-off by the vehicle. The parameter specifications of the components are shown in Table 1.

Table 1: Simulation parameters

Lift vehicle	
Velocity	2 m/s
Acceleration	2.5 m/s²
Deceleration	2.5 m/s²
Pick-up time	2.5 s
Safety distance	0.045 m
Height	0.35 m
Lifting system	
Number of I/O points	1
Number of lift vehicles	1 - 6
Rack	
Number of tiers	30
Height of tier	0.4 m
Position of I/O point	Centered

In order to test and compare the developed scheduling algorithms in different scenarios, a series of simulation experiments is performed.
In each simulation experiment, a list of transport jobs (storage and retrieval) for the lifting system is generated after system initialization, and scheduled for the lift vehicles. After completion of all jobs the throughput capacity of the system is calculated by measuring the time needed for fulfilment.

4.2. Model Validation

Since storage and retrieval locations (tiers) are determined randomly during job generation, the number of replications of the simulation experiments as well as the number of transport jobs need to be adjusted accordingly, in order to reduce the luck factor. In a preliminary study, we varied the number of replications of a reference experiment from 10 to 1000 replications. In order to determine the throughput of the reference experiment, a simulation with one lift vehicle in a lifting system which is serving 30 tiers with a centered I/O point is conducted. The number of transport jobs is varied from 5 to 5000 jobs in this experiment (see figure 5).

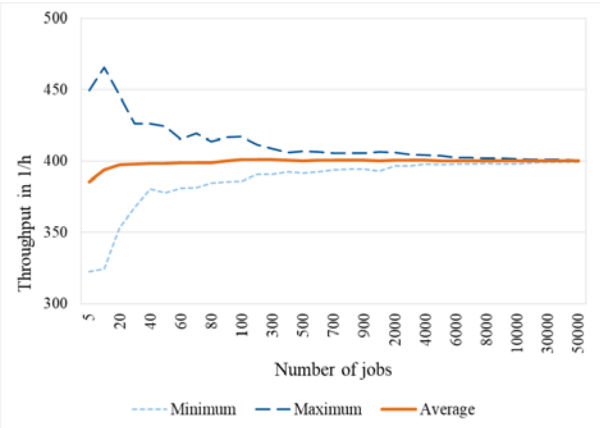

Figure 5: Variation of throughput depending on number of jobs when performing 40 replications

With 40 replications and 500 jobs in each experiment, we obtain a mean value of 400 jobs per hour and a standard deviation of 3.6 jobs per hour, which leads to a 95 % confidence interval of 400 ± 1 job per hour. Since this is considered “sufficient” in this study, this parameter set is used for the following analysis.
As already described in section 3, the computation time of the block-sequencing algorithm is reduced by a heuristic, including chopping partial schedules when the heuristic threshold is passed. In the following analysis, the threshold is set to 300 states and the number of deleted states is set to 30 % of the threshold.

5. SIMULATION RESULTS

In this section, we present and discuss the results of the conducted simulation study on the basis of the simulation model described in the section above.
Figure 6-8 show the improved throughput capacity of the lifting system by deploying up to six lift vehicles and by applying the scheduling algorithms rigid block-sequencing, rolling block-sequencing, and cluster-sequencing. The obtained throughput when deploying only one vehicle is selected as a reference. Essentially, the throughput capacity of a lifting system can be increased by deploying additional lift vehicles. However, the largest relative increase can be achieved by adding one more vehicle to the system. Since only one I/O point is available in the considered lifting system, other vehicles interfere with each other and as a result, throughput capacity increases to a lesser extent. As can be seen in figure 6, the throughput capacity can be improved by 46 % when deploying two vehicles and by applying the cluster-sequencing algorithm to the lifting system. By adding up to six vehicles to the lifting system, the throughput capacity increases by up to 88 %.

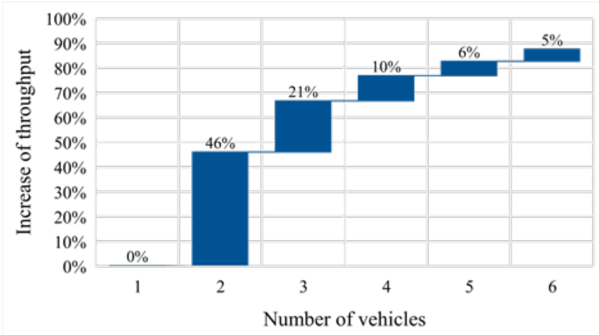

Figure 6: Increase of throughput depending on the number of vehicles by applying cluster-sequencing algorithm (cluster block size of 20 jobs)

Figure 7 shows that by applying the rigid block-sequencing algorithm, throughput capacity can be improved by 61 % when deploying two vehicles and by up to 83 % when deploying four vehicles. However, the throughput capacity decreases when deploying more than four vehicles. An increasing number of vehicles increases the solution space, thus it increases the probability that the applied heuristic in the algorithm excludes the optimum solution.

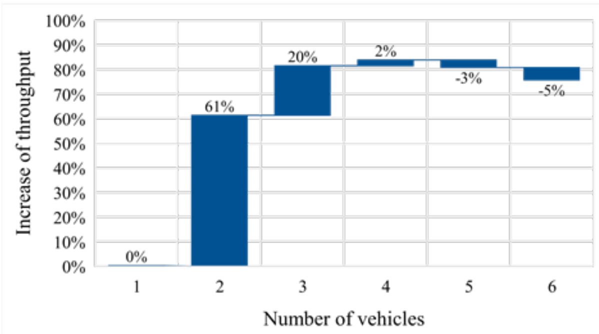

Figure 7: Increase of throughput depending on the number of vehicles by applying rigid block-sequencing algorithm (block size of five jobs)

Similarly, when applying the rolling block-sequencing algorithm, throughput capacity can be improved by 68 % when deploying two vehicles and by up to 92 % when deploying four vehicles (see figure 8).

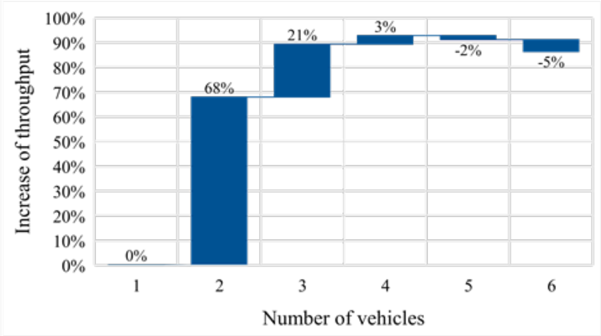

Figure 8: Increase of throughput depending on the number of vehicles by applying rolling block-sequencing algorithm (block size of five jobs)

Due to the applied heuristics in the rolling block-sequencing algorithm, throughput capacity also decreases when deploying more than four vehicles.
Figure 9 summarizes the obtained throughput by applying the different scheduling algorithms with respect to the number of deployed vehicles. Both block-sequencing algorithms strongly increase throughput capacity when deploying up to four vehicles and slightly decrease when deploying more than four vehicles. As already described above, this is due to the applied heuristic in a large solution space. Since the rolling block-sequencing algorithm can reduce waiting times for already finished lift vehicles at each block, it achieves a higher throughput compared to the rigid block-sequencing algorithm. This effect is heightened given an increasing number of vehicles, as more vehicles need to wait for the last one. However, by applying the cluster-sequencing algorithm throughput capacity increases steadily and eventually even exceeds both block-sequencing algorithms when deploying six vehicles.

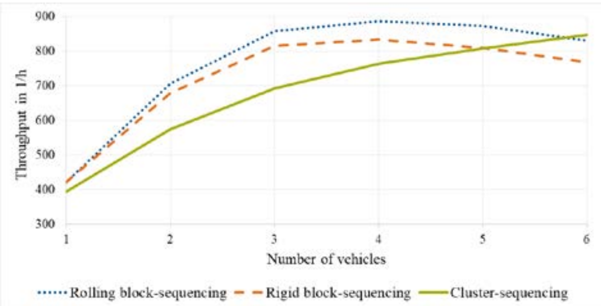

Figure 9: Throughput capacity with respect to number of lift vehicles and applied scheduling algorithm

Figure 10 shows the computation time of the simulation experiment when applying the scheduling algorithms depending on the number of deployed vehicles. The simulation is performed by using the CPU Intel Core i5-4670K (3.40GHz). As can be seen, the rolling block-sequencing algorithm requires the largest computation time. Especially when more than four lift vehicles are operating in the lifting system, the computation time is dramatically increasing.

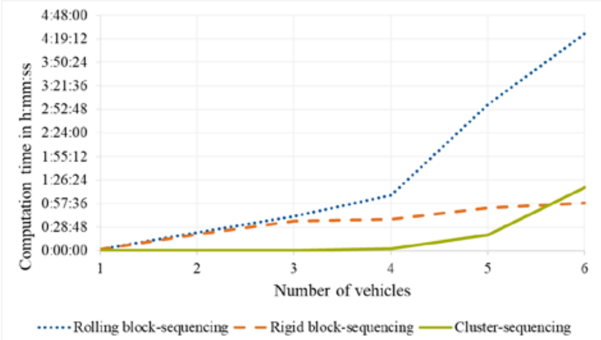

Figure 10: Computation times of the simulation experiment with respect to the number of lift vehicles and applied scheduling algorithm

6. CONCLUSION AND OUTLOOK

In this work, we applied two block-sequencing algorithms as well as a cluster-sequencing algorithm in order to efficiently and robustly control multiple lift vehicles in a common shaft.

It emerges that the throughput capacity of a single lifting system can be increased significantly by deploying more than just one lift vehicle, which is the usual scenario. With the help of rolling scheduling, the waiting times of lift vehicles could be reduced and hence the newly developed rolling block-sequencing algorithm is superior to the existing rigid block-sequencing algorithm. When deploying up to four vehicles, both block-sequencing algorithms are superior to the cluster-sequencing algorithm. However, when deploying more than five vehicles in a lifting system, the cluster-sequencing algorithm outperforms both block-sequencing algorithms, since there is no decrease of throughput.

In future work, the modeled lifting system will be integrated into an aisle of a high-powered AVSRS. In order to reduce the computation time of the overall system, the developed scheduling algorithms should be more efficient in terms of computation. This could be achieved by applying a more efficient heuristic in the block-sequencing algorithms. In order to reduce computation power and redundancy of the cluster-sequencing algorithm, we suggest the caching of already computed clusters.
However, in order to further optimize the cluster-sequencing algorithm, in a similar way to the block-sequencing algorithm, a rolling scheduling could be applied to the cluster block sequencing.
In order to deploy the system in a real industrial environment, we suggest not relying strictly on the schedule times. Instead, the scheduling process could be separated from the execution process in order to increase robustness of the overall system.

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SIMULATION OF HUMAN PIONEERING ON MARS

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ABSTRACT
This paper shows the work developed on the NASA SIMULATION EXPLORATION EXPERIENCE 2019 (SEE 2019) by Faculty of Engineering of Sorocaba (FACENS) team. The SEE is a project based on three-dimensional modeling that involved fourteen teams from ten different countries with the objective of simulating a virtual mission using Distributed Observation Network (DON) and High-Level Architecture (HLA). FACENS team was responsible for developing a mars habitat, containig astronauts and resources that enable astronauts life's during missions.
In this work, seven simulations were developed: two rovers, one excavation mine, one oxygen factory, one mars habitat, one cargo transport and the astronaut.
In order to create this simulation, several surveys were carried out in order to simulate an environment as close as possible to the real one. Being investigated the constitution of soil and atmosphere, acceleration of gravity, pressure, climate, among other similar items. The simulation used JAVA language and three-dimensional modeling in softwares like Blender, SketchUp and 3DS max, in order to facilitate the visualization of what is being simulated in real time.

Keywords: astronaut, DON, HLA, mars habitat, SEE, simulation.

1. INTRODUCTION
The Simulation Exploration Experience (SEE) is an international modeling and simulation (M&S) project created by National Aeronautics and Space Administration (NASA) to integrate various educational institutions around the world. At the beginning of every SEE project, NASA proposes to the member institutions a space mission, which specifies how the environment is and what can be done during the project, which must be fulfilled through cooperation among the participating teams, being each team responsible for the creation of its own part of the simulation.
Since 2015 FACENS team have participated in the SEE. In 2015 was realized a system to capture asteroids. In 2017, FACENS team was responsible for the modeling and simulation of a functional lunar habitat, with all essential subsystems, as well as for creating an astronaut model. In 2018 was developed a life-support system in Mars, it was developed four simulations: one rover to find water, a second rover to collect hydrated salts from an excavation mine, one oxygen plant responsible for removing water from the salts and one excavation mine.
In this year the focus of our mission in the SEE 2019 was expanded to human colonization on Mars, thus part of the mission was using the four simulations developed on SEE 2018 and making a more complex one by adding three simulations that involves the development of the astronaut's accommodation and the resources that enables theirs life during missions. Thus was developed a mars habitat, codename HOME, capable of housing astronauts on long-duration mars missions, a cargo transportation, codename SPEL and the astronaut, codename MANS.
The habitat was designed and developed having in mind many aspects and meeting the necessary requirements to provide survival and living conditions, as well as safety and comfort. The HOME has different areas and environments and it was designed to be replicated and expanded. The cargo transportation was designed to transport loads in the surface of Mars.

2. SEE MISSION 2019
The 2019 NASA's mission was to create a Mars colony, a base for future exploration missions. Continuing and expanding the project developed in SEE 2018, making a simulation more complex in architecture, with the creation of a colony on Mars, as a basis for future exploration missions linked to the simulation of extraction area of resources that enable astronaut life during missions and a cargo transportation.
This project consists in simulating the colonization, use and extraction of resources that enable life on Mars in the Jezero crater, always seeking reality. The FACENS team developed a virtual simulation of a habitat in the soil of Mars, presenting the possibilities in future exploration missions and extraction of resources necessary for survival. With this purpose was developed an excavation mine to remove the hygroscopic ore, calcium perchlorate, the same being excavated by the Mars miner rover (MAMI) to the oxygen factory where it will also store water obtained from the subsoil of Mars by the Water Finder rover (WAFI) for both resources to be transformed into water and oxygen for its use in the habitat (HOME) for astronaut (MANS) consumption, as well as simulated transport of cargo on the Martian surface with the development of the Space Elevator

(SPEL)

The Mars colony is composed of Rovers: Water Finder and Mars Miner; housing: Mars Habitat; areas for exploration and obtaining resources: Excavation Mine, Oxygen Factory; cargo transportation: Space elevator; and finally the astronauts who are the inhabitant of this colony.

The objectives of the team were in the development and availability of resources, planned so that survival on Mars is possible and adapted for future manned missions, always using real data for the simulation to be consistent.

3. MARS ENVIRONMENT SIMULATION

Considering the proposals of the SEE 2019 mission, it was necessary to consider in this project the extreme environmental conditions that can be found in Mars.

3.1. Environmental Conditions

3.1.1 Gravity

The Mars gravity on the surface of the Equator is 3.72 m/s². (Hamilton, 2018)

3.1.2 Pressure

The pressure of Mars varies every six months and according to the formation of a snow cover, due to carbon dioxide at the poles, alternately in each one. Therefore, when the South Pole cap is higher, the average pressure observed by the Viking 1 probe was of 0,68 kPa while in other times the average pressure was 0,9 kPa, the pressures observed by the Viking 2 probe at the same time that the southern cap was higher, were 0,73 and 1,08 kPa. (Hamilton, 2018)

Inside the Habitat (HOME) the ideal internal pressure to which the astronaut should be subject is the atmospheric pressure of the Earth. Higher pressures can cause the formation of gas bubbles in the bloodstream and the lungs, leading to death, so the ideal internal pressure should be around 101.4 kPa (62,600 kg/m2) in order to obtain a safe environment for astronauts. (Ruess, Schaenzlin and Benaroya 2006).

3.1.3 Atmosphere

The atmosphere is composed mostly of carbon dioxide mixed with some gases, such as the most common: oxygen, water, neon, argon and nitrogen. (Hamilton, 2018)

3.1.4 Humidity

Mars humidity depends on the temperature and amount of steam in the atmosphere, during the summer afternoon the humidity is 5% and 100% on the autumn and winter nights. (NASA, 2015)

The ideal humidity for humans is in the range of 30 to 60%, because lower humidity conditions, such as those that can be found on Mars, can generate dryness and dermatitis in the skin, besides respiratory problems, while higher humidity can make the environment propitious to the appearance of fungus. (Hinrichsen 2011).

3.1.5 Temperature

The surface temperature ranges from -140 °C to 20 °C (-220°F to 68°F), with a medium temperature of -63 °C (-81, 4°F) in the day and night transition, occurring in 24 hours and 37 minute cycles. (Hamilton, 2018)

3.1.6 Resources

Its composition is somewhat similar to that of the Earth, the crust and the surface have a composition of iron-rich basaltic rock. (MARS NASA)

3.1.7 Radiation

Mars radiation varies about 210 micrograms per day. This variation is due to the shielding difference that the atmosphere of Mars provides in the period of one day. (ESPINOZA, 2013)

3.1.8 Structural requirements

The construction of the habitat structure on Mars demands some requirements, such as sustaining loads safely, using little structural material, being lightweight, with high rigidity and resistance, ductile, durable, resistant to rips and pierces, with low thermal expansion and with little maintenance. The structure should be designed to have a short construction time, and the astronauts should have minimal contact with the handling of the equipment, minimize transportation costs/time and be compatible with the internal environment. (NASA´s, 2018)

4. GENERAL ARCHITECTURE OF THE SEE 2019 ENVIRONMENT

For the development of the project different technologies are used, the main technology used in the project was High-Level Architecture (HLA), defined by an IEEE 1516 standard, so that all teams follow the same communication prototype of the simulation components. Another technology applied to complement it, is the Federation Object Model (FOM), which is based on an object-model representation that can be loaded at runtime. An FOM file contains the data that will be transited within a federation, all object definitions, data types and federate interactions.

Members of the SMASH Lab of the University of Calabria developed a framework in order to facilitate the development of a federate, it is the "HLA Starter Kit", which offers a set of features for the development and annotations for mapping objects with the data contained within the FOM files. The Starter Kit Framework (SKF) project receives constant improvements to fulfill the demands of the Simulation Exploration Experience (SEE). The version used by the FACENS team in the federations was the 1.5.

4.1 HLA – High-Level Architecture

In a distributed simulation, each component integrated in the system produces information, which is transmitted to

the control center, which analyzes and decides the next action of the component.
For this reason, it is necessary to use an architecture standard that manages and administers the communication between the simulation components. That is why the SEE project adopted the use of the IEEE 1516 standard called HLA.
There are several implementations of IEEE 1516, but those commonly found in SEE editions are those developed by Pitch Technologies and VT Mak, from which temporary licenses are made available to the teams participating in the SEE. Both companies have implementations in Java and C++.
For the simulation to work, it is necessary to configure the Run-Time Infrastructure (RTI), which is a middleware that has the function of acting as a means of intercommunication between the simulation components. (Möller et al.2012).
During a distributed simulation, the name Federate is given to the components that are integrated into the simulation and Federation is the simulation itself.
With a Federation configured in the network, it is possible to have Federates instances integrating the simulation that use the RTI to intercommunicate.

