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spatial-temporal data,
trajectory outlier detection, trajectory clustering

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ANALYTICS AND DATA SCIENCE APPLIED TO THE TRAJECTORY OUTLIER DETECTION

Abstract

Nowadays, logistics for transportation and distribution of merchandise are a key element to increase the competitiveness of companies. However, the election of alternative routes outside the panned routes causes the logistic companies to provide a poor-quality service, with units that endanger the appropriate deliver of merchandise and impacting negatively the way in which the supply chain works. This paper aims to develop a module that allows the processing, analysis and deployment of satellite information oriented to the pattern analysis, to find anomalies in the paths of the operators by implementing the algorithm TODS, to be able to help in the decision making. The experimental results show that the algorithm detects optimally the abnormal routes using historical data as a base.

1. INTRODUCTION AND MOTIVATION

In the las few years, land transportation has been the most used by most companies for merchandise distribution. Product distribution represents an important percentage in the total amount of costs in the companies supply chain, that is why the main focus for the companies should be the cost reduction and optimization. Recent studies (Sarmento, Renneboog & Matos, 2017) underline the importance of the logistic costs, including transportation cost, for example,

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to Latin America, it represents between 18% and 32 % of the total monetary value of the product; a really high percentage in comparison to that of the countries that belong in The Organisation for Economic Co-operation and Development (OCDE). At the same time, it focuses the logistics cost of the set of countries of the OCDE, which is in a 9% average, even a smaller percentage than in the United States of America, which is 9.5 %.

In the current context, the transportation and logistics sector are a fundamental factor to increase the competitiveness of their productive sectors, promoting the supply and distribution of goods and services. This last area generates deficiencies in the productivity of the product delivery with delays in the supply chain management. Contributing negatively to more than half of the losses in the companies, this makes it to be a shrinkage and decline factor in Mexican companies. Hence, there is a need to identify and control all those cost factors to ensure the companies competitiveness. The operators in charge to deliver supplies in many occasions define the rout planning in an empirical way by delivering thousands of supplies according to the demand of each customer. The empirical assignation consists of the way in which supplies are delivered according to the operator's experience. In many times, the election of alternate routes outside the panned ones causes the logistics companies to provide poor quality services by using vehicles that risk the merchandise and the supply chain. Small companies are the most affected party by this situation. As a consequence, they bring down medium sized and large companies in the country.

Data science techniques for the processing and analysis of the Global Positioning System (GPS) can help obtain more precise information about the routing options for the vehicle fleets, as it is shown in figure 1, and as it was probed by (Marković, Sekuła, Vander Laan, Andrienko & Andrienko, 2019), who popularized the potential of the GPS data for the research in the behavior according to the routs specially by studying the variability of time. According to what was previously stated, a good way to act in an optimum manner when facing possible facts that can interfere with the rout optimization is the detection of the paths outside the pattern. Having precise information about the operator routes for a period of time will allow to learn, calculate, and to detect abnormalities in the route planning, thus facilitating the decision-making process according to the operational costs. Taking as a base what has been said, this work tackles the problematic of finding abnormal trajectories considering the historical information of the operators. To detect spatial-temporal data abnormalities it is necessary to find atypical values or patterns that indicate atypical behavior in the driving routes of the fleet operators, in this work a hybrid algorithm is used distance-based and cluster-based, then the grouping results are used to determine abnormal routes. The algorithm used is Trajectory Outlier Detection and Segmentation – TODS (Schmitt & Baldo, 2018).

Fig. 1. Data Science and Analytics for the Detection and Control of Anomalous Routes

The rest of this paper is organized as it follows: section 2, related works; section 3, methodology; section 4, obtained results; section 5, conclusion of this work.

2. RELATED WORKS

The abnormal trajectory detection algorithms are mainly classified in four classes, based on statistics, distance, density, and the methods based on grouping. For our study, we will briefly review the different approaches.

The methods based on statistics can be quite effective and efficient when there is enough data and previous knowledge, however, this kind of methods are not ideal when high dimension data is applied. It can also use existent models or create new ones to evaluate the adjustment degree of data according to the model. The most used data models include the Gaussian distribution (Shaikh & Kitagawa, 2014) the Gaussian multivariate distribution (Hazel, 2000), among others.

Distance based methods are more widely used in statistic methods, for they are easier to design and to determine significant distance measurements in a data set that determines the statistic distribution models. The advantage of this models is based simplicity on the implementation, however, the complexity in the worst-case scenario can come up to O(m^2), this could be too expensive to handle grate volume data. Besides, this method is also sensitive to parameters. In the (Munoz-Organero, Ruiz-Blaquez & Sánchez-Fernández, 2018) work, an algorithm based in distance called Center of Sliding Window (CSW) was proposed to detect driving abnormal locations caused by particular traffic conditions like traffic lights, intersections or roundabouts. The goal was to filter the atypical driving points related to random traffic conditions, such as a congested highway. Infrastructure

elements (Lee, Han & Li, 2008) proposed the TRAjectory Outlier Detection (TRAOD) algorithm in which the similarity measurement called angular distance is applied, in which the direction of the abnormal sub- trajectories is different than the adjacent sub-trajectories.

The methods based on density are related to the atypical detection methods based on distance. This is due to density being generally defined by distance, specially the Euclidian distance as well as the angular distance (Schmitt & Baldo, 2018). From the density point of view, the atypical values are low density regions. The atypical detection methods based on relative density can process multiple density data sets in an effective way. The temporal complexity of this kind of methods can reach O(m^2), which is comparable to the approaches based on distance. (Han, Kamber & Pei, 2012) introduces several detection methods of atypical values based on density according to the calculation of the density. (Liu, Pi & Jiang, 2013) proposed a detection algorithm of atypical values based on the density trajectory to compensate for the algorithm disadvantages TRAOD Lee et al. that cannot detect abnormal flaws when there is a local factorial and dense. In the work (Cao, Shi, Wang, Han & Bai, 2014) proposed to use a new concept of atypical value based on the uncertain data density to quickly detect the atypical values.

The cluster-based methods are used to discover data groups that are strongly connected, while the atypical value detection is used to discover objects that are not strongly related to other data. In the group result, those calculi that are away from other calculi, or that are not as relevant for others can be marked as abnormalities. That's why the group can be used to detect atypical values. There are a lot of grouping algorithms to detect atypical values in a data set such as K-means, DBSCAN, STING and BRICH (Yuan, Sun, Zhao, Li & Wang, 2017). Liao (Liao, 2005) pointed out that the atypical values are a sub product of the group. Dominguez et al. (Domínguez, Redondo, Vilas & Khalifa, 2017) applied a grouping algorithm based in density, obtaining the city's pulse, thus allowing the detection of anomalies (unexpected behaviors) in the New York users. Fontes et al. (Fontes, de Alencar, Renso & Bogorny, 2013) atypical values were found between interest regions, using the grouping algorithm that takes the space and time context to find anomalies in the trajectories. The atypical semantic trajectories are calculated between interest regions where the objects have a similar movement intention. As a first step, the algorithm extracts the candidates that are the sub trajectories that have a similar move intention. In a second step, normal and abnormal trajectories are found. There are several works that present hybrid approaches using based methods on clustering and distance as it is shown in Lei and Mingchao (Lei & Mingchao, 2018) It uses the similarity measurement of the angular distance and the relative distance grouping special groups based on density on application with noise in between de data, using the DBSCAN algorithm to generate patterns from original trajectories.

3. PROPOSED METHOD

To tackle this problem, a hybrid approach based in grouping and in distance was applied, using the similarity measurement called Euclidian distance and angular distance with the purpose of segmenting normal routes with a high number of drivers on that path and abnormal trajectories with a minor number of drivers in determined time intervals, with the implementation of TODS algorithm (Schmitt & Baldo, 2018) to provide a solution for the detection of anomalies in trajectories using historical data. As described in figure 2, the trajectory data of the devices is gathered and stored in the data base. After they are processed using a series of filters to finally group them and segment them in two sets abnormal and normal accordingly. The main algorithm is divided in 3 phases; 1 extraction and data processing; 2 grouping and 3 segmentation. It can be seen on algorithm 1 and their entrances are defined as follows:

- Start region (SR) and end region (ER): They represent the interest regions where the selected trajectories should intersect.
- Start hour (SH) and end hour (EH): They represent the time interval in which the trajectories SR and ER should intersect. This should respect the inequality SH < EH.
- Interpolant size (I), standard deviation (SD) and sigma (σ): these are parameters used for processing and cleaning trajectories.
- The similarity measurements applied for this work are the Euclidian distance (D) and the angular distance (θ): They are used to identify the couple of segments; abnormal and normal.
- The number of groups that make a referral to same pattern groups (KS): It is the minimum number of normal groups to find.

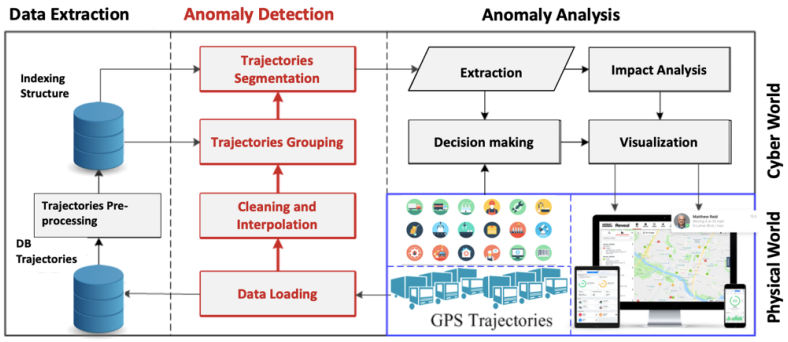

Fig. 2. Data extraction and analysis process for the detection of abnormal trajectories

The algorithm output are normal and abnormal arranged trajectories sets with their respective segments classified in sequences.