4.1.1 Federation Object Model

A FOM allows the interoperability between Federates in a simulation supported by OMT specification. (Dumond and Little 2003).
It is based on object-model representation that can be loaded at runtime. In a FOM file, it is encountered mainly a definition of objects, data types and interactions. Usually it can be called as "the language of federation" (Möller et al.2014) because it contains the definition of data exchanges between the federates.

4.2 SEE HLA Starter Kit

To improve the performance of SEE teams, members of the SMASH Lab of Calabria University have developed a Starter Kit Framework (SKF) that provides a kit containing all preconfigured information regarding RTI and the Federation used in the simulation, the "HLA Starter Kit". The project has been evolving over the years with improvements and updates based on the Environment developed by NASA. The code and versions of the project are available in GitHub.
The project implements annotations that facilitate the mapping of objects with the data defined in the FOMs. In addition to implementing easy Federate configuration, Federation integration, lifecycle, and default objects for all Federates (Garro and Falcone 2017).
One of the main functionalities of the project is the facilitation of the implementation of classes that operate like capture of Federates properties like position and rotation, information that will be used in the 3D simulation application (DON – Distributed Observation Network).

4.3 3D Models

A visual facilitator is needed to better understand the progress of the simulation, so each team needs to build a 3D virtual model that represents each of its Federates, since it is a software-level simulation. These templates can be built into software like 3ds Max, SketchUp or AutoCAD, in extension ".obj" format that will be loaded into the DON application.
Our team used 3ds Max which is a three-dimensional modeling program developed by Autodesk and SketchUp another three-dimensional modeling program but developed by Trimble Navigation to create the 7 Federates (Mars Habitat (HOME), Astronaut (MANS), Space Elevator (SPEL), Excavation Mine (MINE), Mars Miner (MAMI), Oxygen Factory (O2FAC) and Water Finder (WAFI) based on the structural requirements of the SEE.

5. FEDERATES

The development of the SEE 2019 has considered the continuation of the project developed in the SEE 2018, therefore a new group of federates was developed consisting of 3 (three) federates, all located on the surface of Mars, which has totaled 6 (six) federates since 2018. The focus of the SEE 2019 mission was the colonization of Mars, providing therefore a safe environment on Mars for the astronaut during the missions.
Among all the federations developed by FACENS team, there is the Excavation Mine (MINE) which is a representation of a place full of hydrated salts, there are two types of autonomous exploration vehicles, the Mars Miner (MAMI), an excavation vehicle, which will collect the hydrated salt, calcium perchlorate, and the Water Finder (WAFI) which is a vehicle that searches and collects water in the Martian subsoil in Jezero crater. All resources collected will be transported by MAMI and WAFI to the Oxygen factory (O2FAC), an automated factory specialized in the production and storage of water and oxygen, where the calcium perchlorate will serve as raw material. Finally the new federates incorporated in the 2019 simulation making the architecture more complex, is the Mars Habitat (HOME), which is a permanent habitat for the colonization on Mars, it will provide a safe place for astronauts as well as being able to produce food consumed there, the Astronaut (MANS) who is the habitant of HOME, he is able to walk on the ground of Mars as well as enter the O2FAC and explore the ground of Mars, thanks to his space suit. Lastly, completing the 7 (seven) federates, it was developed the Space Elevator (SpEl) which is responsible for transporting loads from the surface of Mars to space.

5.1 Excavation mine – MINE

The first Federate is the Excavation mine (MINE), whose main functions are to provide data regarding the Martian soil to be used as extraction information for the rovers.
MINE was developed to simulate a proper site for excavation in Martian soil where it has a large amount of valuable resources for the production of water and oxygen in Mars with hydrated ores (hygroscopes), such materials will be excavated by Mars Miner. The Figure 1

shows the mine modeled for the simulation.

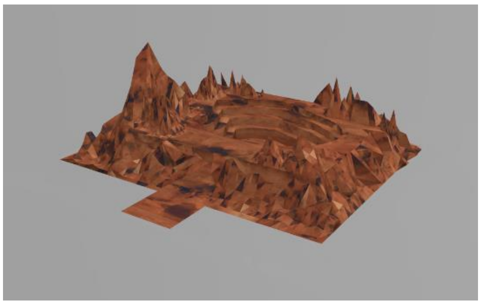

Figure 1. Excavation mine.

5.1.1 FOM of Excavation mine

The defined properties used by MINE in the simulation and its FOM definition are listed below and in Figure 2:

- Depht: Represents the depth of the MINE;
- Diameter: Represents the excavated diameter of the MINE;
- Number_of_mars_rover: Represents the number of rovers inside the MINE;
- Maximun_capacity: Represents the maximum capacity of rovers in the MINE;
- Temperature: Represents the soil temperature of Mars;
- Pressure: Represents the pressure of Mars;
- Area: Represents the total area of MINE;
- Volume: Represents the volume of the MINE;

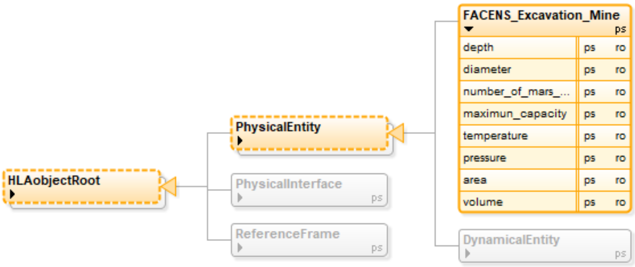

Figure 2. Representation of MINE to federation.

5.2 Mars Miner - MAMI

The Mars Miner (MAMI) is a medium-sized vehicle with six wheels. It also has a drill, to excavate rocks in the MINE, and a mechanical claw, with the objective of collecting ores and placing them in a container, attached to the back of the vehicle, has its function due to solar energy associated to a battery attached in its interior. Figure 3 shows the 3D model created from Mars Miner. At the boundary of the mine, Mars Miner moves freely exploring, digging with its drill, clawing with its mechanical claw, and looking for hydrated ores, such as calcium perchlorate for the use of water absorbed in ores for the production of oxygen and the possible use of it in the production of fuel.

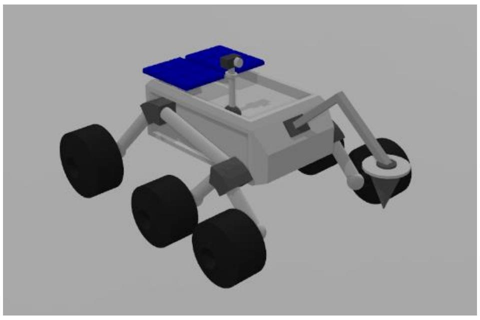

Figure 3. Mars miner.

5.2.1 FOM of Mars Miner

The defined properties used by MAMI in the simulation and its FOM definition are listed below and in Figure 4:

- Battery_level: Represents the battery level of the rover;
- Mass: Represents the total weight of the rover (loaded mass added to the weight of the rover itself).
- Mars_miner_Status: Represents the spatial position of the rover;
- Temperature: Represents the temperature of the rover;
- Speed: Represents the speed of the rover;
- Maximum_capacity: Represents the maximum capacity of the rover;
- Loaded_mass: Represents the amount of mass loaded by the rover;
- Height: Represents the total height of the rover;
- Width: Represents the width of the rover;
- Lenght: Represents the length of the rover;

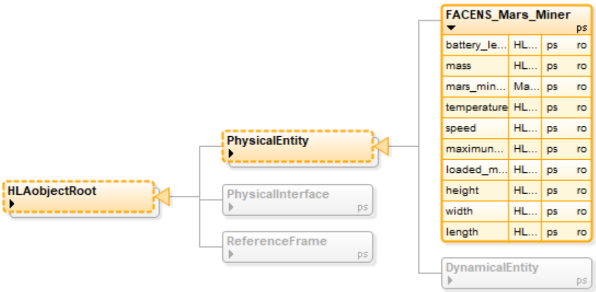

Figure 4. Representation of MAMI to federation.

5.3 Oxygen Factory – O2FAC

The Oxygen Factory (O2FAC) will be used for two functions, the first as a rover's control center in which it is responsible for the decision of the actions taken by the rovers, and the second being responsible for the manufacture of oxygen and water in an automated way. O2FAC is powered by solar energy and has all its communication panels in a remote and automated way controlled by HOME. O2FAC will use the water extracted from the hygroscopic ore called calcium perchlorate or the frozen water in the subsoil of Mars for the production of oxygen. Figure 3 shows the outside view of O2FAC and for better visibility Figure 4 shows the O2FAC without the dome.

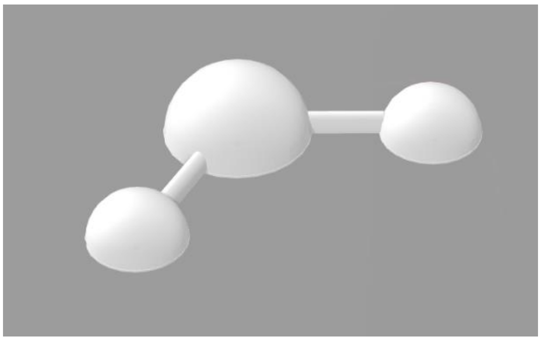

Figure 5. O2FAC.

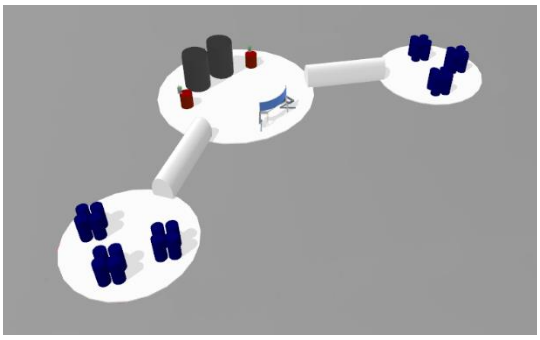

Figure 6. O2FAC without the dome.

5.3.1 FOM of Oxygen Factory – O2FAC

The defined properties used by MAMI in the simulation and its FOM definition are listed below and in Figure 7:

- Max_Water_Volume: Represents the maximum volume of water within the factory;
- Current_Water_Volume: Represents the current amount of water within the factory;
- Max_Oxygen_Volume: Represents the maximum volume of oxygen within the factory;
- Max_Raw_Material_Volume: Represents the maximum volume of raw material that can be stored in the factory;
- Current_Raw_Materials_Volume: Represents the current volume of raw material stored in the factory;
- Energy_Consumption: Represents the energy consumed by the plant;
- Oxygen_Production: Represents the amount of oxygen produced;
- Factory_Area: Represents the area of the plant;
- Factory_Volume: Represents the O2FAC volume;
- Temperature: Represents the temperature inside the plant;
- Pressure: Represents internal factory pressure;
- Factory_Humidity: Represents the internal factory humidity;

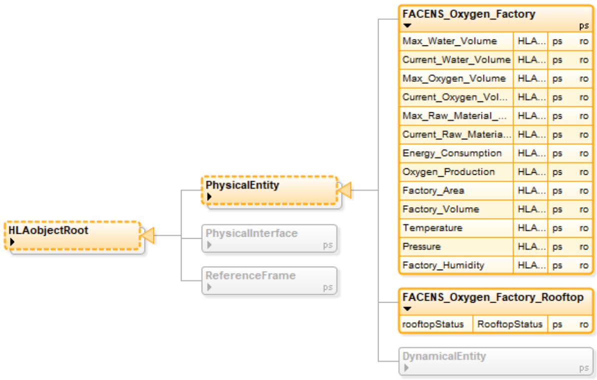

Figure 7. Representation of O2FAC to federation

5.4 Water Finder - WAFI

In order to search for water points in Martian soil, a specialized rover with a Ground Penetration Radar (GPR) is used to map the subsoil of Mars to locate water and ice, a Long Range Drill (LRD) to excavate the soil and obtain a sample of the water or ice found. A battery with solar panels will power the vehicle and the collected samples will be stored in the Sample Tube Storage (STS), which has capacity for 30-tubes.

The GPR will analyze the ground as the rover moves. If the data show signs of ice or water on the spot, the rover stops and picks up a sample, using the LRD, and stores it in the STS. Figure 8 shows the Water Finder model created for the simulation.

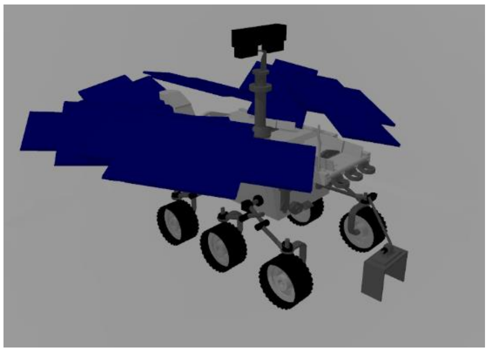

Figure 8. Water finder.

5.4.1 FOM of Water Finder - WAFI

The defined properties used by WAFI in the simulation and its FOM definition are listed below and in Figure 9:

- Battery_level: Indicates the battery level of the rover;
- Mass: Indicates the total weight of the rover (water samples added to the weight of the rover itself);
- Total_tuber: Indicates the total number of tubes that the rover can carry;
- Remaning_tubes: Indicates the number of tubes remaining to collect more water samples from the ground of Mars;
- Temperature: Indicates the temperature of the Mars soil;
- Height: Represents the total height of the rover;
- Width: Represents the width of the rover;

- Lenght: Represents the length of the rover;
- Speed: Indicates the instantaneous speed of the rover;
- Water_finder_Status: Represents the spatial position of the rover;

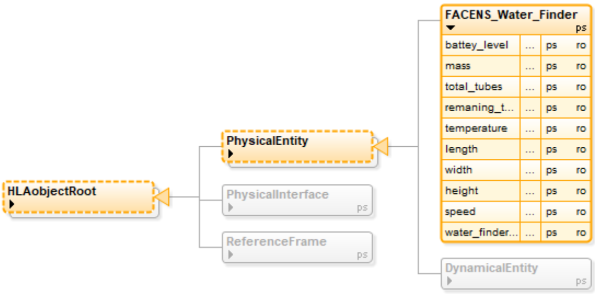

Figure 9. Representation of WAFI to federation.

5.5 Astronaut - MANS

The federate Astronaut (MANS) was developed to simulate the astronauts in missions that inhabit the habitat on Mars, to which was taken into account their basic needs, all their daily routine and their vital signs. In Figure 10, we have an image of the astronaut created.

The federate was focused on simulating astronauts in missions, being considered the vital signs of the astronauts, the consumption of energy/food, as well as the available path to be traveled to move inside the habitat during the simulation.

The calculation to find the best way to get from one point to another of the habitat map by the astronaut was done avoiding collisions with other astronauts and with physical objects within the habitat. To solve this problem, a map based on the habitat floor was implemented in the simulation.

With these definitions, it was possible to simulate the routine of the astronauts in the habitat on Mars, and the data published by the astronauts were captured by the habitat (HOME), making it possible to update the position and perform actions in real time.

Figure 10. Astronaut

5.5.1 Astronaut´s FOM

Based on researched data, the astronaut's FOM in the simulation was developed. The defined FOM properties are listed below and in Figure 11:

- Pulse_oximetry: Pulse oximetry that a saturation of 100% indicates that hemoglobin is fully occupied by oxygen molecules. (SpO2);
- Heart_rate: The heart rate of astronaut (bpm);
- Temperature: It gives an indication of body temperature. It is expressed in Fahrenheit degree (°F);
- Blood_pressure_systolic: Represent systolic pressure of the astronaut;
- Blood_pressure_diastolic: Current diastolic pressure of the astronaut;
- Amount_oxygen: Amount of oxygen breathed by the astronaut;
- Amount_carbon_dioxide: Amount of carbon dioxide emitted by the astronaut;
- Amount_calories: Number of calories spent by the astronaut, it is expressed in calories (cal);

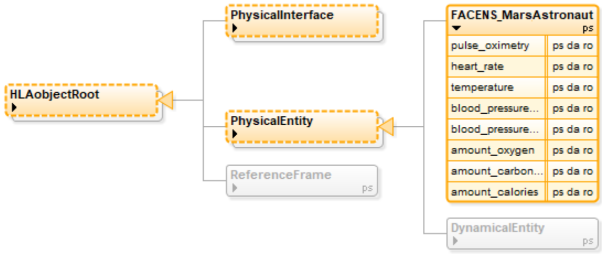

Figure 11. Representation of astronaut to federation.

5.6 Mars habitat – HOME

The federate Mars Habitat (HOME), as seen in Figure 12, is a permanent home for astronauts during missions and colonizations on Mars. First a better format for the habitat was studied, taking into consideration the difference of internal and external pressure, concluding that, the ideal shape for the habitat would be circular/rounded (dome shape) in order to minimize the effects of pressure.

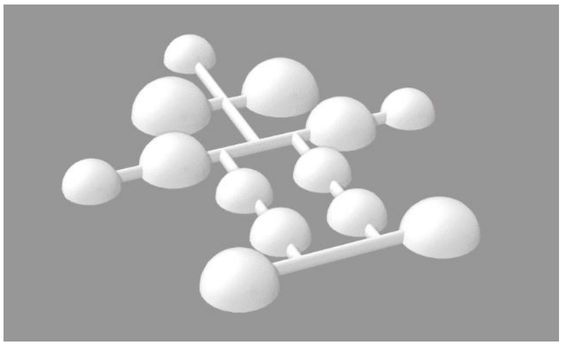

Figure 12. Mars habitat (HOME)

HOME has modules that are connected by tunnels equipped with safety systems, to prevent possible ruptures in the structure that could endanger the life of the astronaut as well as the entire habitat.

Some parameters of resources necessary for the survival of the astronauts were adopted to establish the environments and their functioning, so the HOME has as information, the basic conditions of a construction, such as: pressure, temperature, surface area, volume, humidity of air, and important information to the astronaut life, such as energy consumption, oxygen consumption and carbon dioxide emission.

For the HOME simulation, several spaces were proposed. They can be seen in the list below with their main characteristics:

- Depressurization chamber: entrance/exit of astronauts in mission on Mars and return/exit of the tasks outside the Mars habitat;
- Bedroom: resting place for astronauts during the mission;
- Bathroom: personal hygiene care;
- Cafeteria: to prepare meals and store food from Earth;
- Warehouse: storage of materials/tools;
- Fitness center: for physical exercise, an important part of astronauts' daily routine, to prevent bone and muscle loss (Wild 2016).
- Control Center: where astronauts have access to habitat´s data such as temperature, humidity, pressure, gas (oxygen, carbon, nitrogen, hydrogen and others) levels of each module, communication with the control tower, and Earth, daily habitat reports, outpatient reports, O2FAC and SPEL control and communication with the rovers in ground exploration.
- Outpatient: for periodic examinations of each astronaut and small emergencies (first aid),
- Greenhouse: supply and production of food for the astronaut,
- Solar panels: production of electricity for the habitat.

In addition, their amount of production and food consumption that they could provide to the astronaut was also recorded. For the successful execution of a simulation with several objects, the exchange of data is fundamental. The SEE HLA Starter Kit provides two types of communication and data exchange, the first named *interaction*, is based on sending data to a specific federate receiver. In addition, the second known as *subscription*, is based on sending data to the federation, which is responsible for forwarding the information to all other federates.

In SEE 2019, the HOME federate interacts with O2FAC and the Astronaut federate both developed by us, and the interactions were based on the recipiency of the amounts of oxygen, carbon dioxide, food consumed and produced, vital signs by the astronauts, with this information the interactions between HOME and Astronaut were performed, which HOME sent an interaction to the greenhouse module, making the request for the desired amount of food. The subscriptions that HOME sends are their own data information and it uses this resource to monitor the Astronaut, making it possible to act upon receival of vital signs and basic needs below the limits.

To represent a better visualization of the simulation and to show the astronaut's actions inside of Home, it was necessary to create two different objects, one to represent the habitat itself and the other one to represent its rooftop, as seen in Figure 13.

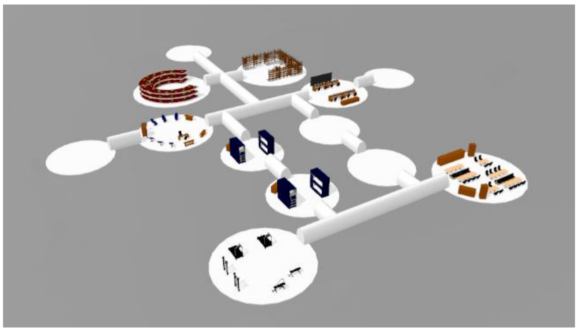

Figure 13. Mars Habitat without the rooftop

5.6.1 FOM of Mars habitat

The defined properties used by HOME in the final study and their FOM definition are listed below and in Figure 14:

- Pressure: Internal pressure (in Pascal) inside HOME;
- Temperature: Represents the temperature (in Celsius) inside of the Mars Habitat;
- Area: Total area (in m²) of Mars Habitat;
- Volume: The internal volume (in m³) of the Mars habitat;
- Energy_consumption: Accumulated consumed of electric energy (in Watts) of the HOME;
- Oxygen_consumption: Total consumption of oxygen in Mars Habitat;
- Carbon_dioxide_emission: The carbon dioxide emission in Liters;
- Air_humidity: Percentage of air humidity inside the Mars Habitat;
- Calories_consumption: The calorie consumption (in cal) in the Mars Habitat;
- Maximun_capacity: The maximum number of astronauts inside the Mars Habitat;
- Number_of_astrounauts: The number of astronauts currently inside of the Mars Habitat;

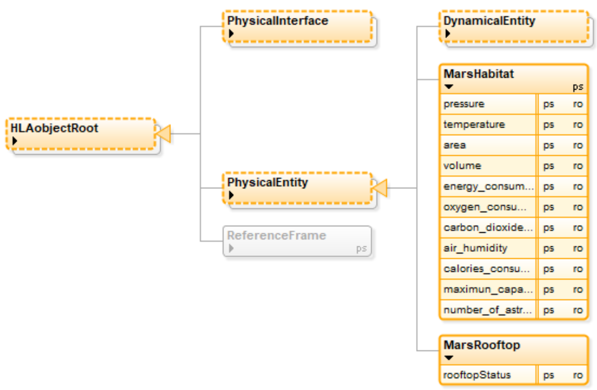

Figure 14. Representation of HOME to federation.

5.7 Space elevator – SPEL

The space elevator (SPEL) was developed to transport loads from the surface of Mars to space, using a fixed transport route to place, control and transport loads in space, as seen in Figure 15.

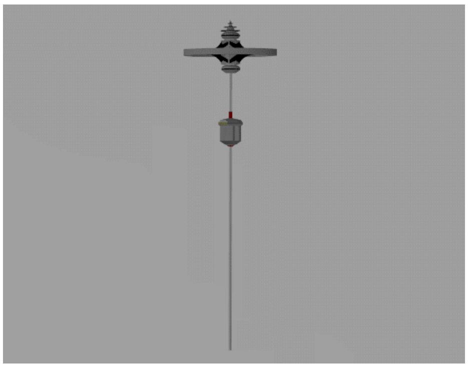

Figure 15. Space elevator

It is composed of two main parts. One of them is composed of a high base tower of approximately 17,000 km in height, to which it has a long cable tied at the top that extends from the surface of Mars to space with its center of mass in geostationary orbit. The other part that composes the space elevator is the electromagnetic vehicle, as shown in Figure 16, which travels a path along the cable that has the function of a mass transport system to move astronauts and payloads, between Mars and space, without the need to use rocket propulsion. However, for the base tower of the elevator to remain stable on the planet is attached to it, a counterweight mass attached to the geostationary orbit. (PRICE, 2000).

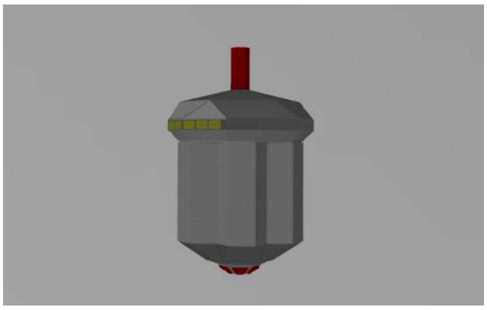

Figure 16. Electromagnetic vehicle

5.7.1 FOM of Space elevator – SPEL

The defined properties used by SPEL in the final study and their FOM definition are listed below and in Figure 17:

- Power_supply: Indicates the energy available to use SPEL;
- Power_Consumption: Indicates the energy consumed for SPEL operation;
- Battery_Level: Indicates the battery level of the SPEL;
- LauncherStatus: Indicates the position of the electromagnetic vehicle in relation to the base tower;

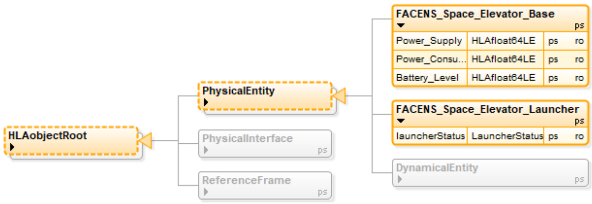

Figure 17. Representation of SPEL to federate.

6. RESULTS AND VALIDATIONS

After all the FACENS federates idealized and developed in the modeling softwares and the definitions of the boundaries in FOM, as seen previously in Figure 2, Figure 4, Figure 7, Figure 9, Figure 11, Figure 14 and Figure 17, it was possible to integrate the codes in the DON and test the interactions between all the federates based on the survival needs of astronauts and obtaining resources developed by the FACENS team were running simultaneously. They are Mars Habitat (HOME), Astronaut (MANS), Space Elevator (SPEL), Water Finder (WAFI), Mars Miner (MAMI), Excavation Mine (MINE) and Oxygen Factory (O2FAC).

The interactions between the federates worked as planned, the astronaut moved inside the habitat and it was possible to see increase and decrease in his vital signs, such as pulse oximetry, heart rate, body temperature, blood pressure, amount of oxygen, carbon dioxide and calories, the Mars Miner moved around the mine collecting ores and the Water Finder moved around the Mars soil collecting the subsoil water samples where and the data from the astronaut and the two rovers were read and managed by HOME as expected.

During the development of the project, the FACENS team were divided between modeling and programming, with weekly internal integrations, and worldwide once a week with a specific schedule to check on the progress of each one, and with these meetings, it was possible to establish an exchange of knowledge.

The tests of the federates in the simulation software were carried out several times, in order to correct errors related to bugs, texture, position and interaction between the federates.

This way the federates were ready to be presented at the event that was held at Florida Institute of Technology (FIT) in USA, on April 7, 2019, closing the SEE 2019 project.

7 CONCLUSIONS

With the developed project, it was possible to create a simulation of a colonization on Mars, considering the continuation of the project developed in the SEE 2018, updating the past federations and presenting new federates, simulating the production and consumption of basic resources for the survival of the astronauts in an inhospitable environment like Mars. Beholding a more complex architecture, the team focused on Mars colonization with the creation of HOME, which provides a shelter during the manned mission on Mars, as well as raising raw material (calcium perchlorate) and necessary resources through the rovers, MAMI and WAFI, for the production of oxygen and water in the O2FAC that collaborates to maintain the astronaut's housing during their mission on Mars, the MANS that is the astronaut that inhabits HOME and transport cargo using SPEL. However, this simulation did not consider parameters such as meteor problems, to which they would be added in future research and studies on these topics. NASA's Modeling and Simulation project in partnership with FACENS was a great opportunity for team members to expand their horizons, interact with each other and with other teams, exchange ideas, and develop skills and gain experience.

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PROPOSED FRAMEWORK DEVELOPMENT FOR E-GOVERNMENT IMPLEMENTATION IN NEPAL

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ABSTRACT

E-Government is an essential system to disseminate the citizen centric information and knowledge sharing of Government. E-Government is in a growing stage in all developing countries. For the development and Implementation of the e-Government System, the Framework is essential for e-Government system implementation in all countries. Before the development of e-Government, we should have design and develop a reliable and usable framework to reduce the gap of design and reality. So, this paper has been suggested E-Government Citizen Centric Frameowrk for Government Citizen Centric Services (GCCS) which is a reliable and a better framework for the Government of Nepal and other developing countries to implement effective and efficient e-Government. In the context of Nepal, the e-Government Implementation System is in pre-matured stage. This research paper has produced a flexible implementation system framework suggest to measure the solid (tangible) and intangible benefits of e-Government to gain the matured stage. So, this research proposed a very reliable Citizen Centric Service Oriented Architecture (CCSOA) for the e-Government Implementation, which is a Framework. In the context of Nepal, e-Government Implementation is very far stage for the development and public information transformation. So, this paper has suggested a reliable framework of e-Government Implementation in countries (developing and least developing countries).

Keywords: e-Government, Framework, CCSOA, Verification, Challenges, System

1 INTRODUCTION

E-Government pass on to delivery of required national, regional, district and local information and Government's services through internet, intranet with the help of web services. Nepal is in primitive stages to develop and implement e-Government for information dissemination to the citizens, businesses and other stakeholders. So, e-Government facilitates provision of relevant all kinds of information in e-Form (Digital Form) to the stakeholders that are Citizens and Businesses in a regularly and timely manner or approaches as well as empowerment of all citizens [1]. According to Beijing E-Government Vision and Framework, the overall technical framework of Beijing E-Government is displayed E-Government access channels, E-Government portals, Applications of E-government, unified application support platform for services. This service mainly targeted at enterprises, the public, government and civil servant etc. [2]. The India framework is far different from other countries. It is more complex with multi-tier constitution of departments or Government agencies at central, state and local level. The proposed framework is a Government Enterprise Architecture Framework (GEAF) for India; intend to deliver integrated e-Government services to its stakeholders. The framework aims the seamless exchange of data and information between Government agencies in different geographical locations across India by means of the e-Government Interoperability. There consists five main entities of the framework are Stakeholders, National Portal, Service Providers, Architectural Domains and Service Delivery Gateways. The framework for e-Government Interoperability leads to a Service Oriented Government Enterprise Architecture (SOGEA) in Indian Perspective. This SOGEA uses two layers that are Business Service Layers, Service Integration Layer [3]. The framework for Palestinian e-Government Central Database have used only four layers that are Presentation Layer, Integration Layer [including Orchestration, Registry and Metrics and messaging], Service Layer [including Information Services, Replication Services and Security Services] and Database Layer [including Data Access Services, List of Procedures, Diverse Database Types, Integrated Central Database and Ministries Database , Accesses Database through predefined procedures previously defined database operator]. The Central Database model in the Palestinian e-Government technical framework lacks are Interoperability, Flexibility, and Manageability[4]. The service oriented e-Government architecture provides the efficient and transparent governance to citizens. So, the mapping service oriented architecture in e-Governance plays an effective role for the development and design the e-Government Framework using different layers to desiminating the government informations to citizens [5].

2 FRAMEWORK

The development technology trend in e-Government implementation is a part and the rights of citizens to transform government services using ICTs in the context of Nepal. The materialization of information, communication and technology (ICT) that has been provided government services for high speed, efficient and better communication of public information's means the processing of data, exchange and utilization of all kinds of information that are based on citizen centric. So, electronic government has established as a very fast and effective technology and also a mechanism for growing government productivity and efficiency, which mechanism used to provide services to the citizens (citizen centric services). This research attempts to identify and explores the major or key challenge which is influencing for the implementation and development in Nepal, factors make a failure country in e-Government system in Nepal.

So, the purpose of this research is to develop strategies and frameworks for the development and implementation of e-Government services in Nepal and other developing countries which are facing such kinds of problems.

They can have used this research as a guide/a manual.

This research's solution or output helps to reduce the gap between reality and design. For adopting of e-Government system the research has proposed the solutions (Framework) that are the better, effective and efficient solutions.

So, the results of this research are validated. Verification findings of this research study provide the frameworks for the development and implementation of the e-Government system.

The following are the validate outcomes which came from verified findings. The proposed e-Government Implementation System Framework is the validated outcome these are e-Government Strategy, e-Government Relationship, E-Government Delivery Framework, E-Government Domains, E-Government Connectivity, E-Government Interoperability Frameworks (e-GIF) and e-Government Implementation System Framework.

The frameworks become from verified challenges which would be the best and necessary outcome of the implementation of e-Government. The combination of following components provides a strong and effective e-Government Implementation framework which framework shown in figure 3. That are:

Proposed e-Government Strategy, Proposed e-Government Relationship, E-Government Delivery Framework, E-Government Domains, E-Government Connectivity, E-Government Interoperability Frameworks (e-GIF): Policies, business drivers and technology, e-Government IneroperabilityFramework (eGIF), e-Government Application Model.

This research develops the efficient and strong a conceptual framework in the context of Nepal the conceptual framework has framed on the basis technological aspect, which gives a strong and permanent system framework for the establishment and implementation of e-Government system in Nepal. Therefore, this research has identified factors which determine if the citizens will adopt e-Government services, it means adding Governments in accessing that is required for adoption. This research highlights "No System Designed (83.33% weight has scored". So, in the context of Nepal No system design makes by the use of software engineering process for the development of the e-government system.

This e-Government Implementation System Framework provides a better solution to develop e-government implementation system and to increase public participation use of e-Government.

3 e-GOVERNMENTS DELIVERY FRAMEWORK FOR INFORMATION PROCESSING AND ACCESSING SYSTEM

e-Government delivery framework for information processing and accessing is a system which has considered into e-Government Implementation System Framework. This framework considers two layers that are Access Layer and Application Layer which has been used for corporate collaborate and integrate information across different ministries, departments in the center, regional, districts, and villages. So, it is an information gateway of e-Government service delivery.

This framework provides system flexibility, accessibility and security shown in figure 1.

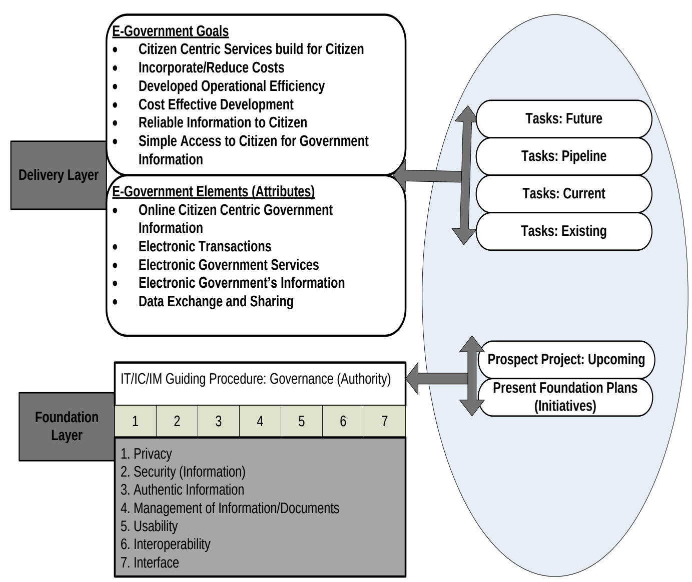


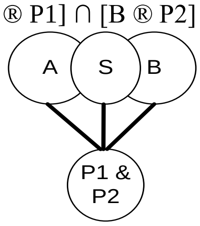
Figure 1 e-Government Delivery Framework for Information Processing and Accessing System (Government)

In the context of Nepal, the Government can be considered this framework for e-Government Implementation System framework; e-Government Master Plan (eGMP) has not considered this framework component to deliver services to citizens. This framework has two layers that are:

1. Foundation Layer (denoted by a capital A) - Consists two entities – e-Government Goal and e-Government attributes associated with the Project (future, pipeline, current and existing) – denoted by Capital P1.
2. Delivery Layer – (denoted by a capital B) - Contains an entity that is e-Government attributes associated with a prospect project and present foundation plans – denoted by capital P2.

The mathematical relationship of two layers with their sets:

[A ® P1] ∩ [B ® P2] € S



P1 is the specific set of A and P2 is another set of B, such as P1 and P2 are then connected with S. So, it is called multilevel framework. Both A and B are associated with each other to process the information and accessing system that is S. This relationship considered into e-Government Implementation System framework of Access Layer and Application Layer.

4 e-GOVERNMENT SYSTEM ARCHITECTURAL STRUCTURE (eGSAS)

This research paper provides or recommends the following structure of the e-Government System.

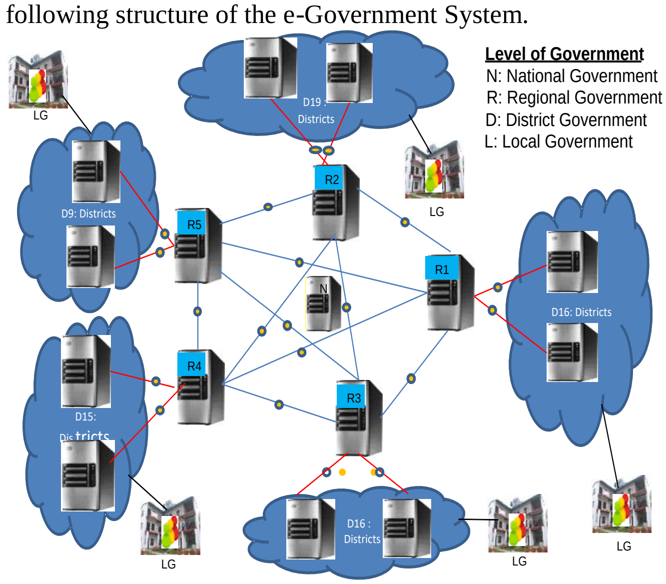


Figure 2 Proposed Architectural Structures of the e-Government System

The eGSAS helps the Government to implement an e-Government system that holds to e-Government rules and strategy; ensured that e-Government environment which can have good and effective e-Government implementation framework design.