Algorithm 1 Main algorithm

Require: $SH, EH, SR, ER, I, SD, \sigma, D, \theta, KS$

```
1: t ← FindTrajectories(SR, ER)
2: for i ← 0 to Length(t) do
3:     FilterNoisePoints(t[i], SD,σ)
4:     InterpolatePoints(t[i], I)
5: end for
6: C ← GetCandidates(t, SH, EH, SR, ER)
7: idx ← CreateClusteringGrid(C, D)
8: GT ← GetTrajectoriesGroups(C, idx)
9: SGT ← GetStandardTrajectories(GT, KS)
10: R ← GetTrajectoriesRoutes(GT, SGT, D, θ)
11: return SGT,R
```

Fig. 3. Main Algorithm

3.1. Data extraction and preprocessing

There is data being obtained from the trajectories without processing from the data base (Find Trajectories line 1 on figure 3). The data base system applied was PostgreSQL, due to its capability to execute geometrical consultation to recuperate all the stored trajectories that intersect two different rectangular trajectories (SR y ER). Once the data has been extracted, the FilterNoisePoints (line 3 on figure 3) method follows with the preprocessing of the data, invalidating two invalid points in two steps. The first steps calculate a normal distribution using the distance in between two adjacent points. The points that extrapolate the confidence interval defined by σ are eliminated with the InterpolatePoints method (line 4 on figure 3). The parameter I defines the superior limit distance between two adjacent points. For that reason, if the distance between two adjacent points is bigger than the I value, an interpolation is executed to insert as many points as needed to adjust the distance if the point is shorter than I. The interpolation increases the points of density in the trajectories to improve the grouping set by the grouping algorithm. The second step calculates the standard deviation of the trajectory points to completely eliminate the trajectories that surpass the SD defined parameter. The next step is to eliminate the trajectories that fail to match the time interval given by SH y EH, filtering segments that respect the direction of the trajectory with the GetCandidates (line 6) method. For the recovery and optimization of the space time consultations, in this work, a system of index structure based in data grid was used to facilitate the consult's resolution by the grouping algorithm. In a way that it is efficient mapping, he points out the trajectories as it can be seen in the algorithm. The grouping algorithm used in this work is called Density-based spatial clustering of applications with noise (DBSCAN) (Gan & Tao, 2015).

3.2. Grouping

The grouping phase uses the similarity measurements based on distance; the Euclidian distance and the angular distance. Algorithm 2 details the function GetTrajectoriesGroups (line 8) from algorithm 1. The entries of the algorithm are the candidate's C set and the indexation system idx. Both variables are produced by the extraction phase and preprocessing, the output of the algorithm is a group team (GT), where each group contains trajectories with a similar route between SR y ER, as it can be seen on Figure 4.

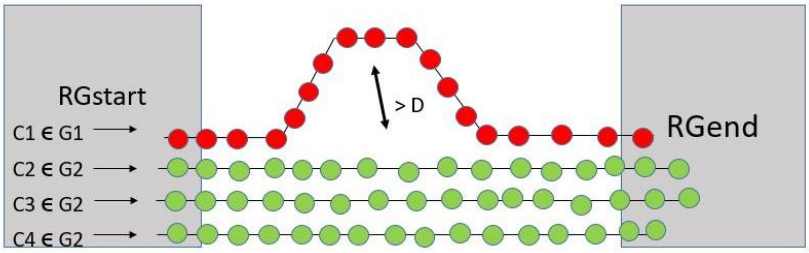

Fig. 4. Candidates grouping

Algorithm 2 starts to arrange the list of candidates in ascending order by the total of points (line 1). For each candidate, the algorithm starts to clean the variable currentGroup (line 4 on figure 5). After that, it makes a comparison between the current C candidate and the elements in the group GT (line 6). If the candidate matches an existing group, the variable currentGroup stores this respective group and finalizes the search (lines 7–8 on figure 5). The FitInGroup function uses the structure of the index to verify the distance of all the points that belong to c in the current trajectory grouping G. of the G group is not found (line 11 on figure 5), a new group is created to assign the candidate (line 12 on figure 5) and it is added to the GT group. Finally, the candidate c is added to the current group (line 15 on figure 5) and the next candidate is taken to comparison (line 3 on figure 5).

Algorithm 2 Trajectory grouping algorithm

Require: C, idx
1: $SortTrajectories(C)$
2: GT $\leftarrow CreateSetStructure()$
3: **for all** c $\in$ C **do**
4: $currentGroup \leftarrow empty$
5: **for all** c $\in$ C **do**
6: **if** $FitInGroup(c, G, idx)$ **then**
7: $currentGroup \leftarrow$ G
8: $break$
9: **end if**
10: **end for**
11: **if** $currentGroup = empty$ **then**
12: $currentGroup \leftarrow CreateGroup()$
13: $AddGroup(GT, currentGroup)$
14: **end if**
15: $AddCandidate(currentGroup, c)$
16: **end for**
17: **return** GT

Fig. 5. Trajectory grouping algorithm

3.3. Segmentation

Before proceeding with the segmentation, the standard group set is defined (STG) and the non-standard group is set (NSTG) in the GetStandardTrajectories method on the line 9 on figure 3, arranging the trajectory groups in descending order and selecting the superior KS groups with the most number of trajectories as the standard data set (STG) and the rest are marked as non-standard data sets (NSTG). The input parameters on figure 6 are: group set (GT), standard group set (STG), non-standard group set (NSTG), grouping distance (D), and the threshold of the angular distance (θ).

The segmentation process consists of two steps. The first step (found on figure 7) makes the segmentation by grouping the trajectories using the Euclidian distance. It identifies all the points in the trajectories as normal or abnormal using the grouping function HasNear. It classifies a specific point as normal due to its proximity to other points in the trajectories on figure 7. The second step makes the correction of segmentation, assessing the angular difference between trajectory segments, reclassifying the points from the beginning to the end of the abnormal segments calculating the angular difference between them and the normal segments using the BackExtension and FrontExtension, functions respectively. In figure 8, the segmentation can be seen by angular difference. At last, a composed route is created by normal and abnormal segments labeled as DS y NDS, respectively.

Algorithm 3 Trajectory segmentation algorithm

Require: GT, STG, NSTG, D, θ

$res \leftarrow CreateList()$
for all C $\in$ NSTG **do**
  for all p $\in$ C.points **do**
    $p.std \leftarrow HasNear(STG, p, D)$
  end for
  for all p $\in$ C.points **do**
    if p.std = FALSE **then**
      $BackExtension(p, C, STG, D, \theta)$
      $FrontExtension(p, C, STG, D, \theta)$
    end if
  end for
  $R \leftarrow CreateRoute()$
  $R \leftarrow CreateRoute()$
  $Split(R.DS, R.NDS, C)$
  $AddRoute(res, R)$
end for
return res

Fig. 6. Trajectory segmentation algorithm

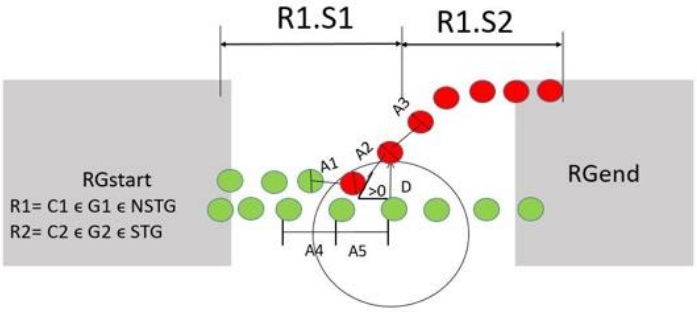

Fig. 7. Candidate segmentation by angular difference

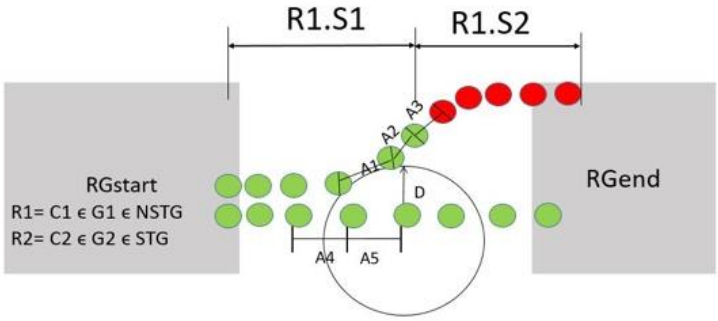

Fig. 8. Candidate segmentation by distance

4. EXPERIMENTAL RESULTS

For the development of the represented module on figure 9, Java was used (JDK version 1.8.0_121) as a programing language due to its execution and performance. For the management of consultations and information recovery, the data base manager applied was PostgreSQL, for it counts with an extension to manage geo spatial data and has as main characteristics the spatial kind of data, spatial indexes and functions that operate over them. According to the hardware specifications, a macBook Air was used with an Intel Core I5 processer and 8GB RAM to execute the module.

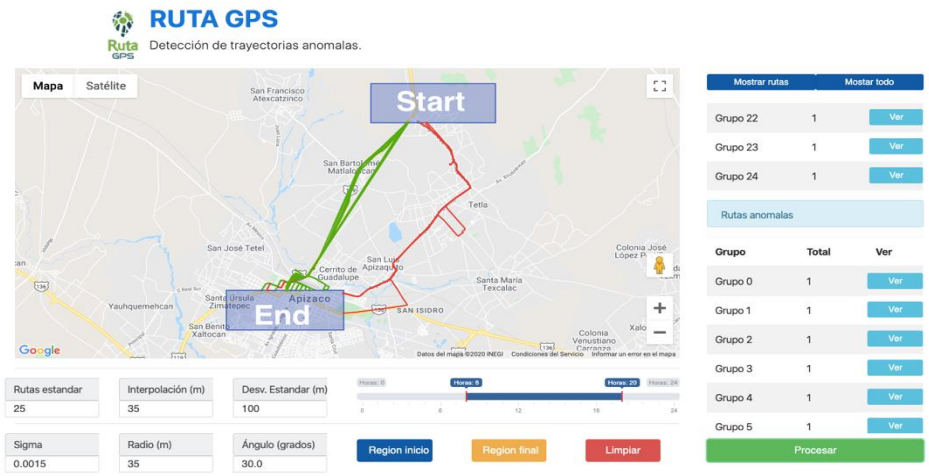

Fig. 9. Module interface

Tab. 1. RutasGPS format route

RutaGPS				
Device	**Latitude**	**Longitude**	**Time**	**Attribute**
15	19.5607	-98.130251	2019-04-05 11:48:01	{distance:14.43,totalDistance:41148}
15	19.5606	-98.130277	2019-04-05 11:50:53	{distance:14.43,totalDistance:41148}
15	19.5609	-98.130509	2019-04-05 11:51:15	{distance:14.44,totalDistance:42111}
15	19.5610	-98.130599	2019-04-05 11:58:04	{distance:14.44,totalDistance:42500}
15	19.5613	-98.130476	2019-04-05 12:00:04	{distance:14.44,totalDistance:45123}

For this work the data set of the project RutaGPS was applied, thus allowing space, time information of more than 50 users in a 6-month time period, which means from March 2019 through September 2019. It contains 17,621 trajectories and 6,798,282 points, including the users. On chart 1, the data format can be seen. On Figure 10, the visual representation of the spatial representation is shown.