The implementation of the e-government system has structures to transfer information and data which show the different levels for the implementation of system for government services. The following figure 2 depicts the architectural structures which have used for the implementation of this structure using e-Government Implementation System Framework.

Nepal has 5 regions and 75 districts and many villages and cities are situated in this country. By the statistical non-parametric method the research proves the illustrated architectural structure of the e-government system that is the connectivity of five layers of contains elements which is:

N, R, D, L => S (System)

Here, N = National Level Government;
R = Regional Level Government;
D = District Level Government;
L = Local Level Government

The structure of connectivity of the architectural structures, layers elements or entities.

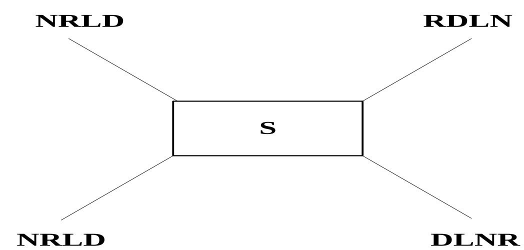


Table 1 National, Regional, Districts and Local Government

National Government	Regional Government	District Government	Local Government
N2N,	R2R,	D2D,	L2L,
N2R,	R2D,	D2L,	L2N,
N2D,	R2L,	D2N,	L2R,
N2L	R2N	D2R	L2D

The group elements of connectivity:
NNNN NRDL RRRR RDLN DDDD DLNR LLLL LNRD

The sequence of connecting elements is:
N, N, N, N, N, R, D, L, R, R, R, R, R, D, L, N, D, D, D, D, D, L, N, R, L, L, L, L, L, N, R, D

The connectivity of elements would use the following symbols, they're contained four occurrence elements layers.

$\mu1=N, \quad \mu2=R, \quad \mu3=D, \quad \mu4=L$

Therefore, $\mu1=8, \quad \mu2=8, \quad \mu3=8, \quad \mu4=8$

In this case the values of µ1, µ2, µ3, and µ4 must be operates 8 times, accessibility for efficient and effective e-Government implementation nationwide. The research shows the five layers elements of the given architecture. The architecture of an e-government system has equal participation and the same range of connectivity and accessibility. So,

$$\text{System (S)} = \{\mu1 \leftrightarrow \mu2 \leftrightarrow \mu3 \leftrightarrow \mu4\}\ldots \quad (1)$$

This equation (1) allows to access and transformation of information by citizens because all elements of layers are connected to each other. It can prove that:

{N belongs to RDL}, {R belongs to NDL}, {D belongs to NRL},{L belongs to NRD} U System
= N{R,D,L},R{N,D,L},D{N,R,L},L{N,R,D}
= {N} + {R} + {D} + {L}…………… (2)

Therefore, S= {NRDL} All layers of elements have the same relationship which allows for transformed information from N entity (element) to L entity (element) which has existed in mentioned layers.

5 RECOMMENDATION OF E-GOVERNMENT IMPLEMENTATION SYSTEM FRAMEWORK

For the development of e-Government System must have a framework for implementation of e-Government framework provides a uniform or homogeneous set of software apparatus for the new development and running e-Government applications. All the developed and some developing countries are applying the e-Government system framework for effective operations of application for dissemination of government services and required information to citizens using different framework layers. This framework provides general elements and set of the usual templates which are naturally required to implement or developed a system, reduced replica (duplicated) work. Basically, the system framework has expected to help or support member areas or locations for saving time and cost in developing the new e-Government applications.

So, the e-Government development is frequently defined in different context and from various perspectives. This has been controlled processes which should have implemented right-through the entire structure of public administration. E-Government framework is a process which builds or generate methodological, technological, organizational and personnel conditions for the efficient and effective application/purpose of ICTs in public and government administration, and a controlled process of ICT application. In the context of Nepal no have such kind of e-Government framework build for the development of the e-Government System. The e-Government System Framework should have developed or construct on the basis of country's geographical infrastructures. So, this research proposed the constructed e-Government System in the context of Nepal.

So, based on the collected data analysis and verification the research presents a modern citizen centric information based e-Government framework for effective and efficient implementation of government e-Services. Therefore, this research suggests the following types of e-Government System framework which has permeated systematic approach in taking all plans, idea and scheme in the modern cloud based e-Government implementation. The e-Government framework consists of five elements layers which has shown in the figure 3 below. In this figure 3 upper section layer which is access layer consists of user of e-Government Services, Receiving and Sending Channels that is data and information communication devices. Second section of layers which is e-Government Layer consists of Portal for information that is Government Integrated sign on portal. Third layer section is the application layer consists of processing application with an interface. In the fourth section of the layer is Information and Data System layer consists of Government Data sources through different organizations. Such as in fifth section or lower layer which is Infrastructure layer consists of information dissemination network infrastructure that is a foundation which has used to process and transformation of information in the access layer of user of e-Government Services sending and receiving sections.

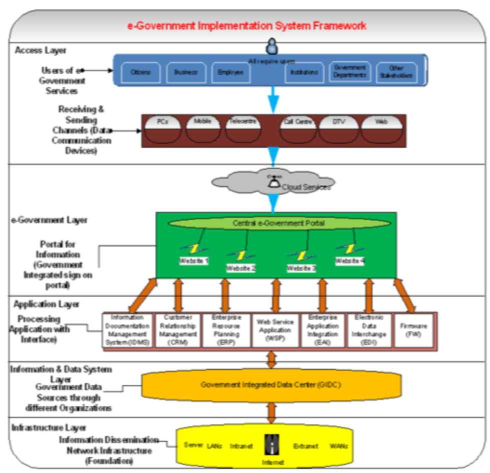


Figure 3 e-Governments Implementation System Framework

There consist of following five layers in e-Government

1. **Framework Layer:** Access Layer
Variable: Citizens, Businesses, Employee, Institution, Government, Departments, Others Stakeholders
Medium: PCs, Mobile, Telecenter, Call Center, Digital Television (DTV), Web

2. **Framework Layer:** e-Government Layer
Variable: Central e-Government Portal, Number of Websites
Medium: All Citizens and Stakeholders

Framework Layer: Application Layer
Variables: Information Document Management System (IDMS), Customer Relationship Management (CRM), Enterprise Resource Planning (ERP), Web Service Application (WSA), Enterprise Application Integration (EAI), Electronic Data Interchange (EDI), Firmware (FW)
Medium: Data System – Database and Datawarehouse

3. **Framework Layer:** Information and Data System Layer
Variables: Government Integrated Data Center (GIDC)
Medium: Government Data Sources through different organizations

4. **Framework Layer:** Infrastructure Layer
Variables: Server, LANs, Intranet, Internet, Extranet and MANs
Medium: Networks

On the basis of the e-Government System, IT is enabling administrative process between Citizen and Government (G2C), among Government Institutions (G2G), Government and Business (G2B) which presenting the given figure 4.

1. **Access Layer:** Includes two variables that are Government Users (Recipient of Government Services) and Data communication Devices (Channel/ Medium). Government users can access the various types of services using data communication channel or devices. Government service users are citizens, businesses, employee, institutions, Government Departments and other stakeholders. Service medium or channel that has been using services access point are PCs, Mobile, Tele-center, Call Center, DTV, Web. Access Channels are critical components of e-Government.
2. **E-Government Layer:** Portal for information dissemination. Includes number of websites known as a web portal. So, this layer uses for integrating digital data of various organizations into a web portal. This has been used to provide the highest quality of services, better access to Government resources, So, it enables to provide all kinds of better services to users.
3. **Application Layer:** Processing Application with Interface. Consist various Information Technology and processing component applications which have used data processing and data integration. The main functions of being layer are knowledge sharing and information processing using ICT applications and tools. This layer makes a strong base to construct e-Government Portal which is mentioned in e-Government layers. It provides real time communication between systems at both data and process level. Information Document Management System (IDMS), Customer Relationship Management (CRM), Enterprise Resource Planning (ERP), Web Service Application (WSA), Enterprise Application Integration (EAI), Electronic Data Interchange (EDI), Firmware (FW) is included.
4. **Information and Data System Layer:** It is a Government Data Source has managed through different organizations. The main variable is Government Integrated Data Center (GIDC) which should have established with different organization's data and information domain sources. All citizen centric information stored into this integrated data center. By the functions of this center users can access the citizen centric government services (information).
5. **Infrastructure Layer:** Information dissemination network infrastructures that are foundation of e-Government Implementation System, which have shown in figure 3. Building an information of nation requires information communication technology infrastructure which can flow and communicate all needed information to citizens and other stakeholders. So, this layer mainly focuses on technologies that should have to build before e-Government services offered. Server, LANs, Intranet, Internet, Extranet and WANs are the variables of this framework's Infrastructure (Foundation) layer. The information dissemination medium is Network.

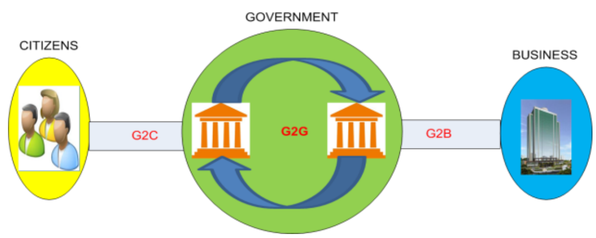


Figure 4 e-Government IT enables administrative process

This figure 4 shows the transactions between citizen, government and business for communication of information that are G2C , G2G and G2B. This system framework covered the following types of government services that are G2G, G2E, G2I, G2B, and G2C. The use of figure 3 e-Government Implementation System Framework provides the structure for the implementation of citizen centric informatics e-Government shown in figure 2.

6. CLOUD COMPUTING

Cloud Computing has been developing today as a commercial infrastructure that eliminates the need for maintaining expensive computing hardware. Through the use of virtualization, clouds promise to address with the same shared set of physical resources a large user base with different requirements. Thus, clouds promise to be for scientists an alternative to clusters, grids, and supercomputers (Simon et al., 2010).

Cloud Computing is emerging rapidly, with its data centres growing at an unprecedented rate. However, this has come with issues over privacy, efficiency at the expense of resilience, and environmental sustainability, because of the dependence on Cloud vendors such as Google, Amazon and Microsoft. Community Cloud Computing (C3) provides an alternative architecture, created by combing the Cloud with paradigms from Grid Computing, principles from Digital Ecosystems, and sustainability from Green Computing, while remaining true to the original vision of the Internet. It is more challenging than Cloud Computing, having to deal with distributed computing issues, including heterogeneous nodes, varying quality of service, and further security limitations. However, these are not undefeatable challenges, and with the need to retain control over digital lives and the potential environmental consequences (Marinos and Briscoe, 2012).

Cloud Computing is the implication of Internet-based technologies for the demand of services originating from the cloud as a metaphor for the web, based on depictions in computer network diagrams to abstract the complex infrastructure (Haynie, 2009). It can also be observed as a commercial evolution of the Grid Computing, succeeding where Utility Computing struggled, while making greater use of the self-management advances of Autonomic Computing. It facilitates the illusion of infinite computing resources available on demand, with the elimination of upfront commitment from users, and payment for the use of computing resources on a short term basis as per the requirement (Armbrust et al., 2012). Three categories of cloud computing services were identified: Infrastructure-as-aService (IaaS), which is raw infrastructure and associated middleware, Platformas-a-Service (PaaS) , that is, APls for developing applications on an abstract platform, and Software-as-a-Service (SaaS), which is support for running software services distantly. The scientific community has not yet started to adopt PaaS or SaaS solutions, primarily to avoid porting legacy applications and for lack of the needed scientific computing services, respectively. Unlike traditional data centers, which lease physical resources, most clouds lease virtualized resources which are mapped and run transparently to the user by the cloud's virtualization middleware on the cloud's physical resources. For example, Amazon EC2 runs instances on its physical infrastructure using the open-source virtualization middleware (Barham et al., 2003).

7 CONCLUSION

In this research paper, propose an effective (successful) e-Government Implementation System Framework. The research paper provides detail layers which include in the proposed framework. In the framework includes five layers that are Access Layer, e-Government Layer, Application Layer, Information and Data System Layer and Infrastructure Layer and their functions. Nepal Government can be used this framework to establish the effective and efficient e-Government System to provide the citizen centric services for the peoples and businesses. Because, Nepal has very complex administrative structure, consists four government components that are National (Central), Regions, Districts and Local Level Governments. Nepal Government and other Developing countries can be applied e-Government Implementation System Framework for the implementation of e-Government for the providing of Government services. So, the e-Government System Framework is the most important challenges for development and implementing the e-Government to disseminate the citizen-centric services. Without appropriate designed of e-Government System Framework, it is not possible to implement the citizen centric e-government system in Nepal and other developing countries. At First it is necessary to have a strong and appropriate designed e-Government System Framework with efficient ICT infrastructure to implement e-government. The research basically recommended the model and framework which are the validated outcome. According to model and supported frameworks develop an e-Government Implementation System framework. The proposed framework strongly recommended Implementation system.The future work will be the establishment of e-Government based on e-Government Services incorporation in the e-Government System.

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SIMULATION MODELING: OBJECT APPROACH VS RELATIONAL APPROACH

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ABSTRACT
This article describes a new relational approach, compared to the more traditional object approach, for using simulation to model and analyze manufacturing (assembly) systems. The proposed approach uses relational schemes that are based on "lean thinking" and PFEP (Plan for Every Part) as the main integrator. In addition to definitions of relations and tables, the paper introduces mechanisms for automating the construction of simulation models and providing means for analysis.

Keywords: Simulation modeling, assembly system, relational approach

1. INTRODUCTION

The use of simulation tools and data processing to collect and analyze data from assembly lines is of great value to employees who want to better understand industrial conditions and processes. Simulation is one of the key industry 4.0 principles (Schwab 2017). The author's experiences over the past several years in simulation projects involving assembly operations have led to this change in approach for modeling assembly systems. The traditional approach is based on building simulation models from a library of objects; an approach used by many commercial simulation programs, such as: FlexSim, Simio, Arena, ProModel, and Anylogic. The author believes that while the traditional approach is good for simple productions systems, the proposed approach speeds up modeling and significantly shortens analysis time for more complex systems,.
The main purposes of this article are to:

- Compare the object and relational approaches for simulation modeling,
- Identify the strengths of the relational approach,
- Describe a means for implementing the proposed relational approach that both automates the construction of simulation models and provides means for analysis.

This article is organized as follows. Section 2 describes the traditional approach for simulation modeling, Section 3 defines the research problem, describes the relational scheme for modeling assembly operations, and describes the means for generating parts of the models automatically. The proposed solution is described in Section 4. The means for implementing the proposed solution is described in Section 5

2. LITERATURE BACKGROUND

The literature shows that the traditional, classical approach to discrete-event simulation is an object-oriented approach (Mierlo and Vangheluwe 2018); i.e., one where simulation models are built from a set of objects. Many authors indicate that the systems that are being analyzed, designed, and built are becoming much more complex. This complexity stems from a variety of sources, such as the complex interplay of physical components (sensors and actuators) with software, large amounts of data that these systems need to process, etc. Almost always, these complex operations systems exhibit event-processing behavior: the system reacts to stimuli coming from the environment (in the form of input events) by changing its internal state that can then influence the environment through output events. Such event-processing systems are fundamentally different from more traditional software systems, which are transformational (i.e., they receive a number of input parameters, perform computations, and return the result as output). Reactive systems run continuously, often have multiple concurrently executing components, and are reactive with respect to the environment (White and Ingalls 2018).
Such complex processing of events must be specified in the appropriate language to verify the behavior with respect to its specifications (using verification and validation techniques, such as formal verification, model checking, and testing techniques), and eventually implement the software on the hardware components of the system. Traditional programming languages have been designed for transformational systems and are not well adapted to describing synchronous, autonomous, reactive and concurrent behaviors.
In fact, describing complex systems using threads and semaphores quickly results in unreadable,

incomprehensible, and unverifiable program code (Lee 2006).

This is partly due to the cognitive gap between the abstractions offered by languages and the complexity of the specifications, and sometimes badly defined semantics of programming languages, which makes it difficult to understand. As an alternative, the State-chart formalism, was introduced by (Harel 1987). Many simulation programs use state charts as a main tool for simulation modeling (Anylogic, Simio). Another modeling tool is Process Flow, offered by FlexSim (FlexSim Software Products Inc.), which combines programming language with graphics - it replaces nearly all computer code with a flowchart. These tools focus on the details of the modelled system and require the user (production engineer, logistics) possess programming skills and be familiar with a large number (hundreds) of functions. Based on the author’s experiences, these users do not want to deal with the details of the simulation programs (primarily programing); they want to solve problems in terms of their language and operational concepts.

3. RESEARCH PROBLEM

Traditionally, a process perspective is used to model production flows by creating models using a “top-down” approach that drives model development from the general to the specific. In this process-driven approach, the flows of parts between processes create demands on resources; i.e., a part moves to a workstation and demands resources to complete an operation. While this methodology is fine for many applications, it does not allow resources to complete tasks that are not flow related. For this, a task-driven approach is needed. For example, an operator (mobile resource) performs a set of inspections on idle equipment when not engaged in process work. The task-based approach enables an operator (task executor) to create tasks or activities that are independent of the processing activities. Such tasks may require travel and the acquisition of other tools or resources. As such, the task-driven approach incorporates “intelligence” into resources by enabling them to decide what jobs to do and when.

In the literature it is often, recommended that simulation projects start by building a map of the value stream (Rother and Shook 2003). In such cases a process approach is used to define part flows through a production system. (Beaverstock, Greenwood and Nordgren 2017). This approach is commonly described in the simulation modeling literature and is used by simulation software proudcts, such as: Simio, Anylogic, Arena, ProModel, Tecnomatix, and FlexSim. This approach works in a “top-down” manner; i.e., modeling at a high level of abstraction and moving downward into more detail as needed. This follows a classical approach. (Hall 1962).

When building simulation models, we use elements, often called objects, that reflect or approximate the behavior of the real system. They are abstract objects (e.g. graphic icons) or objects to which certain behaviors are assigned. Graphic icons are elements of graphical modeling languages, e.g. VSM (Value Stream Mapping) (Rother and Shook 2003), IDEF0 (Santarek 1998) or OFD (Object Flow Diagram) (Greenwood, Pawlewski and Bocewicz 2013). Objects are assigned certain behaviors, such as: source, buffer, processor ,and operator. These objects can be used to model at different levels of abstraction depending on the problem being considered (Beaverstock, Greenwood and Nordgren 2017).

Generally, building models from objects involve placing the objects selected from a library on to a work area and defining the relations (connections) between these objects based on item flow. Building a simulation model of an entire factory in this manner is laborious and time consuming.

Our goal is to change this situation by describing assembling operations using relational schemes and generating many parts of the model automatically.

4. SOLUTION OF PROBLEM

The proposed way of thinking about factory simulation modeling is based on “lean thinking,” as described in (Rother and Harris 2001), (Rother and Shook 2003), (Harris, Harris and Wilson 2003), (Smalley 2003), (Glenday 2005).

A main component of the approach is a database called PFEP (Plan For Every Part). It is a part of a database that contains information about all parts, components, supplies, WIP (Work In Progress) inventories, raw materials, finished goods, and any other material used in manufacturing processes. The definitions and requirements of a PFEP vary depending on specific needs and the industry; but in general, PFEP fosters the accurate and controlled management of commercial information. PFEP is an essential lean tool and, when combined with quality, delivery, true cost sourcing, value stream mapping, and supplier development initiatives, it can transform average supply chain operations into world-class, just-in-time lean enterprises. PFEP enables organizations to more effectively plan completion dates, true costs of parts, and production launch risks. Then, after a product is launched, PFEP is used to proactively maintain high-functioning supply chain operations by managing and optimizing inventory costs, inbound logistics costs, and part supply change costs. See Figure 1 for a simple example. Details for using PFEP for simulation modeling of production systems are explained by (Pawlewski 2018).

	Part	Part Name	ID	Length	Width	Height	Capacity
Row 1	C001	Packed three	KLT4147	0.20	0.80	0.30	20
Row 2	C002	Packed left m	Euro	0.40	0.70	0.50	5
Row 3	C003	Packed right	Pallet134	0.20	0.60	0.05	60
Row 4	Z004	Packed middl	KLT6280	0.60	0.70	0.20	10

Figure 1: The view of PFEP.

PFEP is connected to two other databases: Locations and Containers.

The Location database is a table that contains information about all of the locations of containers in a factory. A location is an area (a rectangle) with length and width dimensions, angles of rotation relative to the X, Y and Z axes, and is at a specified height. Locations have no thickness. Parts and assemblies are delivered to a station and are placed in a location. Products are received from a station and are also collected in containers. All resources that carry out transport processes are treated as a "container". For example, a transport trolley is a logical container for transporting a finished product or a large-size part. An example of a Location database is showed in Figure 2.

	X	Y	Z	RX	RY	RZ	Length	Width	MRStop	Assign	Type of conta	Part	Fill	Empty	Position	Shared	Auto
Row 1	1.52	3.36	1	0	15	0	0.40	0.60	MRStop_05	0	0	C005	1	0	1	0	1
Row 2	1.37	2.64	1.40	0	15	0	0.63	0.60	MRStop_05	0	0	C006	1	0	1	0	1
Row 3	1.51	-2	1	0	15	0	0.40	0.48	MRStop_05	0	0	C020	1	0	1	0	1
Row 4	1.30	1.34	1	0	15	0	0.63	0.60	MRStop_05	0	0	C008	1	0	1	0	1
Row 5	0.29	0	0	0	0	0	1.66	0.94	MRStop_05	0	0	W001	0	1	1	0	3

Figure 2: The view of Location database

This database contains parameters that define how to fill locations and containers at the start of a simulation
Part – name of Part – indicates the row in PFEP.
Fill – number of filled containers.
Empty – number of empty containers.
Type of Cont. – indicator to fill the container automatically when the last part is taken from container
Auto – indicator - how to fill in the location

- 0 No automatism related to filling the location of containers Locations at the stand - location replenishment is the result of intralogistics activities - then the Fill and Empty attributes have any values -Type of container setting has
- 1 Automatic refilling of a container when a full container is collected Locations in the Supermarket then attributes Fill = 1, Empty = 0
- 2 Automatic removal of the container when the container is located in the location. This means locations in the finished goods warehouse - then attributes Fill = 0, Empty = 0
- 3 Automatic filling of the empty container when the container is picked up.

These parameters control the creation of containers with parts at their specified location at the start of a simulation experiment. This means that the user only needs to define where, when, and how containers have to be generated.
The Containers database is a table where information about the containers that are used in factory are stored, including: ID, size, weight, shape (for 3D visualization), etc.
All operations are performed by Operators. This is a class that consists of the following types:

- Humans,
- Robots,
- Forklifts
- AGV's

The parameters for these types are defined in separate tables where rows describe subtypes..
Operators are objects that can perform operations. For example, a forklift with a driver can be considered an Operator, but without a driver it cannot. Operators perform operations that are stored in tables assigned to each Operator. A special language was developed to describe the behaviors of Operators. This script language consists of 64 operations that are grouped into the in following categories: travel, loading/unloading, operations, controlling. A full list of instructions can be found in (Pawlewski 2018).
The structure of a factory is described in two tables:
- Groups that define production lines and/or cells and are connected to the PFEP database
- Workstations that define elements of groups (locations, Operators, Working tables, Assembly stations, Disassembly stations)

The overall system of databases is presented in Figure 3

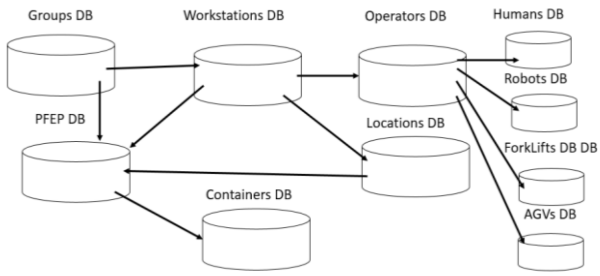

Figure 3: The view of Simulation Database System

5. IMPLEMENTATION

The database system shown in Figure 3 is implemented within the LogABS simulation application that is developed using the FlexSim simulation software environment. (Pawlewski 2018b) FlexSim is treated as a SOS (Simulation Operating System). The FlexSim software was chosen because it is core 3D (working directly in a 3D environment) and it is an open system, i.e., system logic can easily be defined. (Beaverstock, Greenwood and Nordgren 2017).
An example is provided for building a simulation model of an assembly station in LogABS. The system is shown in Figure 4, where the objects are: A - a rack with four shelves for containers with parts, B – an Operator (human), C – a work table, and D – a handcart for transport. The operator assembles a finished product from two parts, which are collected from containers in the rack.

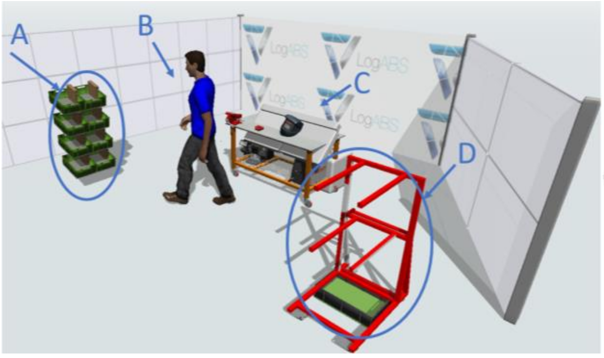

Figure 4: The view of assembly station

The assembly station simulation model is built by completing the following steps:
Step 1: Define the set of containers via the Containers database
Step 2: Define PFEP as a set of parts and finished goods with connection to the Containers database
Step 3: Define a Group of workstations (production line/cell) by defining the Line_ID, connecting to the appropriate PFEP, and defining the number of workstations in the Group. A workstation is created or updated with empty records using the Update Control Table button, as shown in Figure 5.

LogABS Groups

LogABS Groups

Open Control Table

Add Row | Copy Row | Delete Row | Update Control Table

	Line_ID	PFEP_Name	Nr_Of_Workstations	X	Y	Z	S
Row 1	L1	PFEP_Templ	1	0	0	0	

Figure 5: The view of Groups Database

Step 4: Define Workstations (every record or row in the table), as shown in Figure 6 by providing the name of the workstation, number of locations (for example from figure 4, five locations), number of Operators (in this case, 1), and number of Assembly Stations (in this case, 1).

Control Table

Update Workstations | LogABS Groups | Read Only

Add Row | Copy Row | Delete Row | Delete All

	WorkStation_	Line_ID	PFEP_Name	NrLocations	ToteGen	NrOperators	N
Wks_11	Wks_11	L1	PFEP_Templ	5	1	2	

Figure 6: The view of Workstation Database

The Update Workstations button in Figure 6 generates a simulation model of the work area, with default coordinates, as shown in Figure 7..The green rectangle is the floor of the workstation; its size and color can be modified.

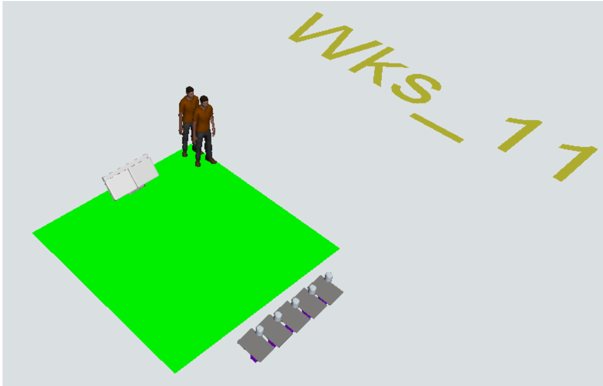

Figure 7: The view of generated simulation model

Step 5. Pick by mouse location or sign the right cell in Workstation Database to open window with Locations Database connected to this workstation – figure 8

	Length	Width	MRStop	Assign	Type of conta	Part	Fill	Empty	Position	S	Auto
Row 1	0.40	0.60	MRStop_01	0	1	C001	2	0	1	)	0
Row 2	0.40	0.60	MRStop_01	0	1	C001	2	0	1	)	0
Row 3	0.40	0.60	MRStop_01	0	1	C002	2	0	1	)	0
Row 4	0.40	0.60	MRStop_01	0	1	C002	2	0	1	)	0
Row 5	0.40	0.60	MRStop_01	0	1	Z004	0	1	1	)	0

Figure 8: The view of Locations Database

This involves defining the proper coordinates of locations, names of parts (connections to PFEP), method for generating filled or empty containers, number of containers.
Step 6. Pick by mouse Operator or sign the right cell on Workstation Database to open window with set of tables where the instructions for an operator can be defined. For example, the set of instructions for an operator who assembles a finished product from two parts, which are collected from containers on a rack is shown in Figure 9.

	ID	Where	Activity	Param
Row 1	1	Ass_01	SetAssembly	2
Row 2	2	N_02	Travel	0
Row 3	3	P_02	CheckPartInToteWait	2
Row 4	4	P_02	LoadFromTote	2
Row 5	5	G_01	TravelLoaded	0
Row 6	6	Ass_01	Unload	2
Row 7	7	Ass_01	Assembly	10
Row 8	8	Ass_01	Load	1
Row 9	9	N_05	TravelLoaded	0

Figure 9: The view of Operator's Instruction Database

Step 7. Run Simulation experiment.
Step 8. Analyze results.
An Operator's instructions are saved in a database that is created at the beginning of the simulation experiments. The database records save the names of the instructions, start time of the instruction, its completion time, and the value added attribute, as shown in Figure 10.

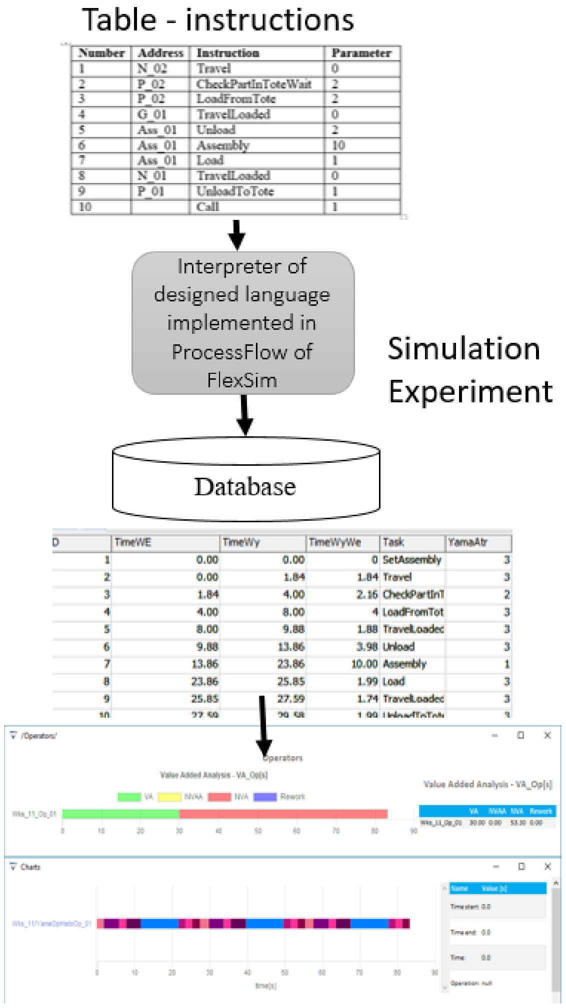

Figure 10: The scheme of mechanism to generate results: time diagrams and value added analysis

6. CONCLUSIONS

The paper presents an approach for building simulation models based on a relational database system The paper defines and describes the relations and tables needed to model assembly operations. The methodology for building simulation models using a relational approach is presented. A comparison of the traditional object approach and the proposed relational approach is provided in Table 1..

The proposed approach is implemented via the LogABS simulation application that is developed in the FlexSim simulation software environment. The approach and LogABS application have been presented to engineers and logisticians at assembly factories in a number of industries (primarily bus and automotive) through workshops. Based on the five workshops conducted so far, the reactions of the participants has been very good; therefore, commercialization activities for LogABS has begun.

Table 1. Comparison of object and relational approach for simulation modeling.

Criteria	Object Approach	Relational Approach
Level of detail	Low	Medium/high
Number of functions for describing behaviors	A large numer of functions (hundreds)	Small number of functions (several dozen)
User skills	Programming skills	Ability to set up operator's itinerary
Ability to automatically generate simulation models	No	Yes
Focus on:	States of objects	Operations
Compliance with lean manufacturing	Depends on modeler	High
Built-in value-added analysis	No	Yes

ACKNOWLEDGMENTS

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A CONTINUOUS SIMULATION MODEL OF THE DIFFUSION OF TOXIC GASES IN A TUNNEL

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ABSTRACT

In this work we study the diffusion of toxic gas in a tunnel due to an explosion in order to realize a system—via a wireless network of active sensors—for identification and immediate containment procedures.

Keywords: Continuous Simulation, CBRN, Toxic Gas, Tunnel Diffusion

1 INTRODUCTION

It is passed over 15 years from the September 11 attack in NYC, therefore, even today, terrorist attacks represent a major threat and there are multiple vulnerabilities. From this point of view one of the most dangerous menaces is represented by the CBRN Category addressing Chemical, Biological, Radiological and Nuclear threats. Indeed the diffusion of these substances, especially within an urban environment represent a major threat (Lemyre et al., 2005; Rogers et al., 2007; Leung et al.,2004). Considering these issues it is evident the importance to model the related scenarios to reduce vulnerability (Hignett et al., 2019); by the way this context does not related just to terrorist attacks, but it could deal also with accidents (Stefanescu et al., 2018).

2 RESTRICTED SPACES AS POTENTIAL CBRN TARGETS

Indeed the research team of the authors developed in past models to study this phenomena indoor in Industrial Plants as well as in tunnels and undergrounds (Cianci et al, 2014, Bruzzone et al. 2016, 2017).

In facts, due to the complexity of this environment, the use of simulation is considered to be fundamental and the authors proposes hereafter the use of continuous simulation to study a case related to diffusion of a generic toxic gas within a tunnel (Hogue et al. 2009). In fact, the potential terrorist attack into "*restricted space*" such as underground is considered a major issue also respect previous attacks (Anghel et al.2011).

Considering the proposed case of toxic gas diffusion into a tunnel by an initial explosion it is evident that to this end one or more aspiration pumps are expected to be turned on, suddenly, at some distances from the explosion to mitigate the effects of the terroristic act. The research is intended also as a tool for decision support and consider, in the first instance, some aspects and modeling of the events occurred in previous terrorist attacks (e.g.Tokyo subway in 1995 and London underground 2005), even if in some cases diffusion resulted quite different based on sarin contamination of railings surfaces (Karlsson et al., 1995; Jordan 2008).

We exactly find the diffusion concentration in order to provide a solution useful for comparison to other models: numerical ones or models with many aspiration pumps. The model is described by the diffusion partial differential equation (PDE) with a non-homogeneous term which models the aspiration pump. A model with more suction pumps is presented.

3 THE MODEL ONE-PUMP

The study of this section deals with a single suction pump turned on instantaneously at a distance of b meters from the explosion and find exactly the diffusion in order to provide an exact solution for comparison to other models with many pumps suction. The model is described by diffusion PDE with a non-homogeneous term which models the suction pump. The Fourier and Abel transforms are used by calculating the effect of the pump and by imposing the matching conditions. An exact analytical solution is found and a multi pumps model is outlined.

Consider firstly the 1-pump equation:

$$\frac{\partial^2}{\partial z^2} C(z,t) - \frac{\frac{\partial}{\partial t} C(z,t)}{D} = p\, C(b,t)\, \delta(z-b)$$

where C(z,t) is the concentration, D the diffusion coefficient. Z is the spatial coordinate and p a coefficient proportional to the power of the pump which is assumed present in z=b. Some further remarks on the partial differential equation. The term $p\, C(b,t)\, \delta(z-b)$ simulate the aspiration pump by using the generalized Dirac function. At the initial time we simulate an explosion in z=0 $C(z,0) = Q\,\delta(z)$. Compute now the Fourier transform:

$$C(z,t) = \int_{-\infty}^{\infty} e^{-2 I \pi z q}\, a(q,t)\, dq$$

and get

$$\frac{4 D \pi^2 a(q,t)\, q^2 + \frac{\partial}{\partial t} a(q,t)}{D} = -p\, C(b,t)\, e^{2 I \pi b q}$$

This equation can be solved and the solution is

$$a(q,t) = -p D \left(\int_0^t C(b,s)\, e^{4 s \pi^2 q^2 D}\, e^{2 I \pi b q}\, ds \right) e^{-4 \pi^2 q^2 D t} + N(q)\, e^{-4 \pi^2 q^2 D t}$$

Where N(q) is an arbitrarily function.