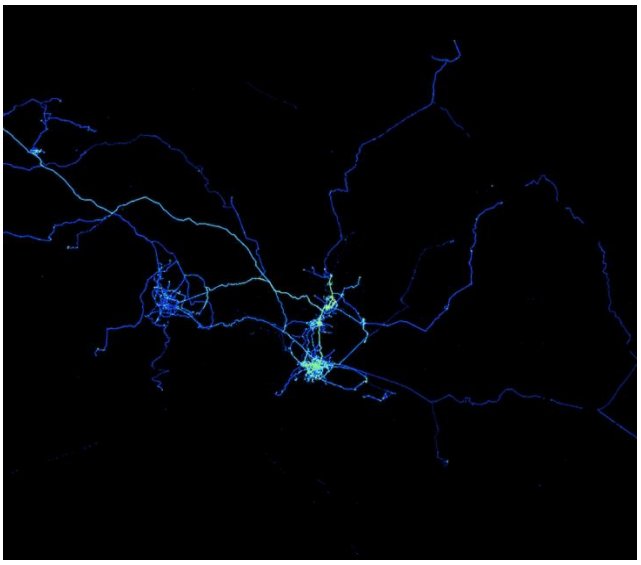

Fig. 10. Visual representation of spatial density

4.1. Case studies

For testing effects and to show an algorithm behavior, a module for a user who travels from Tlaxco, Tlaxcala to Apizaco, Tlaxcala was executed. The operator generally has a mobility pattern following a trajectory using the "carretera federal" Tlaxco-Apizaco for the logistics process can be seen in color green on Figure 11a. On the other side, an abnormal trajectory with the color red can be seen on Figure 11b, taking a different route, deviating from his trajectory in some segments that lead to routes outside the mobility pattern of the operator, arriving to Apizaco, Tlaxcala city using different segments from the "carretera federal Tlaxco-Apizaco".

Although the observed trajectory in red represents an abnormal event, it can be determined that the gas usage is larger due to the frequent stops in each intersection, every 200 meters than in segments where the average speed can reach 100 km/h. Besides, the time spent in road segments is a lot less than the time spent in segments where there are cross streets.

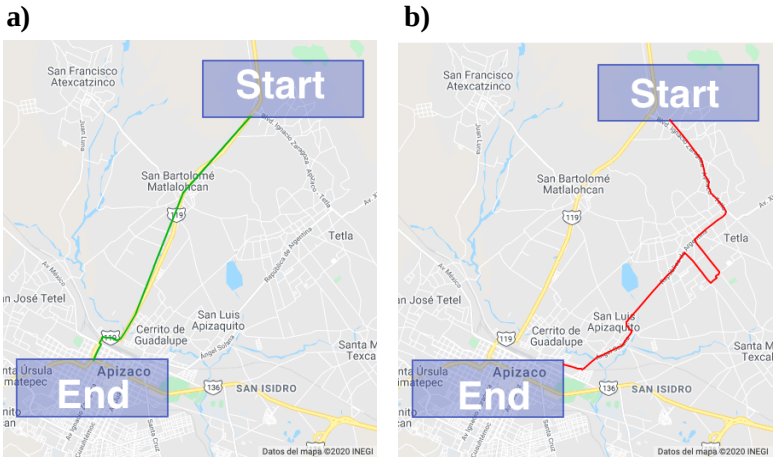

Fig. 11. Trajectory: a) normal; b) abnormal

5. CONCLUSIONS AND FUTURE WORKS

The detection of atypical values in the trajectories is greatly important to reduce and to optimize the operational costs, and to discover the particular events on transportation and distribution in the supply chain. In this paper, TODS algorithm was implemented to detect atypical values in the trajectory, to assign a segmentation and to group trajectories of the operator's technique with a normal and abnormal segments trough the analysis of the historical data. The experimental results showed the effectiveness of the algorithm in the detection of abnormal events according to the performance and viability that was analyzed in environments with real data resources for the detection of anomalies in merchandise logistics transportation and distribution processes. Regarding future researches, the detection in real time can be tested, as well as the auto-parametrization to reduce the configuration of empirical data.

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Type I Diabetes, Second Order Sliding Mode Control, Chaotic Particle Swarm Optimization, BEM model

Ekhlas H. KARAM[*], *Eman H. JADOO*[*]

DESIGN OF MODIFIED SECOND ORDER SLIDING MODE CONTROLLER BASED ON ST ALGORITHM FOR BLOOD GLUCOSE REGULATION SYSTEMS

Abstract

The type1 of diabetes is a chronic situation characterized by abnormally high glucose levels in the blood. Persons with diabetes characterized by no insulin secretion in the pancreas (ß-cell) which also known as insulin-dependent diabetic Mellitus (IDDM). In order to keep the levels of glucose in blood near the normal ranges (70–110mg/dl), the diabetic patients needed to inject by external insulin from time to time. In this paper, a Modified Second Order Sliding Mode Controller (MSOSMC) has been developed to control the concentration of blood glucose levels under a disturbing meal. The parameters of the suggested design controller are optimized by using chaotic particle swarm optimization (CPSO) technique, the model which is used to represent the artificial pancreas is a minimal model for Bergman. The simulation was performed on a MATLAB/SIMULINK to verify the performance of the suggested controller. The results showed the effectiveness of the proposed MSOSMC in controlling the behavior of glucose deviation to a sudden rise in blood glucose.

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1. INFORMATION

Diabetes mellitus is one of the most important chronic diseases which results from a high blood sugar for a long time due to insufficient insulin generation in the blood (Bergman, Phillips & Cobelli, 1981). The concentration of glucose in the bloodstream is naturally regulated by two hormones: insulin and glucagon. Both of these hormones are secreted by β-cells and α cells in the Langerhans islands of the pancreas, respectively. The concentration of glucose ranges from 70 to 110 (mg/dL). Accordingly, there are two states, hyperglycemia (glucose concentration is above the normal ranges) and hypoglycemia (low glucose concentration than the normal ranges) (Basher, 2017).

Diabetes is broken down into two major types. The type 1 diabetes mellitus (T1DM) and Type 2 diabetes mellitus (T2DM) in the first type the patient's body can't produce enough insulin and doses of insulin need to be injected into the human body to control blood glucose levels, while the second type starts with insulin resistance, a condition in which cells do not respond properly to insulin. This type of diabetes is a common type and known as noninsulin-dependent diabetes (Sylvester & Munie, 2017).

In order to prevent the effects of high blood glucose levels the best approach is to administer insulin during a moment when blood glucose is supposed to rise. With the Advance of technology, the so-called artificial pancreas emerged its consists of three main components, glucose sensor, insulin pump and control techniques to generate the necessary insulin dose based on glucose measurements (Kaveh & Shtessel, 2006). The block diagram of the closed – loop system for glucose level control shown in Figure 1.

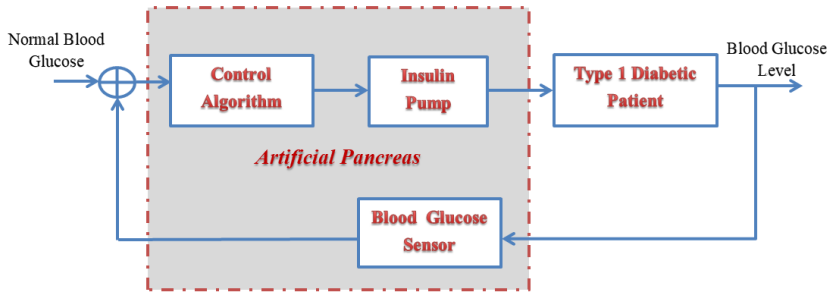

Fig. 1. Block diagram of closed-loop insulin delivery system

There are several studies that use a closed-loop controller to keep blood glucose (BG) diabetic concentration within the appropriate range, such as: (Kaveh and Shtessel, 2006) used higher order sliding mode controller (HOSMC) to regulate the levels of blood glucose. (Garcia-Gabin, et al., 2009) suggested a sliding mode predictive control (SMPC) which is the combining sliding mode control technology

with model predictive control (MPC). In a (Abu-Rmileh & Garcia-Gabin, 2011) used a combination of the robust sliding mode control (SMC) and the Smith predictor (SP) structures. Nasrin et al. suggest a Sliding Mode Control (SMC) based on Backstepping technique (Parsa, Vali & Ghasemi, 2014). Waqar et al. suggest a non-linear super twisting control algorithm based on SMC approach has been addressed for regulation of glucose concentration in blood plasma of type 1 diabetes patients (Alam, et al., 2018).

In this paper, the MSOSMC is suggested to regulate the levels of blood glucose, the CPSO algorithm was used for tuning the parameters of the controller. To accomplish these objectives Bergman Minimal (BEM) mathematical model which considered here. The outliner of this paper as follows: The BEM mathematical model of blood glucose system presented in section 2. The details of the SOSMC described in section 3, while the design of the MSOSMC explained in section 4. And the CPSO algorithm illustrated in section 5. The proposed controller's analysis and simulation results will be discussed in section 6, while the final conclusions listed in the last section.