Now we return to the concentration function and get:

$$C(z,t) = -p D \left(\int_{-\infty}^{\infty} e^{-2 I \pi z q}\, e^{2 I \pi b q} \left(\int_0^t C(b,s)\, e^{4 s \pi^2 q^2 D}\, ds \right) e^{-4 \pi^2 q^2 D t}\, dq \right) + \int_{-\infty}^{\infty} e^{-2 I \pi z q}\, N(q)\, e^{-4 \pi^2 q^2 D t}\, dq$$

We impose now initial condition $\int_{-\infty}^{\infty} e^{-2 I \pi z q}\, N(q)\, dq = Q\,\delta(z)$

and obtain $N(q) = Q$. In such a way we get:

$$C(z,t) = -p D \left(\int_{-\infty}^{\infty} e^{-2 I \pi z q}\, e^{2 I \pi b q} \left(\int_0^t C(b,s)\, e^{4 s \pi^2 q^2 D}\, ds \right) e^{-4 \pi^2 q^2 D t}\, dq \right) + \frac{e^{-\frac{z^2}{4 D t}}\, Q}{2 \sqrt{\pi} \sqrt{D t}}$$

Now we compute the first integral and obtain:

$$C(z,t) = -\frac{p \sqrt{D} \left(\int_0^t \frac{e^{\frac{(-z+b)^2}{4 D (-t+s)}}\, C(b,s)}{\sqrt{\pi} \sqrt{t-s}}\, ds \right)}{2} + \frac{e^{-\frac{z^2}{4 D t}}\, Q}{2 \sqrt{D} \sqrt{\pi} \sqrt{t}}$$

We remark that in this integral the value of the concentration in z=b is required. We put so z=b and get:

$$C(b,t) = -\frac{p \sqrt{D} \left(\int_0^t \frac{C(b,s)}{\sqrt{t-s}}\, ds \right)}{2 \sqrt{\pi}} + \frac{e^{-\frac{b^2}{4 D t}}\, Q}{2 \sqrt{D} \sqrt{\pi} \sqrt{t}}$$

This integral equation is a second type Abel integral equation. The solution is

$$C(z,t) = -\frac{Q p\, \mathrm{erfc}\left(\frac{D p t + |-z+b| + b}{2 \sqrt{D t}} \right) e^{\frac{p\,(D p t + 2 |-z+b| + 2 b)}{4}}}{4} + \frac{Q e^{-\frac{|z|^2}{4 D t}}}{2 \sqrt{D \pi t}}$$

We remark that the term

$$C_0(z,t) = \frac{1}{2} \frac{e^{-\frac{1}{4} \frac{z^2}{D t}}\, Q}{\sqrt{D \pi t}}$$

denoted the free evolution while the erfc function is defined as:

$$\mathrm{erfc}(x) = 1 - \frac{2 \left(\int_0^x e^{-t^2}\, dt \right)}{\sqrt{\pi}}$$

In z=b, we have

$$C(b,t) = -\frac{1}{4} Q p\, \mathrm{erfc}\left(\frac{1}{2} \frac{D t p + b}{\sqrt{D t}} \right) e^{\frac{1}{4} p\,(D t p + 2 b)} + -$$

Some plots are presented.

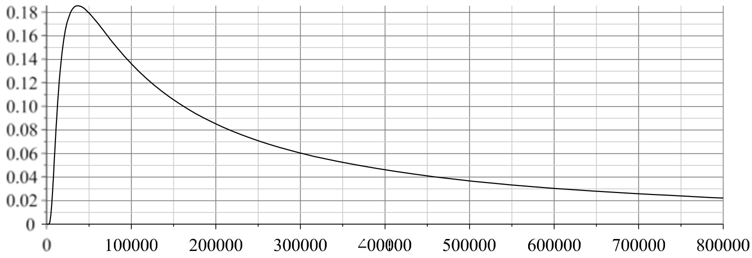

Figure 1, Plot Concentration

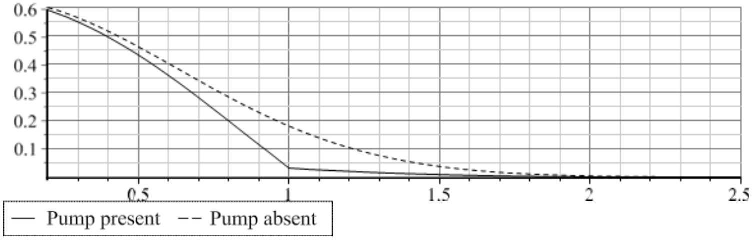

Figure 2, Plot Concentration

In this Figure 1, we plot concentration in a point z=2. At t=0 there is no gas, the the concentration increases and, finally, it tends to zero. The following values are assumed: D=1E-5, Q=1, p=1, b=1.

As next step, we present the plot in figure 2, where we plot C(z,t) , for t=1E-5s compared with free diffusion case. D=1E-5, Q=1, p=25, b=1.

4 AN OUTLINE OF THE MULTI PUMP MODEL

We consider here two pumps in z=b and in z=u, with u>b>0. The differential equation that we have to solve is

$$\frac{\partial^2}{\partial z^2} C(z,t) - \frac{\frac{\partial}{\partial t} C(z,t)}{\mathrm{D}} = p\, C(b,t)\, \delta(z-b)$$

By using the Fourier transform technique we get

$$\frac{4\,\mathrm{D}\,\pi^2 a(q,t)\, q^2 + \frac{\partial}{\partial t} a(q,t)}{\mathrm{D}} = -p\, \big(C($$

The solution is

$$a(q,t) = -p\,\mathrm{D}\left(\int_0^t \left(C(b,s)\, e^{2 I \pi b q} + e^{2 I \pi u q} C(u,s)\right) e^{4 s \pi^2 q^2 \mathrm{D}}\, ds\right) e^{-4\pi^2 q^2 \mathrm{D} t} + N(q)\, e^{-4\pi^2 q^2 \mathrm{D} t}$$

Again, by assuming initial data conditions and inverting the Fourier transform, we get:

$$C(z,t) = -\frac{p\sqrt{\mathrm{D}}\left(\int_0^t \frac{e^{\frac{(-z+b)^2}{4\mathrm{D}(-t+s)}} C(b,s)}{\sqrt{t-s}}\, ds\right)}{2\sqrt{\pi}} - \frac{p\sqrt{\mathrm{D}}\left(\int_0^t \frac{e^{\frac{(-z+u)^2}{4\mathrm{D}(-t+s)}} C(u,s)}{\sqrt{t-s}}\, ds\right)}{2\sqrt{\pi}} + \frac{e^{-\frac{z^2}{4\mathrm{D}t}}\, Q}{2\sqrt{\mathrm{D}}\sqrt{\pi}\sqrt{t}}$$

This equation gives rise to a non linear effect. The knowledge of C(b,t) and C(u,t) is necessary. If we put z=b and z=u, we get two integral eqautions

$$C(b,t) = -\frac{p\sqrt{\mathrm{D}}\left(\int_0^t \frac{C(b,s)}{\sqrt{t-s}}\, ds\right)}{2\sqrt{\pi}} - \frac{p\sqrt{\mathrm{D}}\left(\int_0^t \frac{e^{\frac{(-b+u)^2}{4\mathrm{D}(-t+s)}} C(u,s)}{\sqrt{t-s}}\, ds\right)}{2\sqrt{\pi}} + \frac{e^{-\frac{b^2}{4\mathrm{D}t}}\, Q}{2\sqrt{\mathrm{D}}\sqrt{\pi}\sqrt{t}}$$

and

$$C(u,t) = -\frac{p\sqrt{\mathrm{D}}\left(\int_0^t \frac{e^{\frac{(b-u)^2}{4\mathrm{D}(-t+s)}} C(b,s)}{\sqrt{t-s}}\, ds\right)}{2\sqrt{\pi}} - \frac{p\sqrt{\mathrm{D}}\left(\int_0^t \frac{C(u,s)}{\sqrt{t-s}}\, ds\right)}{2\sqrt{\pi}} + \frac{e^{-\frac{u^2}{4\mathrm{D}t}}\, Q}{2\sqrt{\mathrm{D}}\sqrt{\pi}\sqrt{t}}$$

5 CONCLUSIONS

This mathematical modeling approach is interesting to create effective models devoted to support design, engineering and decision making respect threats in underground transportations, however it is evident that this approach should be combined with effective modeling of the boundary conditions including the geometrical aspects and different compressors and fans disposition within the area as well as coupled with human behavior modeling to estimate the impact on people. In facts, we should also state that the final system of integral equations is very difficult to solve exactly, even by using different techniques. Therefore this additional development will be the focus for future works of the authors and different techniques of continuous simulation numerical modeling will be applied..

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STRATEGIC ENGINEERING MODELS DEVOTED TO COUPLE SIMULATION, DATA ANALYTICS & ARTIFICIAL INTELLIGENCE IN LIQUID BULK LOGISTICS

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ABSTRACT
This paper proposes a realistic case of maritime logistics related liquid bulk that appears pretty basically, therefore the introduction of stochastic phenomena makes it pretty challenging to deal with it. The authors propose a progressive modular approach to study the system and to develop a combined use of Simulation, Artificial Intelligence and Data Analytics to optimize management of this logistics system as example of applying the innovative concepts related to Strategic Engineering

Keywords: Simulation, Modeling, AI, Data Analytics, Strategic Engineering, Logistics, Liquid Bulk

1 INTRODUCTION
Logistics is a challenging environment for many reasons, but for sure the presence of many stochastic factors and the high number of interactions among the entities and external factors are among major causes for the related challenges (Al-Khayyal et al. 2007; Panayides et al.2009). This is a classic example of external complexity that usually requires to adopt modeling and simulation to properly address the problem. Taking into account the context of maritime logistics the problem still present and it could be declined in many different ways including Docking and Yard Optimization, Port Activities, Container Terminals, Oil Terminals, etc.(Bruzzone et al. 1998; Li et al. 2010, 2012; Caliskan et al. 2018). Indeed the authors have long experience in this field by combining use of Simulation and other methodologies including Artificial Intelligence to analyze these problems and support engineering and management within maritime logistics. In this paper, the authors are proposing a case related to maritime flows of liquid bulks declined into a basic way; therefore even the very simple scenario proposed in the following results pretty challenging due to the presence of stochastic elements such as production flow variability and ship sailing time uncertainty as well as due to the interference among ships due to limited docking capabilities into the ports. The authors use this basic case, therefore very realistic and corresponding to real problems proposed by major industries (Bruzzone et al., 2003), as example to apply the concept related to Strategic Engineering that combine Simulation, Data Analytics and AI (Artificial Intelligence) to find a solution that is robust and able to deal with the stochastic factors. Indeed, the authors present both simplified and advanced solutions

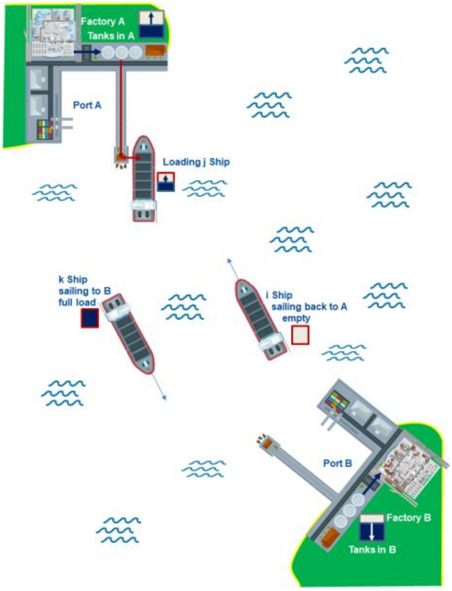

Figure 1: The Scenario to be optimized

2 LIQUID BULK SCENARIO

The proposed case is corresponding to a real problem extracted from a set of scenarios that the authors addressed in the past for maritime logistics of a major Petrol Chemical Industry and could be seen as one of the *Simplest Problems* in Maritime Logistics (Bruzzone et al., 1998, 1999, 2002, 2011b, Massei et al., 2013); however it should be pay attention to the fact that solving the real problem, respect simplified model based on deterministic approach, is rather complex to be managed and optimized; so immediately it emerges the need to use extensively Modeling and Simulation (M&S).

So the scenario is defined as following:

just 2 Ports, with 2 corresponding Industrial Plants that need to be connected by a Supply Chain for an Intermediate Chemical Product. It is economically inconvenient to use a pipeline due to distances and flows. The Plants are located in two sites separated by sea, so the solution is to book a set of Ships (Chemical Tankers) of proper capacity and characteristics for a period (1 year each year) and to use them to move the product from A to B. Each ship sails to Port A, loads the Product from the Tanks of the Factory A, sails to B, unloads the Product in the tanks of the Factory B and sail back to A closing the cycle. The Factory A fills up the Tanks in Port A. Factory B fills up the Tanks in Port B; until there is still product in B, the B Factory is enabled to continue production and until there is free space in Tanks of Port A, Factory A can continue to go. These Chemical Plants should not stop to avoid very big extra costs. Each Port have a single dock position. As simplified hypothesis that corresponds mostly in the real industrial problem we accept the idea to use the same contract and type for all the ships; indeed if we apply this approach to the case of a maritime logistics flow this is common in many case and even the speed of the ship, within small range of differences due to similarity of selected ships, normally don't affect the sailing time among the two ports; so in facts it is almost true that the ships are equivalent, so it is possible to think in terms of time distance between ports corresponding to their average speed and to assume the same contract for them; by the way these assumptions in case of specific problems could be easily overridden using M&S (Bruzzone et al., 2011a). In addition despite the importance to try to close the return with some other compatible flows and/or avoid empty return it is evident that the regulations related to use of ship tanks and incompatibilities among different chemical products make this opportunity pretty unfeasible in most of the cases, so hereafter we don't consider possibility to use multiple product ships.

So, in this case, the basic data include:

- Chemical Production Flows in Factories
- Capacities of Tanks in the Ports/Factories
- Available Dock in Port Terminals
- Loading/Unloading Capacities in Ports
- Ship Contract Type
- Tank Capacities of the Ships
- Number of the Ships
- Sailing Distance between Port A & B

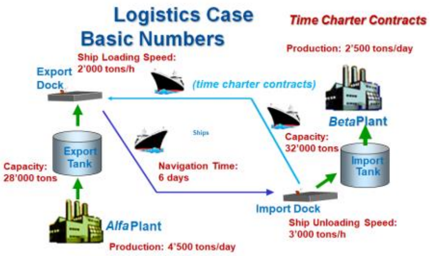

Figure 2: The Basic Data

In facts the authors decided to solve the problem considering to use contracts based on Time Charter Approach; these are pretty popular when the related fees are convenient and correspond to similar solutions in case of using proprietary ships; also in this case the use of different contract time could be easily implemented in equivalent way in the hereafter proposed methodology. Therefore it is important to note that there are several mutually interacting stochastic factors that should be considered to identify valid solutions; these include among others:

- Sailing Time affected by Weather Conditions, Ship Malfunctions, Problems with Port and Technical Nautical Services, etc.
- Loading and Unloading Operations in ports affected by Pump & Lines Problems, Blackout, Strikes, etc.
- Production Rate in Plant A and B due to overproduction or malfunctions
- Unexpected requests by other Plants or Customers of the A & B Production

3 SOLVING THE PROBLEM

The problem proposed is related to guarantee a Sea Supply Chain between Alfa & Beta (e.g. Ethylene Production in from Alfa 4’500 tons/day and required by Beta Plant around 2’500 tons/day). By analyzing the scheme and data and by integrating them with hypothesis it is possible to determine the logistics solution necessary to be adopted to guarantee effective, efficient and sustainable production over this echelon of the supply chain (Bruzzone et al., 2011a, 2012).

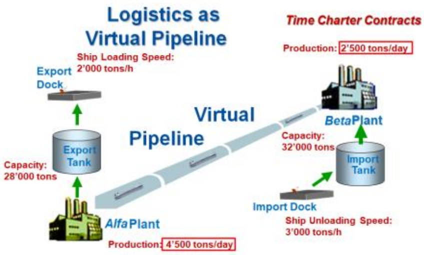

Figure 3: The Logistics Pipeline

As first step the authors propose the methodology to solve this case respect a deterministic approach as summarized in the proposed charts; first important step is to accept the point that the import and export flows, respectively from B and A plants, should be balanced as always should be in logistics flows (see figure 3); this means that logistics will operate as a pipeline and flow differences should managed separately (e.g. selling the extra export production to somebody else or buying the extra import quantities from some other sources) as proposed here

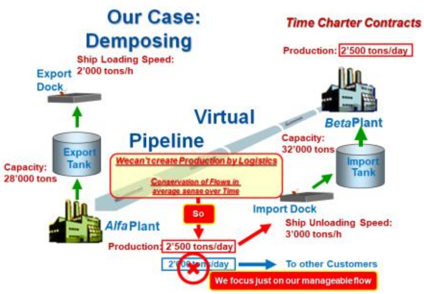

Figure 4: Balancing the Logistics Flows

Next step is to determine the frequency of ship arrivals that should be consistent with the Production Autonomy guaranteed by the Import and Export Tanks of the facilities within the Two Ports.

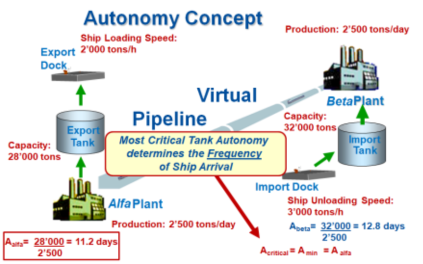

Figure 5: Evaluating Plant Autonomies

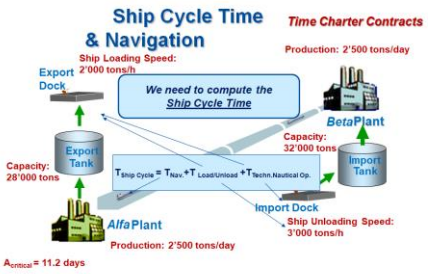

Figure 6: Modeling Ship Cycle Time

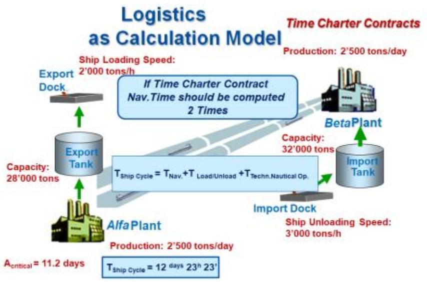

Figure 7: Calculating Ship Cycle Time

By identifying the most critical autonomy, it turns possible to finalize the definition of ship number in consistency with the overall time required to complete a cycle with the ship tankers based on the model proposed in figure 6.

Currently the Ship Cycle Time still depend from the capacity of the ship that influence the loading and unloading time at ports; this durations could seem pretty limited, therefore in real problems it corresponds to a significant part of the cycle; it is possible to address this issue in many ways, therefore hereafter it is proposed the simplest approach relying on choosing a capacity and determine the solution by progressive iterations as proposed in following figures. As first tentative, it makes sense to adopt as ship capacity the minimum storage capacity between the port tanks in A and B, considering that any larger ship will results underused. As soon as the Ship Cycle Time is estimated, it turns possible to compute the required number of ships that guarantee to reduce their inter arrival time in the ports in consistency with Plan Autonomy (see figure 8.1, 8.2, 8.3).

Obviously this solution correspond to the smallest number of large ships able to satisfy the supply chain. A larger number of smaller vessels corresponds also to suitable solutions, therefore adopting the general concept that few bigger ships are cheaper than many small ones, this is expected to be the optimal solution; this assumption in the reality is not true and the real fees for finalizing the contracts should be taken into consideration and used to finalize the details of the fleet to be used.