2. BERGMAN GLUCOSE-INSULIN REGULATION MODEL

Specific mathematical models have been suggested to explain the complexities of diabetes and to compare the interaction between models of glucose and the delivery of insulin that helps design a diabetes model. Among these models, the minimal Bergman model, a common reference model in the literature, approaches the dynamic response of blood glucose concentration in a diabetic to insulin injections. Bergman model consists of three differential equations as follows (Sylvester, 2017), (Abu-Rmileh & Garcia-Gabin, 2011):

$$\begin{aligned} \dot{G}(t) &= -p_1(G(t) - G_b) - X(t)G(t) + D(t) \\ \dot{X}(t) &= -p_2X(t) + p_3(I(t) - I_b) \\ \dot{I}(t) &= -n(I(t) + I_b) + \gamma[G(t) - h]^+ t + u(t) \end{aligned} \tag{1}$$

where: $G(t)$ is the plasma glucose concentration in [mg/dL], $X(t)$ proportional to the insulin concentration in the remote compartment [1/min], $I(t)$ is the plasma insulin concentration in [mU/dL], and $u(t)$ is injected insulin rate in [mU/min], $(p_1, p_2, p_3, n, h, \gamma)$ are parameters of the model. The term, $\gamma[G(t) - h]^+$ in the third equation of this model, serves as an internal regulatory function that formulates insulin secretion in the body, which does not exist in diabetics, the $u(t)$ represent the rate of exogenous insulin. The value of p_1 will be significantly reduced; therefore it can be approximated as zero (Parsa, Vali & Ghasemi, 2014). Which $D(t)$ is disturbance signal (meal disturbance) can be modeled by a decaying exponential function of the following form (Fisher, 1991):

$$D(t) = Aexp(-B(t - t_{meal})) \tag{2}$$

where: B represents the absorption rate of the meal, A is meal size and t_{meal} represents the beginning time of meal digestion.

3. SLIDING MODE CONTROLLER DESIGN

SMC is a robust and simple procedure for synthesizing controllers for linear and nonlinear processes based on the Variable Structure Control (VSC) principles.

The discrete control has high switching frequency, which causes a "chattering-phenomenon", it considered undesired property that appear in SMC's control action (Djouima, et al., 2018). There are different methods that have been used to overcome the chattering phenomena such as replacing the sign(s) by boundary function like sat(s), using terminal SMC, integral SMC, and other different methods. One of the most efficient methods to overcome this problem by using Second Order Sliding Mode Control. There are different SOSMC algorithms, such as Sub-Optimal (SO), Twisting (TW) and Super-Twisting (ST) algorithm. ST-SMC does not require the information of $\dot{s}$ in its formulation and application which is simpler and preferable (Matraji, Al-Durra & Errouissi, 2018).

The ST-SMC utilized similar design steps as standard SMC. The same sliding surface as in Eq. (3) is applied and the control laws are stated in Eq. (8). The sliding surface can be introduced as:

$$s(t) = \gamma e(t) - \dot{e}(t) \tag{3}$$

where $e(t)$ and $\dot{e}(t)$ is error and derivative of the error respectively, $e(t)$ is given by:

$$e(t) = r(t) - y(t) \tag{4}$$

where $r(t)$ is the reference input (Basal Value) and $y(t)$ is the output signal (measured glucose).

The constant γ is chosen to be positive. The choice of γ decides the convergence rate of the tracking error.

The ST algorithm is defined by the following control law (Matraji, Al-Durra & Errouissi, 2018; Levant, 2013):

$$u = u_1 + u_2, \tag{5}$$

$$u_1 = -a_1 sign(s) \tag{6}$$

$$u_2 = -a_2 |s|^{0.5} \text{sign}(s), \tag{7}$$

where a_1 and a_2 are positive bounded constants. The control law of the super twisting SOSMC is given by:

$$u(t) = -a_1 sign(s(t)) - a_2 |s(t)|^{0.5} \text{sign}(s(t)) \tag{8}$$

4. MODIFIED SLIDING MODE CONTROLLER DESIGN

In this paper, a Modified SOSMC based on super twisting is suggested as shown in fig. 2, which considered as improvement to the SOSMC, the control law of the super twisting SOSMC (Eq. (8)) is modified to:

$$u(t) = -a_1 sign\big(s(t)\big) - a_2|s(t)|^{0.5}\text{sign}\big(\text{s(t)}\big) + u_n(s(t)) \tag{9}$$

where $u_n(e(t))$ is nonlinear auxiliary part given by:

$$u_n(e(t)) = \frac{L_1(1-\exp(L_2 e(t)))}{(1+\exp(L_2 e(t)))} \tag{10}$$

where L_1, L_2 are small positive numbers that will be tuning by (PSO and CPSO) algorithms.

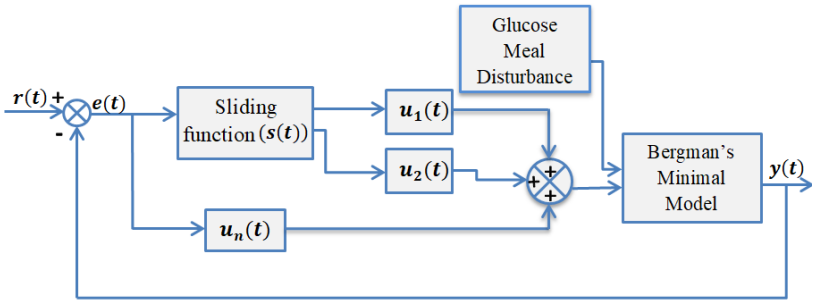

Fig. 2. Modified SOSMC block diagram

5. CHAOTIC PARTICLE SWARM OPTIMIZATION

The Particle Swarm Optimization algorithms (PSO) is the common evolutionary techniques. Which is adopt a random sequence for their parameter. The PSO algorithm is initialized with a population of candidate solutions which is called a particle. *N* particles are moving around in a D-dimensional search space of the problem (Amet, Ghanes & Barbot, 2012).

The position of the i^{th} particle at the i^{th} iteration is represented by $x_i(t) = = \big(x_{i1}, x_{i_2}, \dots, x_{iD}\big)$. The velocity for the i^{th} particle can be written as $v_i(t) = = (v_{i1}, v_{i_2}, \dots, v_{iD})$. The best position that has so far been visited by the i^{th} particle is represented as $pi = (p_{i1}, p_{i_2}, \dots, p_{iD})$ which is also called pbest. The global best position attained by the whole swarm is called the global best (gbest) and represented as $p_g(t) = (p_{g1}, p_{g2}, \dots, p_{gD})$. The velocity vector at the i^{th} iteration is represented as $v_i(t) = (v_{g1}, v_{g2}, \dots, v_{gD})$. At the next iteration, the velocity and position of the particle are calculated according to (11, 12):

$$v_i(t+1) = wv_i(t) + c_1 r_1\big(\text{pbest}_i(t) - x_i(t)\big) + c_2 r_2\big(\text{gbest}_i(t) - x_i(t)\big) \quad (11)$$

$$x_i(t+1) = x_i(t) + v_i(t) \quad (12)$$

where c_1, c_2 are called acceleration coefficients. w is called inertia weight, and r_1, r_2 are random value in the range [0, 1]. The parameters w, r_1 and r_2 is the key factors that effected the convergence behavior (Wang, Tan & Liu, 2018). In the Chaotic Particle Swarm Optimization algorithms (CPSO) the parameters c_1 and c_2 are modified by using logistic map based on the following equation:

$$M(t+1) = \mu \times M(t) \times \big(1 - M(t)\big) \quad 0 \le M(t) \le 1 \quad (13)$$

where μ is s a control parameter with a real number from $[0\ to\ 4]$ and $0 \le M(t) \le 1$. Then introduce a new velocity update as in equations (14).

$$v_i(t+1) = wv_i(t) + M(t) \times r_1\big(\text{pbest}_i(t) - x_i(t)\big) + (1 - M(t)) \times \times r_2\big(\text{gbest}_i(t) - x_i(t)\big) \quad (14)$$

Important advantages of the chaotic optimization algorithm (COA) are summarized as: easy implementation, short execution time and speed-up of the search. Observations, however, reveal that the COA also has some problems including: (i) COA is effective only for small decision spaces; (ii) COA easily converges in the early stages of the search process. Therefore, hybrid methods have attracted attention by the researchers (Hadi, 2019) The flowchart that represented this algorithm illustrated below.

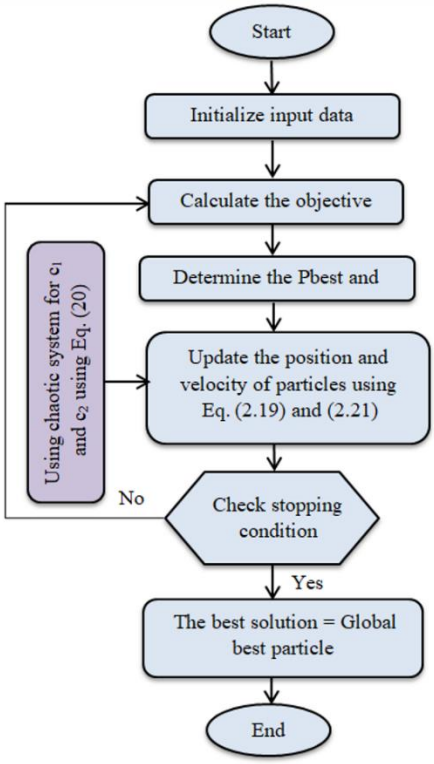

Fig. 3. General flowchart of the CPSO algorithm

6. SIMULATION RESULTS

The results of simulations for BEM model addressed in Eq. (1), parameters of BEM model are available on table (1), and the suggested controller based on the CPSO algorithm are offered in this section for a BG levels of 70 mg/dl. The BEM model response without controller is showen in figure (4). In this paper, the simulations are carried out dynamically for three patients with the initial conditions 220, 200 and 180mg/dl for patients 1, 2 and 3, respectively. In the simulation, the meal glucose disturbance that given in Eq. (2) the value of its parameters are $A = 0.5$, $b = 0.05$, and $t_{meal} = 400$ min.

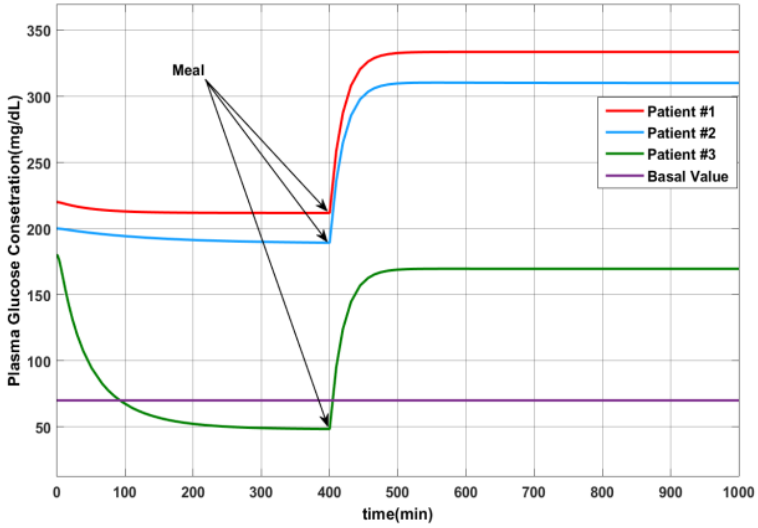

Fig. 4. Glucose output of three patients with disturbance (open-loop glucose regulatory system)

You can note that the glucose value of the normal person is stabilized at the basal level in the presence of the disturbance (meal), while the patient's glucose level remains dangerous outside the range. The simulation second part is the proposed controller is applied to the system and the response of a patients in the presence of the disturbance is tested. To examine the robustness of the control algorithm to the parameter change, three sets of parameters for three different patients have been used. The parameters of CPSO algorithm are considered here as in Table 2.

Tab. 1. Bergman Minimal Model Parameters (Garcia-Gabin, et al., 2009; Abu-Rmileh & Garcia-Gabin, 2011).

Parameter	Normal	Patient1	Patient2	Patient3
p_1	0.0317	0	0	0
p_2	0.0123	0.02	0.0072	0.0142
p_3	4.92	5.3×10^{-6}	2.16×10^{-6}	9.94×10^{-5}
n	0.2659	0.3	0.2465	0.2814
γ	0.0039	–	–	–
h	79.0353	–	–	–
G_b	70	70	70	70
I_b	7	7	7	7

Tab. 2. The parameters of CPSO algorithm

CPSO Parameters	Acronym	Value
Maximum number of iterations	$Iter_{max}$	80
Number of particles	pop_size	20
Acceleration constant	$c_1 \& c_2$	1.5
Inertia weight factor	w	0.9
Random values	$r_1 \& r_2$	0-1
Control parameter	μ	4
Chaotic initial value	$M(1)$	0.3

Table 3 illustrate the optimal parameters for SOSMC and MSOSMC controllers gotten from the CPSO algorithm.

Tab. 3. Optimal controller parameters

Controller	Parameter	Value
SOSMC	γ	0.15
	a_1	9.25
	a_2	0.00013
MSOSMC	L_1	0.037
	L_2	1.5

Figures (5 to 10) shows the response of BEM model for three patients after applying the suggested controllers to regulated the BG level according to Table 3 parameters.

It can be noticed from simulation results (Figures (5 to 10) and Tables (4 to 6)) of the suggested controllers that the glucose output with these controllers tracks the desired BG level with small settling time (t_s), study state error ($e_{s.s}$), and the Mean Absolute Percentage Error ($MAPE$) between the glucose value under the control system and that under the normal model according to the following formula:

$$MAPE = \frac{1}{n}\sum_{t=0}^{n}\left|\frac{BG_{desired}-BG_{measured}}{BG_{desired}}\right| \quad (15)$$

where n is the duration of simulation, $BG_{desired}$ is the glucose value returned by the reference model, and $BG_{measured}$ represents the actual output of the system under the controller.

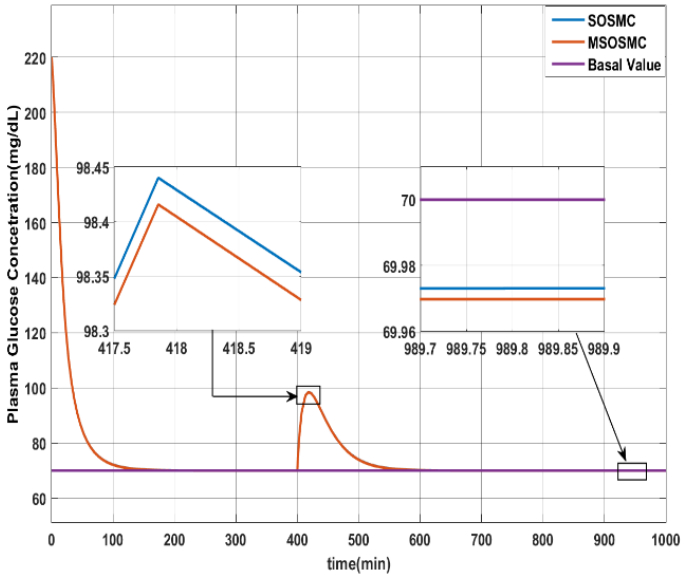

Fig. 5. Blood glucose concentration for patient 1 based on the suggested controllers and CPSO algorithm

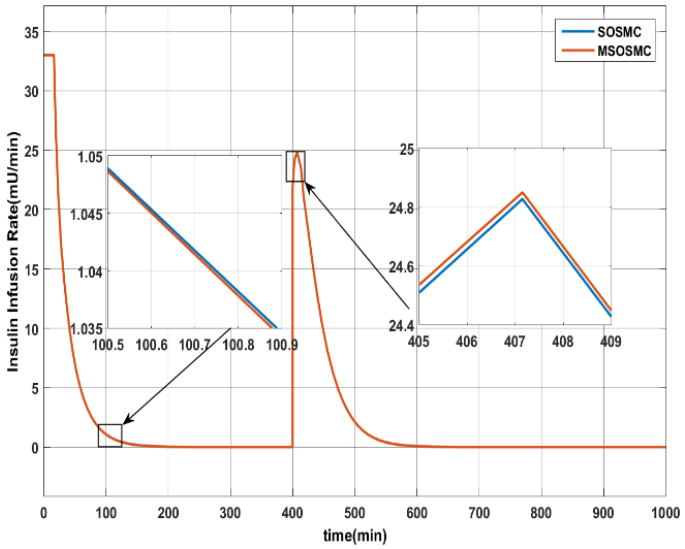

Fig. 6. Insulin infusion rate for patient1 based on the suggested controllers and CPSO algorithm

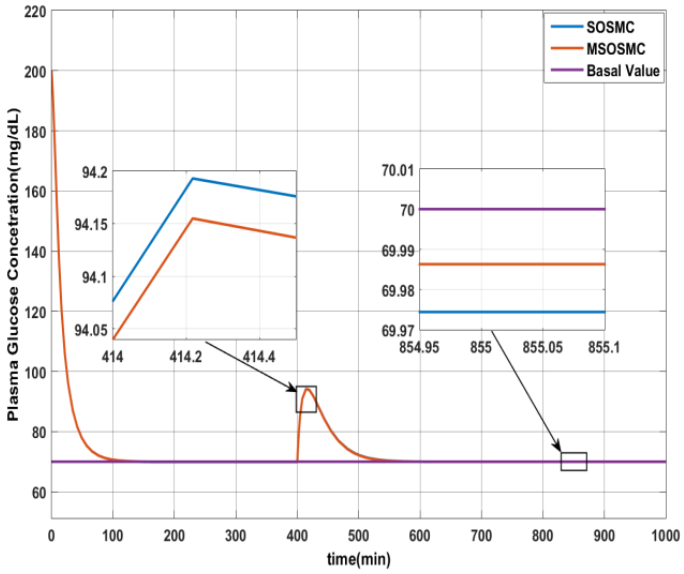

Fig. 7. Blood glucose concentration for patient 2 based on the suggested controllers and CPSO algorithm

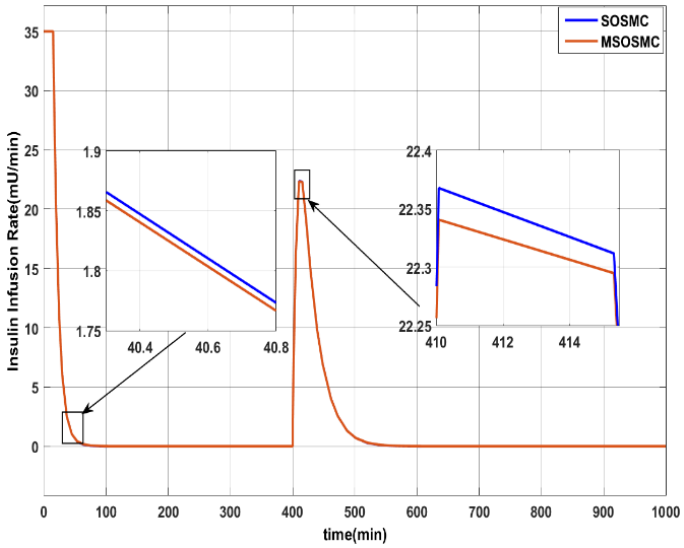

Fig. 8. Insulin infusion rate for patient2 based on the suggested controllers and CPSO algorithm

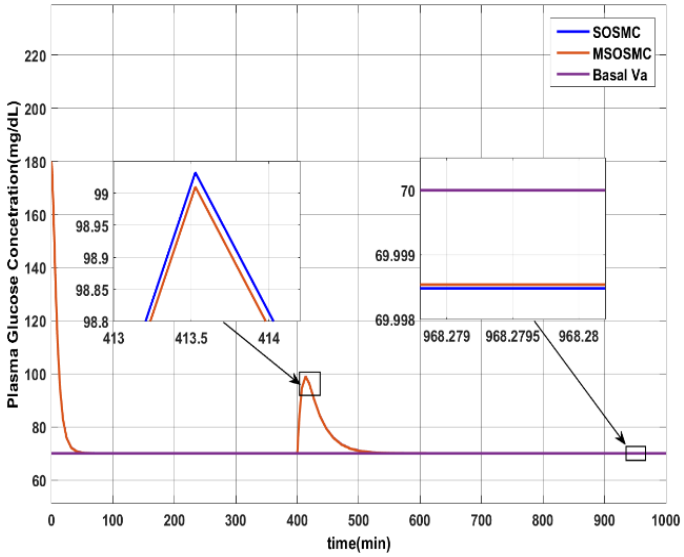

Fig. 9. Blood glucose concentration for patient 3 based on the suggested controllers and CPSO algorithm