However, despite the necessity to check real rates, the proposed methodology still valid considering that it provides the reference baseline to be used for identifying the most convenient ships complaint with the supply chain needs.

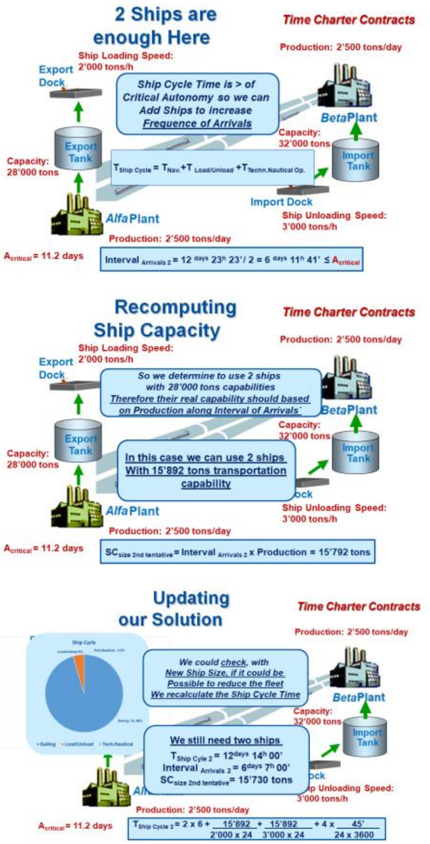

Figure 8.1, 8.2, 8.3: Ship Configuration

Vice versa, other hypothesis adopted in this solutions are not really reliable, in particular that ones that deal with the deterministic approach see figure 9.1, 9.2

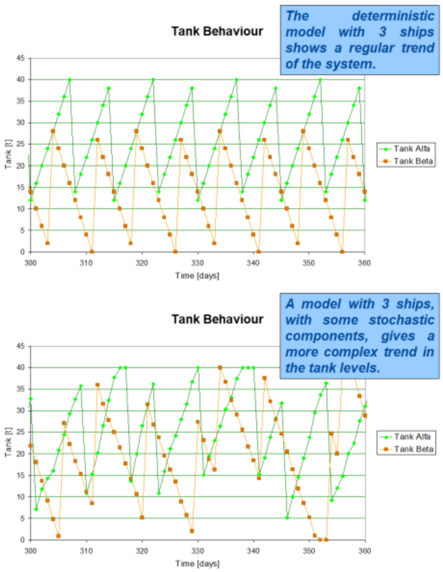

Figure 9.1, 9.2: Deterministic and Stochastic Levels into the tanks

3 SIMULATION TO FIND A REAL SOLUTION

The 9.1, 9.2 figures propose state space representation respect the tank levels in import and export facility and they make it clear that in some moments the B tank (import) turns to be empty, while A tank (export) is time by time totally full.
So the solution identified by the basic model is perfect, but just for Deterministic cases and it results unable to avoid Stockout in B Tank and Stockover in A Tank corresponding to block of production in related Plants and unacceptable extra costs due to the continuous nature of the industrial process. So it is necessary to adopt a more useful model and to avoid the limitations of previous mentioned simplifications; this results possible by creating a simulation Model able to be used to reproduce the system; in this case it is adopted a discrete event stochastic model that reproduce the scenario and allows to estimate, by Monte Carlo techniques, the effective costs, risks and times. In this case the Simulator allows to identify the performance of each ship solution in terms of number and capacity (see figure 10).

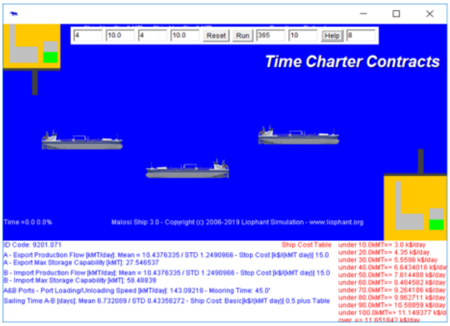

Figure 10: Simulation Model

Therefore, it is evident that Simulation by it self is able just to provide results to a *what if* analysis, while we could be interested to consider additional details and investigate wide ranges to find optimal solutions. Before to proceed we state that the Optimum could be note existing, or better undefined, considering the stochastic nature of the real system; in any case when we talk about finding optimum, we look for a more reliable and highly performing solutions in industrial sense. To find this optimum it is very interesting to use Artificial Neural Networks (ANN) able to learn from a Data Farming process generated by the simulator, as well as from the real data coming from operation activities of the tanker fleet the correlations between ship configurations and performances. These ANNs allow to finalize a metamodel able to support decisions in complex cases.

6 CONCLUSIONS

The proposed approach is a good example of how Simulation, Data Analytics and AI could be combined in order to support decision by creating a dynamic closed loop. The case looks simple, but by considering its stochastic components it results hard to be solved by traditional approaches; therefore it is evident that Simulation benefits from simplified models results to be validated and verified, while it uses enable generation of large data set to better understand the problem and to train AI solutions able to learn correlations among fleet configuration and logistics KPI (Key Performance Indicators). Obviously, these solutions are quite valuable considering that are able to guarantee continuous learning and to be kept up-to-date with real operational data, providing valid proposal to Decision makers. Therefore, as above mentioned, the Decision Makers could the loop being able to test their own variations on the AI Proposal based on personal choices that could consider special elements and factors; indeed the Simulator supports these check and allows to close the loop and guarantee users on properly finalizing their decisions respect risks and boundary condition evolution.

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A REVIEW OF RECENT RESARCH INVOLVING MODELLING AND SIMULATION IN DISASTER AND EMERGENCY MANAGEMENT

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ABSTRACT
The frequency, magnitudes, and consequences of disasters and emergencies, both natural and man-made, appear to have significantly increased in the past several decades. We report on a still ongoing review of recent research involving modeling and simulation (M&S) in disaster and emergency management, as published in various journals over the period 2011-2019. The growing number of articles seems to indicate the keen interest and engagement of scholars, scientists and practitioners in this highly relevant and crucial area of research.

Keywords: M&S, simulation, disaster and emergency management, disaster operations management/disaster management, management of emergency services, emergency medical service, emergency department, fire and rescue service

1. INTRODUCTION

Altay and Green (2006) noted that the operations research/management science (OR/MS) community had "yet to produce a critical mass" of research articles on disaster operations management (DOM). They surveyed 109 articles on OR/MS research in DOM published in various journals over the 25 years from 1980 to 2004, both in mainstream OR/MS journals and in others. They reported that five of the 42 papers (11.9%) appearing in mainstream OR/MS journals involved simulation as principal methodology, as did 13 of all 109 articles (also 11.9%). They separately reported two papers (1.8%) using system dynamics as methodology. This implies a total of 15 (or 13.8%) of the 109 papers in simulation, with system dynamics being generally regarded to be a simulation method.

Subsequently, Galindo and Batta (2013) undertook a survey covering the six-year period from 2005 to 2010, reporting to have found a total of 155 articles on OR/MS research in DOM. They stated that 14 of the 155 papers (or only 9%) used simulation as methodology, while separately reporting two papers (1.3%) under the system dynamics methodology. Altogether, this leads to 16 (or 10.3%) of the 155 research articles being in simulation.

Mathematical programming was reported to be the most used methodology (32.1% in the earlier survey and 23.1% in the latter survey). Simulation is noted by Galindo and Batta (2013) to have maintained its status as one of the "most widely used" methodologies next to mathematical programming in OR/MS research in DOM, and along with decision theory/multi-attribute utility theory.

Table 1 provides a summary of these two previous surveys. [We note that one figure appearing in Galindo and Batta (2013) shows only a total of 30 papers coming from mainstream OR/MS journals. The text, however, mentions a different total of 37.]

Table 1: Previous Surveys of OR/MS Research in DOM

	Altay & Green (2006)	Galindo & Batta (2013)
Time Period	1980-2004	2005-2010
Mainstream OR/MS journals	42	37
Other OR/MS related journals	35	14
Non-OR/MS journals	32	104
Total number of papers reviewed	109	155
Number of papers with simulation (system dynamics* included) as principal methodology	15	16
% of total	13.8%	10.3%

* In each survey, there are two papers reported separately by authors to use system dynamics as methodology.

Gupta, Starr, Farahani, and Matinrad (2016) reviewed papers on disaster management (DM) published from 1957 to 2014 in 25 "major journals" in operations management (OM), MS, OR, supply chain management (SCM), and transportation/logistics. They classified 146 papers according to 'data analysis technique', identifying 15 papers (10.3%) as using simulation. In comparison, 70 papers (47.9%) were classified as using mathematical programming.

The term disaster management (DM) – as used by Gupta et al. (2016) – is henceforth used in the current report, in place of DOM.

With the Altay and Green (2006) and Galindo and Batta (2013) surveys spanning the periods 1980-2004 (25 years) and 2005-2010 (six years), respectively, the current survey covers the period 2011-2019 (nine years). On the one hand, however, we focus on research specifically involving M&S, instead of OR/MS in general. On the other hand, we extend the field of interest of our study to the broader field of disaster and emergency management (DEM), which includes the management of emergency services such as:

- Emergency medical service (EMS),
- Hospital emergency department (ED) or accident and emergency department (AED),
- Fire and rescue service (FRS).

With respect to EMS, Aringhieri, Bruni, Khodapastri, and van Essen (2017) recently conducted a "wide" literature review of OR/MS research articles in EMS since the 1970s through 2016. They pointed out that earlier literature reviews have mainly discussed EMS location problems rather than the full range of EMS systems. Among others, they noted that simplifying assumptions in optimization problems often lead to questionable solutions, and that simulation may be needed to determine how well the solutions that are accordingly found perform in practice. They further identify one of the main challenges in EMS research to be "the development of a general purpose and reusable simulation model… which exploits GIS and real-time traffic information to compute shortest paths on a real network and based on the ABS [agent-based simulation] methodology."
Salmon, Rachuba, Briscoe and Pitt (2018) also recently undertook a review of M&S applied to EDs, and reported on a total of 254 retrieved publications, of which 143 are journal articles, over the period 2000-2016. They observed that new publications have been "up seven fold since 2000."

2. CURRENT SURVEY

2.1. Articles in Mainstream OR/MS Journals

Presented in Table 2 is a summary of the number of DM research articles reported to have been found in mainstream OR/MS journals by Altay and Green (2006) and Galindo and Batta (2013), as well as those in the current survey. It should be noted that the last column of Table 2 (current survey) only reports on research articles involving M&S in DEM that have been found in mainstream OR/MS journals in 2011-2019. On the other hand, the middle two columns pertain to research articles on *all* OR/MS methodologies applied to DM in 1980-2004 and 2005-2010, respectively.
Excluded from Table 2 (and other summaries that follow) are papers where M&S constitutes a supportive, secondary methodology, as in the following cases, among others:

- Use of simulation to test/compare model results vs. those of another model (e.g., Dean and Nair 2014);
- Simulation of results in using different input parameters (e.g., van Barneveld, van der Mei, and Bhulai 2017);
- Testing of conjectures suggested by analytic models (e.g., Saghafian, Hopp, van Oyen, Desmond, and Kronick 2014); and
- Use of Monte-Carlo based heuristics in solving NP-hard problems (e.g., Wex, Schryen, Feuerriegel, and Neumann 2014).

Table 2: Summary of Surveyed Articles Appearing in Mainstream OR/MS Journals

	Altay & Green (2006)	Galindo & Batta (2013)	Current survey
	OR/MS in DM	OR/MS in DM	M&S in DEM
Time Period	1980-2004	2005-2010	2011-2019
Mainstream OR/MS journals			
Annals of OR	3	2	2
Computers & OR	3	4	8
EJOR	10	7	9
Interfaces (INFORMS J Appl Anal)	5	2	1
JORS	9	8	4
Math of OR	0	1	0
MS	5	2	0
Naval Res Logistics	2	2	0
Omega	0	1	0
OR	2	0	2
OR for Health Care	0	0	3
OR Letters	2	0	0
OR Spectrum	0	1	0
RAIRO-OR	1	0	0
Total reported	42	30	29
DM	42	30	20
Emerg Svcs only (EMS / AED / FRS)			9

2.2. Articles in Other Journals

Neither Altay and Green (2006) nor Galindo and Batta (2013) provided summaries of the article sources outside of the mainstream OR/MS journals listed in Table 2 above. For the current survey, a total of 26 M&S in DEM articles were found in five 'Other OR/MS Related Journals' (i.e., *non-mainstream* OR/MS journals) while 65 articles were found in 12 'Non-OR/MS Journals'. Table 3 lists these other article sources for the current survey.

Table 3: Current Survey's Sources of M&S in DEM Articles (Other than Mainstream OR/MS Journals)

Other OR/MS related journals	Non-OR/MS journals
Applied Intelligence	*Cartography & Geogr Info Sci*
Building Simulation	*Computers, Environ & Urban Sys*
Intl J Simul & Process Modelling	*Fire Safety Journal*
J Multi-Criteria Decision Making	*IEEE Transactions Engg Mgmt*
Simulation	*Intl J Disaster Risk Reduction*
	J Coastal Research
	J Hazardous Materials
	J Opns Mgmt
	Natural Hazards Review
	Ocean Engineering
	Southeastern Geographer
	Transportation Research Record

Included in the current survey are six articles that have been accepted to date for a Special Issue on Modeling & Simulation in Disaster & Emergency Management:

Planning, Strategy Formulation, Decision-Making, and Training of the journal *IEEE Transactions on Engineering Management*. The six forthcoming articles are as follows:

- Gosavi, Fraioli, Sneed, and Tasker (2019);
- Asgary, Bonadonna, and Frischknecht (2019);
- Lavalle, Patriarca, Daulne, Hautier, Tofani, and Ciancamerla (2019);
- Shavarani, Golabi, and Vizvari (2019);
- Aiello, Santisi, Hopps, and Venticinque (2019); and
- Behr, Diaz, Longo, and Padovano (2019).

2.3. Summary of All Articles in Current Survey

A grand total of 120 journal articles published over the period 2011-2019 have so far been reviewed, as summarized in Table 4 (see last column).

Table 4: Summary of All Articles Reviewed in Earlier and Current Surveys

	Altay & Green (2006)	Galindo & Batta (2013)	Current survey
	OR/MS in DM	OR/MS in DM	M&S in DEM
Time Period	1980-2004	2005-2010	2011-2019
Mainstream OR/MS journals	42	37	29
Other OR/MS related journals	35	14	26
Non-OR/MS journals	32	104	65
Total reported	109	155	120
With simulation as methodology			
DM	15	16	96
DM + Emerg Svcs			7
Emerg Svcs only (EMS/AED/FRS)			17
Total	15	16	120

Excluding from the last column of Table 4 the 17 articles that pertain only to emergency services M&S, we would be left with 103 M&S in DM articles in the nine years from 2011 to 2019. Those 103 articles do convey a truly exponential growth in the M&S in DM literature, when compared with the 15 simulation/system dynamics articles reported for the 25 years from 1980 to 2004 (Altay and Green 2006) and the 16 articles for the succeeding six years from 2005 to 2010 (Galindo and Batta 2013).

2.4. Articles with Human Behavior Modeling

What may be of interest is that 37 (or slightly over 30%) of the 120 articles in the current survey explicitly include elements of human behavior modeling. Table 5 summarizes these 37 articles according to the journals in which they have been published.

More than half (20) of the 37 articles deal with various forms of evacuation in terms of:

- Human subjects (residents, visitors, pedestrians, crowds);
- Infrastructure (homes, parking structures, high-rise buildings, tunnels); and
- Disasters/emergencies (earthquakes, tsunamis, wildfires, man-made).

Table 5: Surveyed Articles with Human Behavior Modeling (2011-2019)

Mainstream OR/MS journals	
Computers & OR	1
EJOR	2
Interfaces (INFORMS J Appl Anal)	1
OR	1
Other OR/MS related journals	
Building Simulation	1
Intl J Simulation & Process Modelling	1
Simulation	10
Non-OR/MS journals	
Fire Safety Journal	5
Intl J Disaster Risk Reduction	4
J Hazardous Materials	1
Southeastern Geographer	1
Transportation Research Record	9
Total with Human Behavior Modeling	37

In at least 11 of these 37 papers, agent-based models have been proposed.

3. FURTHER WORK

The 120 articles surveyed thus far, as summarized in the last column of Table 4, are by no means an exhaustive compilation of research involving M&S in DEM published in journals in 2011-2019. While we believe that they constitute a fairly significant proportion of such work over that time period, we intend, for the time being, to continue searching for other M&S in DEM research articles.

At WAMS 2019, we will update, as appropriate, the report of articles surveyed. As well, we will provide further observations and summaries with respect to simulation methods or approaches (discrete event simulation, agent-based simulation, system dynamics, hybrid simulation, simulation-optimization), application areas (e.g., disaster risk mitigation, pedestrian/crowd flow and control, etc.), and other relevant aspects/considerations pertaining to M&S in DEM.

APPENDIX

Table A.1: 25 "Major Journals" (Gupta, Starr, Farahani, and Matinrad 2016)

Annals of OR	*Computers & OR*
Decision Sciences	*Decision Support Systems*
EJOR	*IIE Transactions*
Int J Opns & Prod Mgmt	*Int J Prod Economics*
Int J Prod Research	*J Opns Mgmt*
J SCM	*JORS*
MS	*Mfg & Service Opns Mgmt*
Math Programming	*Math of OR*
Naval Research Logistics	*Omega*
OR	*OR Spectrum*
Prod and Opns Mgmt	*SCM: An Intl Journal*
Transportation Research Part B	*Transportation Research Part E*
Transportation Science	

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Asgary, A., Bonadonna, C., and Frischknecht, C., 2019. Simulation and visualization of volcanic phenomena using Microsoft HoloLens: Case of Vulcano Island (Italy). IEEE Transactions on Engineering Management, forthcoming.

Behr, J., Diaz, R., Longo, F., and Padovano, A., 2019. Supply chain modeling in the aftermath of a disaster: A system dynamics approach in housing recovery. IEEE Transactions on Engineering Management, forthcoming.

Dean, M.D., and Nair, S.K. (2014). Mass-casualty triage: Distribution of victims to multiple hospitals using the SAVE model. *European Journal of Operational Research*, 238 (8), 363-373.

Galindo, G., and Batta, R., 2013. Review of recent developments in OR/MS research in disaster operations management. European Journal of Operational Research, 230 (2), 201-211.

Gosavi, A., Fraioli, G., Sneed, L.H., and Tasker, N., 2019. Discrete-event-based simulation model for performance evaluation of post-earthquake restoration in a smart city. IEEE Transactions on Engineering Management, forthcoming.

Gupta, S., Starr, M.K., Farahani, R.Z., and Matinrad, N., 2016. Disaster management from a POM perspective: Mapping a new domain. Production and Operations Management, 25 (10), 1611-1637.