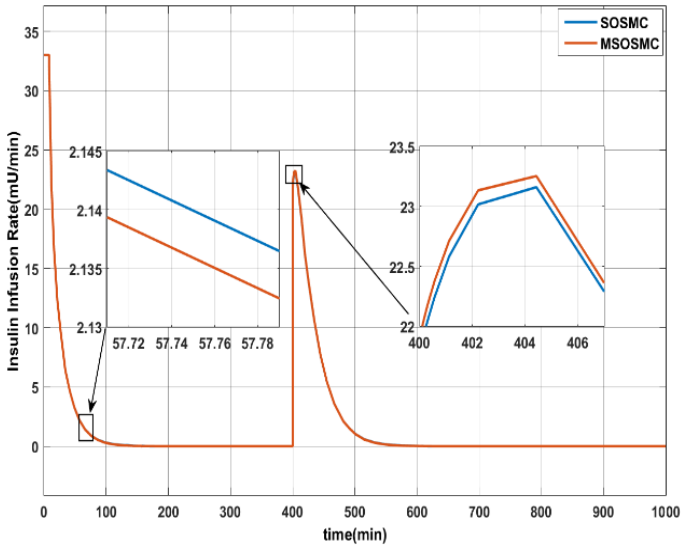

Fig. 10. Insulin infusion rate for patient3 based on the suggested controllers and CPSO algorithm

Tab. 4. The simulation result's evaluation parameters for patient 1

The controller used	t_s (min.)	$MAPE$	$e_{s.s.}$
SOSMC	508.94	0.0565	0.0031
MSOSMC	508.42	0.0564	0.0002

Tab. 5. The simulation result's evaluation parameters for patient 2

The controller used	t_s (min.)	$MAPE$	$e_{s.s.}$
SOSMC	496.14	0.0386	0.0005
MSOSMC	495.16	0.0387	0.0004

Tab. 6. The simulation result's evaluation parameters for patient 3

The controller used	t_s (min.)	$MAPE$	$e_{s.s.}$
SOSMC	476.25	0.0295	0.0008
MSOSMC	475.34	0.0293	0.0007

The comparison between controllers is shown in Tables (4 to 6). This tables illustrates the performance of controllers. The MSOSMC has the best average performance which satisfies the design requirement.

7. CONCLUSIONS

In this paper, a simple modified second order sliding mode controller has been suggested based on ST algorithm and CPSO algorithm. The performance analysis of the suggested control strategy concerning plasma glucose-insulin stabilization is comprehensively demonstrated by computer simulations. To validate the robustness of the suggested controller, the diabetic patient is exposed to external disturbance, that is, a meal. The closed-loop system has been simulated for different patients with different parameters, in the presence of the food intake disturbance and it has been shown that the glucose level is stabilized at its basal value (reference input) in a reasonable amount of time. The effectiveness of the suggested controller compared with the classical SOSMC are verified by simulation results for three patients.

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e-commerce, online purchase, TAM model, Italian university students

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MEASURING PROPENSITY OF ONLINE PURCHASE BY USING THE TAM MODEL: EVIDENCE FROM ITALIAN UNIVERSITY STUDENTS

Abstract

This study aims to investigate the dynamics of online purchasing behavior through the analysis of a sample of students from Italy. The objective is twofold: firstly, to outline a descriptive picture of the type of relationship with the web and the use of the TAM model to highlight the propensity to use electronic commerce by the analyzed sample. An interesting evidence is the prevalence of using the Internet for social activities rather than for purchases. In fact, the propensity to purchase online is still very limited and mainly concerns cultural and tourist services rather than physical products. Mobile devices are the main devices for connecting students to the Web and, consequently, the most used for purchasing online.

1. INTRODUCTION

At the end of the 20th century, after the greatest expansion of e-commerce, the initial expectations of the time have not yet been reached. This fact alone justifies the interest in studying this phenomenon, with the aim of reviewing the strategies and factors that influence online consumer behavior (Jones & Vijayasarathy, 1998; Goldsmith & Bridges, 2000; Rowley & Slack, 2001).

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If we focus on the Italian context, several academic and empirical studies show that Italian customers do not use e-commerce as frequently as customers in other European countries. Even young people seem to have scarce interest in online shopping, although they represent a segment characterized by a strong digital culture and, therefore, prone to online purchases. According to the ISTAT (Italian National Institute of Statistics), in fact, in 2018 the share of Italian web users aged 15 or over who purchased online in the 12 months preceding the interview rose to 55.9%, compared to 53.0% in 2017. Those who buy the most online are males (59.8), young people between 20 and 34 (about 70.0%) and residents in the North of Italy (60.8%). The data show a positive trend, although much less than other European countries. According to Eurostat, in fact, Italy occupies the 23rd position of 28, ahead of Greece, Croatia, Cyprus, Bulgaria and Romania.

There are several factors that determine the growth of e-commerce, such as the convenience that Internet offers the user, the possibility of buying without time constraints, and the opportunity to save money, thanks to greater comparability of offers (Mandelli & Vescovi, 2003; Prandelli & Verona, 2006; Valvi, Frangos & Grangos, 2013). Furthermore, the choice of online shopping would also depend on the ease in finding detailed information on the product of interest, interacting with the company directly and sharing the shopping experience on social networks (Verhoef, et al., 2009; Rose, et al., 2012).

However, there are also several inhibiting factors in online commerce, which could slow down growth in some geographical and social contexts. These factors concern, among others, the lack of security perception and because the product is sold online, the impossibility of carrying out an adequate pre-purchase evaluation of the product, because of its intangibility.

The implications and links between consumer psychographic characteristics and purchasing behavior are several (Dalli & Romani, 2004; Kwek, et al., 2010). Some concern the possibility and the ability to use devices, others concern the use of social media by consumers. In particular, if the user-generated contents within the social community damages the corporate brand, the commercial policies implemented by the company could lose their effectiveness (Nambisan & Watt, 2011; Cherubini & Pattuglia, 2012; Gensler, et al., 2013). Other features relate to people's attitudes towards online purchases (Novak, Hoffman & Yung, 2000), which can be withheld because of the previously mentioned inhibiting factors.

At the same time, it is interesting to note the role played by virtual communities, which are able to influence not only the outcome, but every single phase of the consumer purchase process, from the perception of the need to the final purchasing phase (Kwek, et al., 2010; Riva, 2010). Indeed, there are numerous studies that focus on analysing the role that virtual communities play in the decision-making process (Cuomo, Metallo & Tortora, 2011; Cheung & Thadani, 2012; Li, Wu & Lai, 2013; Yoo, Sanders & Moon, 2013; Cheung, Liu & Lee, 2015). The experience of other consumers has a significant impact on the brand's reputation in the minds of potential consumers; consequently, this experience is able to

decisively influence the propensity to purchase (Cova, 2002; Gensler, et al., 2013). In fact, several studies indicate that users consider social networks as a reliable source of information (Nambisan & Watt, 2011). Therefore, online shopping tends to be increasingly identified as a social experience – the so-called "social shopping" – since it is the result of the interdependence among different subjects, which share the interest for specific categories of products or services that can be purchased online (Novak, Hoffman & Yung, 2000).

The growing diffusion of global e-commerce and the number of studies carried out on the subject show how the analysis of online purchasing behavior becomes increasingly important in order to grasp its determining factors. In fact, the traditional approach studies several factors that influence the adoption of online consumer behavior, and the Technological Acceptance Model (TAM) is widely used for this purpose. The original value of this paper is to consider all the different devices to connect the Internet and, consequently, to buy online.

2. TECHNOLOGY ACCEPTANCE MODEL (TAM)

Several models have tried to explain the process of adopting innovation as an integration of traditional purchasing processes with new technologies (Muñoz, 2008).

For our purpose, we will focus on the Technology Acceptance Model (TAM) proposed by Davis in 1986, which represents an adaptation of the Theory of Reasoned Action (Ajzen & Fishbein, 1980). The TAM model seems to be one of the most widely supported in the literature (Davis, et al., 1989) and the most appropriate for the research we are carrying out.

According to this model there are three key factors that influence the acceptance of innovation (Figure 1):

- The perceived usefulness,
- The perceived ease of use,
- The attitude towards use.

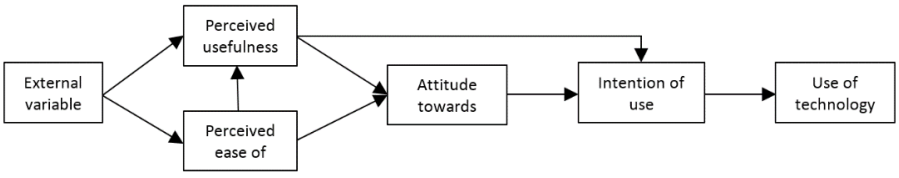

Fig. 1. Technology Acceptance Model (Davis, et al., 1989)

Most studies confirm the positive relationship between perceived utility and attitude (Fenech & O'Cass, 2001; Chen, et al., 2002; Gentry & Calantone, 2002), which also affects behavioral intention (Agarwal & Karahanna, 2000; Liu & Wei, 2003; Pavlou, 2003; Shih, 2004; Herrero, Rodríguez del Bosque & García De Los

Salmones, 2004; Venkatesh & Bala, 2008; among others). In this regard, conclusive results of the influence of ease of use on attitude have not been obtained. However, it is true that some authors do find a positive relationship (Chen, et al., 2002; Fenech & O'Cass, 2001; Van Der Heijden, et al., 2003; Shih, 2004), although this influence can also be mediated by the perceived utility (Adams, et al., 1992; Venkatesh & Davis, 1994; Gefen, 2000). Finally, it has been stated that attitude influences the intention of use (Chen, et al., 2002; Gentry & Calantone, 2002; Van Der Heijden, et al., 2003; O'Cass & Fenech, 2003; Herrero, et al., 2004; Shih, 2004).

Over time the TAM model has evolved, so different authors have added new variables (perceived risk, confidence, ...) or even eliminated some, such as attitude.

Teo et al. (1999) argue that the acquisition of online products is mainly affected by the utility associated with the Internet and, and to a lesser extent, by its perceived ease of use. On the contrary, according to Park et al. (2004) the strongest influence on the propensity to purchase online is exercised by the ease of use and, secondarily, by the perceived utility.

Other authors (Gefen & Straub, 2000; Gefen, 2003; Pavlou, 2003) have also studied the TAM model without including the variable "attitude", and found empirical evidence to maintain the influence of perceived usefulness and ease of use over intention of use.

2.1. Intention of use

The intention of use, or the acceptance of technologies by individuals, represents the dependent variable to be predicted in the TAM model. In our case, the way to measure the intention to use is through a single item that includes the intention of recommending electronic commerce to other users, adapted from the Davis model (1989).

2.2. Perceived usefulness

Perceived usefulness represents the degree to which individuals believe that the use of technology will improve their productivity when making purchases (Gentry & Calantone, 2002; Liu & Wei, 2003).

Different studies justify empirically the relationship between perceived usefulness and intention of use (Davis, et al., 1989; Lee, et al., 2003; Pavlou, 2003). This means that people form the intention to use on the basis of thinking on how to improve the development of the job. For this reason, the following hypotheses are proposed:

H1: Perceived usefulness has a positive influence on the intention of use in e-commerce.

Normally this concept of performance is usually associated with improvements or perceived benefits in the use of technology, such as convenience or improvement of efficiency and effectiveness (Hernández, et al., 2010), cost saving, time saving or the possibility of receiving products at home (Hernández, 2011).

Hernández (2011) states that the study of the multidimensionality of the perceived utility variable has been rejected by previous studies (Chin & Todd, 1995), and it is still a greenfield issue.

In this study, perceived usefulness has a multidimensional nature and it is measured through nine items that refer to the factors that encourage the use of e-commerce by users (Table 1).

Tab. 1. Perceived usefulness

Items	**Average (out of 5 points)**
Ability to purchase without time constraints (U1)	3.17
Opportunity to have a varied choice of products (U2)	3.70
Chance to save money thanks to price comparability (U3)	3.79
Ability to have detailed product information by the seller (U4)	2.98
Possibility to read reviews/opinions from other consumers (U5)	3.46
Ability to interact directly with the seller (U6)	2.44
Ability to share purchases on social networks (U7)	1.42
Chance to save time and money by having the goods at home (U8)	3.48
Possibility to buy with more calm and awareness (U9)	3.43

2.3. Ease of use

Ease of use refers to the degree of difficulty perceived by users for a specific technology, as well as the propensity to use it on the basis of their abilities (Hernández, 2011). In this way, the ease of use of a given system, in terms of clarity and simplicity, allows a greater adoption of the system (Venkatesh, et al., 2003; Yu, et al., 2005; Hernández, 2011); thus, when individuals perceive that a task is easy to perform, they will maintain a more positive predisposition towards the use of that type of system (Davis, 1989). However, this influence is higher and more significant in cases of scarce experience with the technology in question (Venkatesh, et al., 2003; Yu, et al., 2005).

H2: Ease of use has a positive influence on the intention of use in e-commerce.

Other studies have been developed to analyze the antecedents of ease of use, among which self-efficacy has been pointed out. It has been defined in various ways: as the degree to which individuals consider themselves capable of performing tasks in using technology (Chen & Dhillon, 2003; Venkatesh & Bala, 2008),

as the belief in their ability to perform actions (Bandura, 1997) and, considering the context of e-commerce, as the beliefs that individuals have of their abilities to use computers competently (Compeau & Higgins, 1995). The influence of this variable on behavioral intention has been confirmed by several researchers (Ajzen, 1991; Eden, 1992; Godin & Kok, 1996; Bandura, 1997; Shim, et al., 2001; Huh, et al., 2009).

In our case, we measure this variable through an item which represents consumer perception with regard to the capacity to use tools on the Internet.

The relationship between perceived ease of use and perceived usefulness has also been empirically tested in electronic commerce (among others: Davis, 1989; Karahanna & Straub, 1999; Teo, et al., 1999; Agarwal & Karahanna, 2000; Van der Heijden, et al., 2003; Pavlou, 2003; Ventakesh et al., 2003; Herrero, Rodríguez del Bosque & García, 2004; Shih, 2004; Wu & Chen, 2005; Venkatesh & Bala, 2008; Ha & Stoel, 2009; Chang, 2010; Chen & Chen, 2011). It emerges that perceived ease of use is antecedent to perceived usefulness.

H3: Ease of use has a positive influence on perceived usefulness of e-commerce.

2.4. Perceived risk

The nature of electronic commerce justifies the existence of risk, since it is a virtual relationship (Qiu & Li, 2008). Perceived risk is defined as the consumer's perception of uncertainty and adverse consequences when performing an activity (Jarvenpaa, et al., 1999) or an online transaction (Kim, et al., 2008). Some studies have introduced it as uncertainty regarding the negative consequences or losses that could result from the use of electronic commerce (Peláez & Rodríguez, 2009). Among these negative consequences, there is one indicating that the product does not match the desired expectation.

Generally, the existence of two types of uncertainty depending on the origin is accepted (Pavlou, 2003):

- Uncertainty of behavior which derives from the conduct of the seller and includes: economic risks (like fraud), personal risks (products that are unsafe or dangerous for the buyer), risks of the seller's performance (failure to meet deadlines, return, guarantee, etc.), and privacy risks (about buyer's information).
- Uncertainty of the environment which is associated with the intrusion of external agents and includes: economic risks (such as theft of banking information) and privacy risk (such as the improper use of a buyer's private data).

Risks represent the main barrier to the adoption of electronic commerce (ONTSI, 2010) or behavioral intention (McKnight, Choudhury & Kacmar, 2002; Liu & Wei, 2003; Pavlou, 2003; Im, Kim & Han, 2008); so that the perceived risk directly influences consumer behavior (Mayer, Davis & Schoorman, 1995; Gefen, Rao & Tractinsky, 2003).

H4: Perceived risk has a negative influence on the intention of use in e-commerce.

Risk is also a factor related to the perceived ease of use (Liu & Wei, 2003; Pavlou, 2003; Im, Kim & Han, 2008; Shen & Chiou, 2010).

H5: Perceived risk has a negative influence on the ease of use in e-commerce.

In this research, the perceived risk is measured by seven items (Table 2), considered in the questionnaire as those that impede online purchase.

Tab. 2. Perceived risk

Items	**Average (out of 5 points)**
The lack of trust in payment methods (R1)	2.56
The unclear purchase termination procedures (R2)	2.82
The inability to ensure product quality with hands (R3)	3.53
The lack of confidentiality of personal information provided (R4)	2.61
The fear that the received item does not match the purchased one (R5)	3.26
The high delivery costs (R6)	2.56
The high delivery times (R7)	2.48

2.5. Social presence

Teo et al. (2008) add other factors to the adoption model in order to represent the reality more faithfully. Among these factors, there is social presence, that represents the perception of being inside a communication channel shared with other people (To, et al., 2008). Thus, the feeling of social presence or perception of presence favors the increase of a favorable predisposition to the adoption of the system (Hernández, 2011).

H6: Social presence has a positive influence on the intention of use in e-commerce.

Previous studies have also investigated the influence of social presence on ease of use (Karahanna & Straub, 1999).

H7: Social presence has a positive influence on ease of use in e-commerce.

In our case, social presence is measured by using one item, which includes the level of activity in social networks.

2.6. Proposed model

As a result of this theoretical review, the following model is proposed for empirical testing (Figure 2):

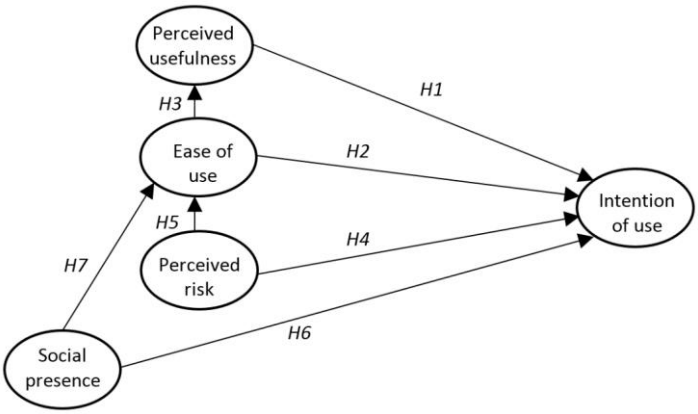

Fig. 2. Structural equation model

3. METHODOLOGY

In order to achieve the objectives of this research, we developed a quantitative technique to collect primary information, by using online survey tools. The fieldwork was developed between May and June, 2016.

The questionnaire collects information about different topics, using the following block structure:

- Block 1: General information about the connection to the Internet.
- Block 2: Information about the use of the Internet to make purchases.
- Block 3: Information about the use of traditional shops to make purchases.
- Block 4: Information about the socio-demographic characteristics of the sample.

The universe is composed by university students of the School of Economics at the University of Perugia (Italy). After proposing the questionnaire to all the population (2.253 students) we collected 335 surveys, so the representativeness is 14.87%. The selection of respondents was conducted by convenience.

All the methodological information is summarized in table 3.

Tab. 3. Technical record of the study

Universe	2,253 (students in the Faculty of Economy)
Sample size	335 (14.87%)
Sample process	By convenience
Technique	Online survey
Fieldwork	May 17 – June 24, 2016

4. RESULTS

The structural equation model used to verify the hypotheses was estimated by the partial squared minima method, using the application SmartPLS 2.0.

The results were analysed on the basis of different techniques, according to the tool to be connected; they are presented firstly in a descriptive form and secondly through the data obtained from the structural model.

4.1. Descriptive analysis

4.1.1. Sociodemographic variables

The analysed sample represents 14.87% of the universe (335 respondents).

Tab. 4. Sociodemographic profile

Variable	Characteristic	Percentage (%)
Gender	Male	38.51
	Female	**61.49**
Studies	**Degree**	**63.28**
	Master	36.72
Employment status	**I am full-time student**	**69.85**
	I work part-time/weekend	24.18
	I have a full-time job	5.97
Monthly income (€)	**Less than 500**	**77.01**
	501–750	14.03
	751–1000	3.28
	1001–1500	4.48
	More than 1500	1.19
Region	**Umbria**	**88.06**
	Others	11.94
Nationality	**Italian**	**90.45**
	Community (EU)	1.79
	Non–EU	7.76

61.49% are women and 63.28% are enrolled in three-year degree courses offered in the School of Economics of the University of Perugia. 69.85% of students declare that they are full-time while 24.18% have a part-time job. The disposable income is less than 500 euros per month in 77.01% of cases; 90.45% of the sample are of Italian nationality and 88.06% are residents of Umbria.

4.1.2. Frequency and motivation of connection, activities on social networks

The 45.7% of respondents consider they have a satisfactory capacity to use Internet tools; while 41.8% consider themselves to be quite adept on the Internet.