Lavalle, L., Patriarca, T., Daulne, B., Hautier, O., Tofani, A., and Ciancamerla, E., 2019. Simulation-based analysis of a real water distribution network to support emergency management. IEEE Transactions on Engineering Management, forthcoming.

Saghafian, S., Hopp, W.J., van Oyen, M.P., Desmond, J.S., and Kronick, S.L., 2014. Complexity-augmented triage: A tool for improving patient safety and operational efficiency. *Manufacturing & Service Operations Management*, 16 (3), 329–345.

Salmon, A., Rachuba, S., Briscoe, S., and Pitt, M., 2018. A structured literature review of simulation modelling applied to Emergency Departments: Current patterns and emerging trends. *Operations Research for Health Care*, 19 (Complete), 1-13.

Shavarani, S.M., Golabi, M., and Vizvari, B., 2019. Assignment of medical staff to operating rooms in disaster preparedness: A novel stochastic approach. IEEE Transactions on Engineering Management, forthcoming.

van Barneveld, T.C., van der Mei, R.D., and Bhulai, S., 2017. Compliance tables for an EMS system with two types of medical response units. *Computers & Operations Research*, 80 (Complete), 68-81.

Wex, F., Schryen, G., Feuerriegel, S., and Neumann, D., 2014. Emergency response in natural disaster management: Allocation and scheduling of rescue units. *European Journal of Operational Research*, 235 (3), 697-708.

<u>**Analytical Index**</u>

Final Program of the 12th International Workshop on Applied Modelling & Simulation

October 30-31, 2019, www.liophant.org/wams

NUSS Kent Ridge Guild House, 9 Kent Ridge Drive, Singapore

WAMS2019 is organized in synergy with AsiaSim & STRATEGOS

Wednesday, October 30TH

845-0900 AsiaSim & WAMS OPENING, Dalvey & Evans Rooms

0900-1000 1st Day Keynote Speeches

1000-1030 *Tea/Coffee Break (WAMS included)*

1030-1200 AsiaSim Best Paper Session

1200-1330 *AsiaSim & WAMS Lunch (WAMS included)*

1400-1730 STRATEGOS Workshop: a New Way to Succeed (Evans)

1800-1930 AsiaSim & WAMS Welcome Cocktail *(WAMS included)*

2100-2230 Night Drink at Long Bar, Raffles Hotel *(no host)*

Thursday, October 31ST

0910-1000 2nd Day Keynote Speeches

100-1030 *Tea/Coffee Break (WAMS included)*

1030-1200 WAMS Evans Room, Session I

Chairs: R.Sburlati, DICCA & I.Arizono, Okayama University

Job Shop Rescheduling with Lot Splitting under Multiple Interruptions
T.Okamoto, Y.Yanagawa, I.Arizono, Graduate School of Natural Scienze & Technology, Okayama Univ., Japan (pg.14)

Scheduling Multiple Lift Vehicles in a Common Shaft in Automated Vehicle Storage and Retrieval Systems
A.Habl, V.Balducci, J.Fottner, Technical University of Munich, Germany (pg.39)

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P.Pawlewski, Faculty of Eng.Management, Poznan Univ.of Technology, Poland (pg.61)

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L.Aresti, P.Christodoulides, V.Messaritis, G.A.Florides, Cyprus Univ. of Tech. (pg.35)

Computational Investigation on Effect of Various Parameters of a Spiral Ground Heat Exchanger
L.Aresti, P.Christodoulides, L.Lazari, G.A.Florides, Cyprus Univ.of Tech.(pg.30)

1200-1330 *AsiaSim & WAMS Lunch (WAMS included)*

Thursday, October 31ST

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Chairman: ***A.G.Bruzzone, Simulation Team & L.Aresti, Cyprus Univ.of Technology***

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Proposed Framework Development for E-Government mplementation in Nepal
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A Continuous Simulation Model of the Diffusion of Toxic Gases in a Tunnel
R.Cianci, A.Alessandri, Genoa Univ., *Kirill Sinelshchikov, Simulation Team, (pg.67)*

Simulation of Human Pioneering on Mars
M.J.D. Bonato, A.B. Carneiro, L.M.A. Fadel, R.Y. Koga, A.L.B.V. Rodrigues, J.L.A. Silva, T.M. Teixeira, G. Todesco, FACENS - Sorocaba Engineering College, São Paulo, Brazil (pg.45)

1900-2200 Gala Dinner at S.E.A. Aquarium, Resorts World Sentosa *(WAMS included)*

Pease note that from suggested Accommodation(*Park Avenue Rochester Hotel & Suite)* there is a free shuttle service to NUSS for ASIASIM & WAMS

Venues in Singapore:

WAMS, AsiaSim & STRATEGOS Workshop Welcome Cocktail (WAMS Included)

@ NUSS Kent Ridge Guild House, National University of Singapore, 9 Kent Ridge Drive

STRATEGOS & WAMS Night Drink (No Host)

@ Long Bar, Raffles Hotel Raffles Arcade, 328 North Bridge Rd,

WAMS & AsiaSim Gala Dinner (WAMS Included)

@S.E.A. Aquarium, Resorts World, 8 Sentosa Gateway, Sentosa Island

WAMS & AsiaSim Lunches & Tea/Coffee Breaks during the Conferences are included for attendees during October 30 & 31

Further details available on
www.liophant.org/wams

APPENDIX 1: VENUE ACCESS

From Ayer Rajah Expressway (AYE), exit and go onto Clementi Road towards NUS.
Turn left into NUS Entrance B and turn right onto Kent Ridge Drive at the first junction.
NUSS Kent Ridge Guild House (KRGH) is located along Kent Ridge Drive.

LOCAL DELEGATES DRIVING TO KRGH

Parking charges at Car Park 15		
Day of Week	Operation Hours	Charges (per minute)
Monday to Friday	0830 - 1930	0.0214
Saturday	0830 - 1700	0.0214
Free parking at all other times		

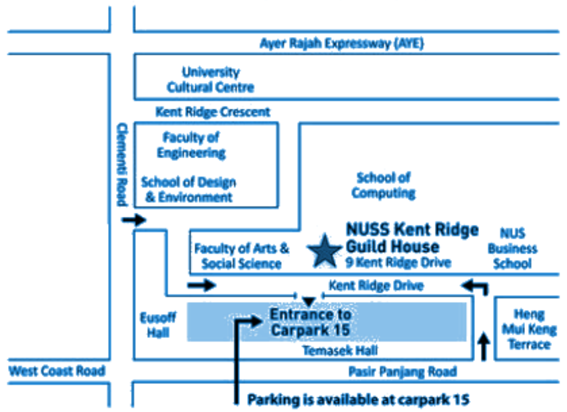
Car park coupons for parking at NUS Car Park 15 are available at **$3.60** (up to 4 hours parking) and **$4.80** (all-day parking) from our reception counter, Monday to Friday, Saturday before 5pm.

Enjoy free parking on Saturday after 5pm, Sunday and public holidays!
NUS Carpark 15 is conveniently located just across the road from KRGH.

SHUTTLE BUS A1 TRAVEL ROUTE

Kent Ridge MRT Station → NUH → LT 29 → University Hall → Opposite Staff Club → Yusof Ishak House → Central Library → LT 13 → AS 5 **(Stop to alight)**

Map of Kent Ridge Guild House | 9 Kent Ridge Drive | Singapore 119241



BY BUS
Kent Ridge Terminal : 10, 33, 95, 151, 151E, 189, 200
Heng Mui Keng Terrace : 10, 30, 30e, 51, 143, 183, 188, 200
Bus Shuttle Service : A1, B, D2, BTC1

BY MRT
Nearest Station: Kent Ridge

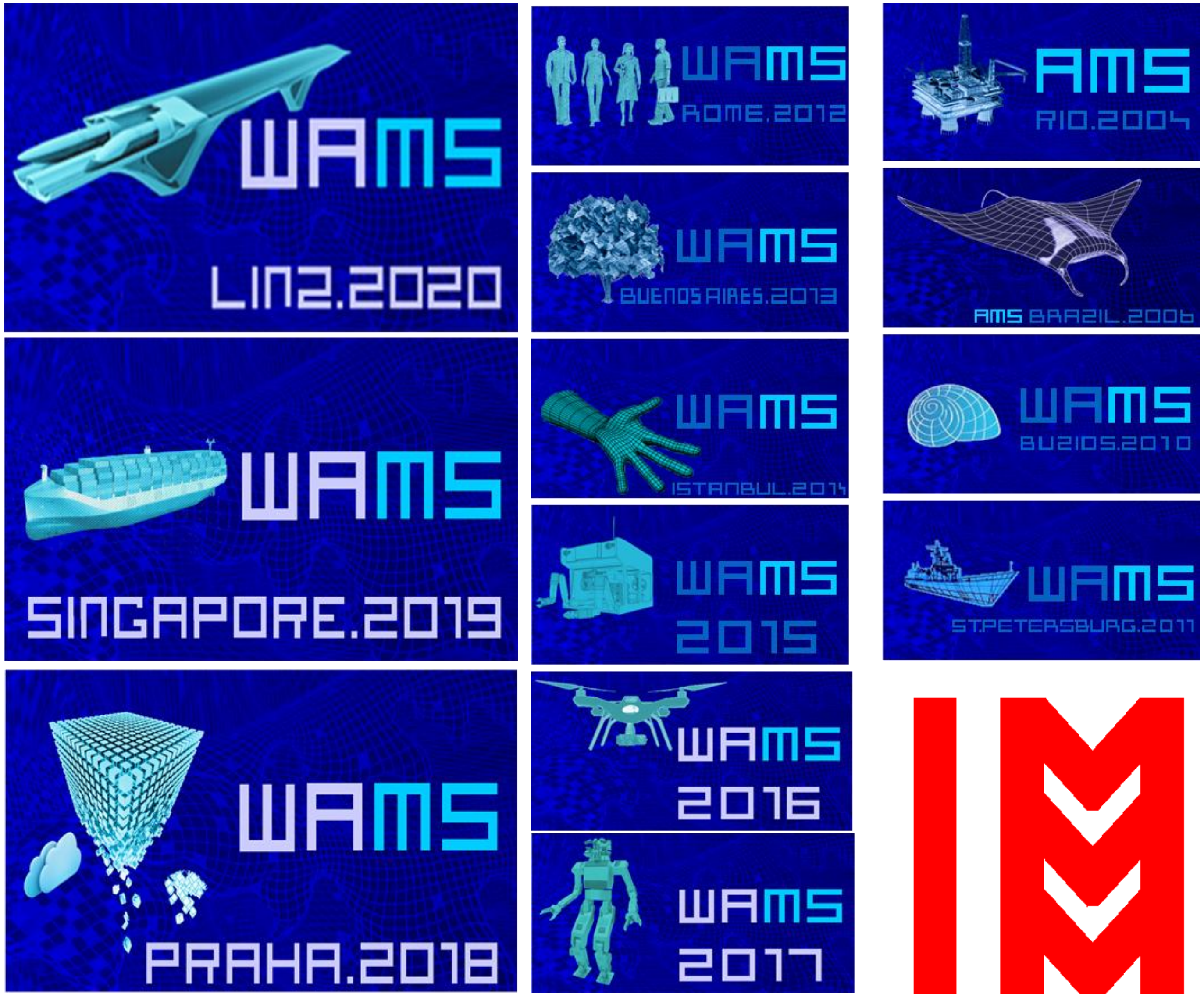
BY CAR
Park at carpark 15 from Clementi Road / Pasir Panjang Road

Visit the following website for the direction guide to NUSS Kent Ridge Guild House using public transport.
http://www.pathwaze.org/guides/nusskr/

NUSS The Graduate Club

A special Panel and Student Competition on Complex System will be organized on 1400-1700, Friday, November 1, at James Cook University, Singapore, jointly with STRATEGOS, Genoa University, for getting an invitation please contact massei@itim.unige.it for details

WAMS: 12 Years of Successes around the World



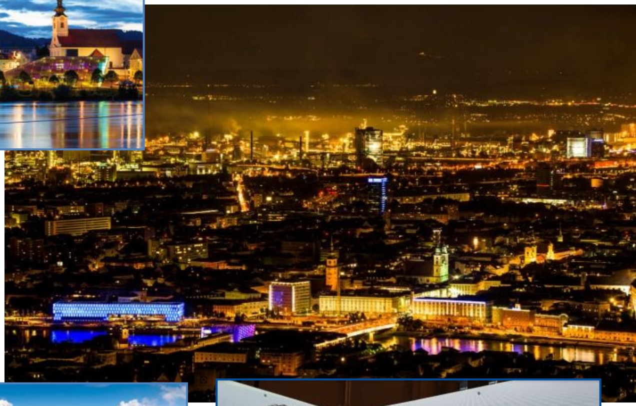
See you next Year, please visit:

www.liophant.org/conferences

Athens 2020

MSc in Engineering Technology for Strategy & Security
STRATEGOS
www.itim.unige.it/strategos

WAMS2020
Linz, Austria
November 18-20, 2020



General Chairs:

Agostino Bruzzone
Simulation Team M&S Net, University of Genoa

Program Chairs:

Fracesco Longo
UNICAL

Adriano Solis
York University

The 13th WAMS concentrates on Applications of Simulation and Computer Technologies. WAMS 2020 is organized in Linz, Austria, and it is a great opportunity for the International Simulation Community to meet together in Europe and to discuss advances in this sector; in fact WAMS is a workshop very effective in networking and very useful to set up new proposals and projects. Worldwide specialists have the opportunity to participate and to interact within this important International Forum on Applied M&S. The audience will include both users, vendors and scientists operating in applying advanced techniques to the main application areas and sectors including Industry, Business, Logistics Environment, Services & Defense. WAMS started as a series of international workshops organized in Latin America, AMS2004 (Rio de Janeiro), AMS2006 (Buzios), WAMS2013 (Buenos Aires); these events were focusing on Application and Theory of Modeling & Simulation. In following years WAMS was organized in both side of Atlantic Ocean (i.e.Brazil, Italian Riviera), while in 2011, WAMS was co-located with the International Marine Defense Show in St.Petersburg Russia organized in Joint Cooperation with SPIIRAS Russian Academy of Science. In 2012, WAMS was held in Rome in connections with the NATO CAX Forum. Therefore after WAMS 2014 in Turkey, WAMS was back in Italy in 2015-2017 and then moved to Prague and Singapore. This year WAMS is attracting scientists, technicians and experts from world leading Universities, Institutions, Agencies, Institutions and Companies

WAMS Exhibitors & Media Partners

WAMS exhibition provides and opportunity to Simulation Company and vendors to present their innovative solution to a wide audience; WAMS welcome also media sponsors of the event; for additional info on these issues please contact luca.bucchianica@simulationteam.com

Tutorial & Professional Courses

M&S SIREN Courses (www.mastsrl.eu/mscourses) and SILENI Seminars (www.liophant.org/sileni)could be held in connection with WAMS Multi-Conference; program, registration modules and tentative schedule will be available on the web, please contact marina.massei@liophatn.org. The M&S Courses are organized in cooperation with MITIM-DIPTEM University of Genoa, Simulation Team and with Patronage Liophant Simulation and include foreground assessment for Simulation Team Professional Certification Program.

Scientifically Sponsored by

Paper Submission

Extended abstracts, full draft papers or other proposals should be submitted for the review process through the conference website.

Each extended abstract must include the title, authors, affiliations, addresses, main body and references for proper positioning in the conference. Each paper will be reviewed by at least two members of the International Program Committee taking into consideration scientific quality, originality and relevance. Only original papers, written in English will be accepted.

Your camera ready paper must be submitted through the conference website. Authors of accepted papers are expected to attend the conference, present their works, transfer copyright and pay conference registration fees at the time their camera ready papers are submitted. Conference best papers will be directed to International Journals for inclusion through content extension.

Deadlines

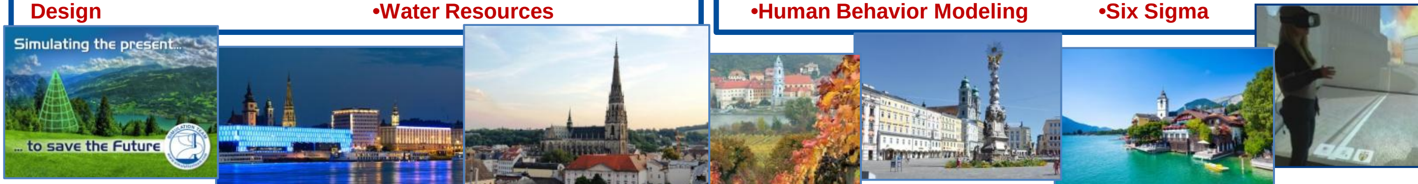
Track Proposals	**February 20, 2020**
Paper submission	**May 15, 2020**
Notification of Acceptance	**June 15, 2020**
Final Camera-Ready Submission	**July 15, 2020**

EXAMPLES OF APPLICATIONS

- Aerospace and Defense
- Agriculture
- Automation
- Autonomous Systems
- Communications
- Customer Relationship Management (CRM)
- Cyber-Physical Systems
- Education & Training (E&T)
- Emergency Planning & Management
- Enterprise Resource Management (ERP)
- Environment Management
- Entertainment
- Food and Beverage
- Finance
- Games & Entertainment
- Health Care Systems
- Human Resource Management
- Industrial Plants
- Industrial Engineering
- Information Support Systems
- Infrastructure Planning & Design
- Intelligent Forecasting
- Inventory Management
- Iron and Steel
- Logistics
- Manufacturing
- Military Applications
- Oil & Gas
- Operations
- Product Data Management (PDM)
- Production Planning & Management
- Project Management
- Power Industry
- Public Services
- Renewable Resources
- Robotic Systems
- Safety and Security
- Sales Forecasting
- Strategic Engineering
- Supply Chain Management
- Sustainability
- Strategic Decision
- Supply Chain Management
- Water Resources

EXAMPLES OF TOPICS

- Agile Manufacturing
- Artificial Intelligence
- Artificial Neural Networks
- Augmented & Virtual Reality
- Automation
- Business Process Re-Engineering
- Business Intelligence
- Cloud Computing
- Company Intelligent Management
- Crowdsourcing
- Customer Satisfaction
- Concurrent Engineering
- Data Analytics
- Data Farming
- Data Fusion
- Data Warehousing
- Decision Support Systems
- Effective Design
- Electronic Data Interchange
- Engineering & Design
- Fuzzy Logic
- Genetic Algorithms
- Human Behavior Modeling
- Interoperable Simulation
- Knowledge Based Systems
- Modeling & Simulation as a Service (MSaaS)
- Mobile Solutions
- M&S Methodologies, Techniques & Applications
- Lean Simulation
- Logistics Networks
- Mixed Reality
- Network Management
- Organizational Modeling
- Process Simulation
- Process Consulting
- Production Simulation
- Social Sciences
- Strategic Consulting
- Total Quality Management
- Resources Planning
- Safety in Work Environment
- Scheduling
- Security & Intelligence
- Serious Games
- Scenario Planning
- Six Sigma



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