As far as frequency is concerned (Table 5), to measure consumer behavior online it is necessary to consider the variety of devise which can be connected to the Internet (Mazurek-Łopacińska & Sobocińska, 2017); despite this variety, the majority of respondents (72.24%) declare that they are "always" connected to the Internet via their smartphones and almost never via desktop PC, laptop and tablet (even less via television and smartwatch devices). The smartphone is smaller in size and weight and having it with you all the time becomes a daily routine (Ghareb, et al., 2018); due o the limitation of small screen sizes the designers need to create a positive mobile user experience (Borys, Czwórnóg & Ratajczyk, 2016).

With regard to the motivation of the connection (Table 6), an important percentage (71.64%) is "always" connected to the Internet for instant messages (such as WhatsApp and Facebook), while 47.46% make connections "several times a day" for activities on social networks and multimedia content viewing, 45.07% for study and work and 40% for news and current affairs. 49.25% of respondents connect to the web to make online purchases only "a few times a month", although 42.99% say they connect "several times a week" to gather information on any products to buy.

Compared to the activity on social networks, the results show that in general 44% of the sample is "fairly" active on social networks and as regards the time devoted to activities on social media, most (41%) admit to spending a time ranging from 30 minutes to 2 hours per day.

Tab. 5. Frequency

	Never	Few times a month	Sometimes a week	A few times a day	I am always connected
Desktop PC	**33.43**	21.19	20.30	18.21	6.87
Netbook/laptop	**36.72**	10.15	21.19	22.99	8.96
Smartphone	0.90	0.00	0.90	25.97	**72.24**
Tablet	**45.97**	15.52	14.03	17.31	7.16
TV	**63.88**	11.04	10.75	12.84	1.49
Smartwatch	**93.73**	4.18	1.19	0.60	0.30

Tab. 6. Motivations

	Never	Few times a month	Sometimes a week	A few times a day	I am always connected
Send/receive e-mail	1.19	10.15	**34.03**	32.84	21.79
Use of social networks	2.39	2.69	6.57	**47.46**	40.90
Instant message (WhatsApp, Facebook,…)	1.19	0.30	2.09	24.78	**71.64**
Search for information about products/services to be purchased	2.99	16.42	**42.99**	28.66	8.96
Purchase product/services	8.06	**49.25**	30.75	8.66	3.28
Watch videos or other multimedia content for pure recreation	2.39	9.85	29.85	**47.46**	10.45
Playing online	**57.01**	16.12	14.63	11.34	0.90
Write reviews	**57.91**	32.84	7.46	1.79	0.00
Download content into podcast (music, e-book,…)	26.57	**39.40**	23.28	8.36	2.39
Update your own website or blog (excluding social networks)	**80.00**	10.45	6.27	2.39	0.90
Read news on websites and information blog	8.36	12.54	29.85	**40.00**	9.25
For study/work	1.79	2.39	27.46	**45.07**	23.28
Update your own website or blog (excluding social networks)	**80.00**	10.45	6.27	2.39	0.90

4.1.3. Frequency, type, and expenditure for online purchases

Purchasing on the Internet is a fairly recent phenomenon. In fact, 70.7% of the participants made their first online purchase after 2009, 13.7% made the first online purchase in 2010, 12.5% in 2013 and 13.4% in 2014.

66.3% of respondents bought products online basically stimulated by their interests and about which they already knew the specific characteristics.

The data show that overall the frequency with which the investigated sample has purchased goods and/or services over the last year is very low; although slight differences can be detected depending on the type of products and services purchased (Table 7). For example, with regard to cultural services, 40.90% have never bought online tickets for concerts, museums, etc., only 35.22% bought at least 1–2 times a year, while 19.10% 3-5 times. The same result emerges with regard to public transport costs, where 31.34% had never purchased air or bus tickets, etc.

while 30.75% did so at least 1–2 times a year. Data relating to foodstuffs is significantly different, whereas for cosmetic products, financial products, and household products, the majority of the sample declares that they have never made online purchases.

As regards to the expense incurred for online purchases (Table 8), the percentage of those who declare that they have not spent in the last year for any of the types of products/services identified is very high overall. However, there are some interesting differences. Most of the sample said they spent between 1 and 100 euros for cultural products (books, films, etc.) (47.16%) and cultural services (tickets for the theatre, museums, etc.) (45.97%), while the percentages for the same products in the higher cost range are not significant. With regards to public transport costs, the percentages tend to be less extreme: 25.97% spent between 1 and 100 euros, 20.60% from 101 to 250 and 13.13% from 251 to 500. A similar trend is also found in the case of expenses for the purchase of hotel services.

Tab. 7. Frequency of online purchases (%)

Have you purchased the following products in the last year?	Never	1–2 times	3–5 times	6–10 times	More than 10 times
Cultural products (digital/non digital) (books, films, music)	**33.73**	26.57	24.48	9.55	5.67
Cultural services (tickets for cinema, theatre, museums,…)	**40.90**	35.22	19.10	2.99	1.79
Clothing	**35.52**	29.85	18.21	10.75	5.67
Apps/software	**48.36**	26.27	13.43	7.46	4.48
Electronics/Appliances	**54.63**	25.97	14.03	3.88	1.49
Tickets of transport (plane, train, bus)	**31.34**	30.75	19.40	9.85	8.66
Accommodation	30.75	**31.34**	26.87	7.76	3.28
Food	**92.54**	5.37	0.60	0.90	0.60
Household items	**64.48**	23.88	9.85	1.19	0.60
Education and training	**45.67**	27.16	15.82	8.66	2.69
Banking products	**79.70**	10.75	6.57	2.09	0.90
Beauty and cosmetics	**70.75**	17.31	8.06	1.79	2.09

Tab. 8. Expenditure of online purchases

Over the past year, what was the cost you spend on online purchases of the following products?	0	1–100	101–250	251–500	More than 500
Cultural products (digital/non digital) (books, films, music)	34.33	**47.16**	14.93	2.99	0.60
Cultural services (tickets for cinema, theatre, museums,…)	43.88	**45.97**	8.06	2.09	0.00
Clothing	**37.91**	31.04	20.90	7.76	2.39
Apps/software	**63.58**	31.64	3.58	1.19	0.00
Electronics/Appliances	**58.51**	23.88	8.96	5.07	3.58
Tickets of transport (plane, train, bus)	**33.73**	25.97	20.60	13.13	6.57
Accommodation	**32.84**	17.01	27.16	17.01	5.97
Food	**93.13**	5.97	0.60	0.30	0.00
Household items	**67.76**	28.66	2.99	0.60	0.00
Education and training	**49.85**	34.93	11.34	2.69	1.19
Banking products	**84.48**	10.45	1.49	1.79	1.79
Beauty and cosmetics	**73.73**	20.90	3.28	1.49	0.60

4.1.4. Online purchase channels

The most used channel to buy online is the marketplace: 32.24% of the sample declares using it "Much" and 27.76% "Very much". Seller websites are less used: 32.54% admit buying "Little" from the seller, while 26.57% "Quite". It is interesting to note that the data concerning the social network channels and that of commercial organizations such as Groupon, for which the interviewees say they "Never" use them (67.16% and 44.48% respectively).

Tab. 9. The channel used to buy online

	Never	Little	Quite	Much	Very much
Seller websites	12.54	**32.54**	26.57	19.10	9.25
Marketplaces	5.97	13.13	20.90	**32.24**	27.76
Facebook or other social networks	**67.16**	23.58	6.27	2.39	0.60
Websites of collective purchase (Offer, Groupon,…)	**44.48**	29.85	16.72	6.57	2.39

Although the use of social networks to buy online is not important, the high connection of respondents in this media obliged companies to make their presence felt on these networks (Infante-Moro, et al., 2016) in order of contact with them. Moreover, these authors state that there is a connection between companies that have online social networks presence and the use of e-commerce to sell their products.

4.1.5. Propensity to share the online shopping experiences

With respect to post-purchase behavior – linked in particular to online sharing – the data shows substantial inactivity, unlike what has been stated by several studies on the subject conducted so far and cited previously. The vast majority of respondents never share the purchase of products online on social networks (80.30%). Similar results for all forms of online socialization, or "I write reviews on specialized sites" (never for 61.19%); "I write on the seller's site (if possible)" (never for 63.38%); "I become a fan of the social network page or register with the site" (never for 43.58%); "I answer questions in forums or groups" (never for 71.94%). The only activity of socialization practiced is summarized by the statement "I speak verbally with family and friends". This happens in the case of "enough" (44.18%), "very often" (23.58%) and "always" (10.15%).

Tab. 10. Sharing of online purchases

	Never	Little	Enough	Very often	Always
I share the purchase on social networks	**80.30**	16.12	2.09	1.19	0.30
I write reviews on specialized sites	**61.19**	24.18	12.24	1.49	0.90
I write on the seller´s site (if possible)	**63.38**	21.79	9.25	3.28	1.79
I become a fan of the social network page or I register with the site	**43.58**	24.18	22.39	7.76	2.09
I speak verbally with family and friends	7.46	14.63	**44.18**	23.58	10.15
I answer questions in forums or groups	**71.94**	22.69	3.88	1.49	0.00

4.2. Structural model analysis

In this section we carried out the estimation by partial squared minima method, using the application SmartPLS 2.0, to verify the hypotheses proposed in this paper.

4.2.1. Reliability and validity of the measurement instrument

The original proposed model has been refined in order to satisfy the individual reliability properties. For this reason, three items have been removed: U7, R6, and R7, in order not to go over the level of 0.55 (Falk & Miller, 1992). After this process, the validity and reliability of the measurement instruments were satisfied (Table 11).

Regarding the reliability of the scales, both scales pass the level of 0.7 established in Cronbach's Alpha (Cronbach, 1970; Nunnally, 1978).

The composite reliability (IFC) is also supported, because every scale passes the limit of 0.6 (Bagozzi & Yi, 1988).

The convergent validity is also confirmed in both scales, because the AVE indicator passes the limit of 0.5 (Fornell & Larcker, 1981). The discriminant validity is also confirmed as each item weighs more than the latent factor which it is assigned.

Finally, the measurement scales used in the proposed model satisfied the validity and reliability properties.

Tab. 11. Properties of the scales

	Items	Standardised factor	t	Cronbach's Alpha	IFC	AVE
Perceived usefulness	U1	0.661	16.639***	0.897	0.909	0.558
	U2	0.791	32.906***			
	U3	0.784	28.240***			
	U4	0.768	27.277***			
	U5	0.769	27.776***			
	U6	0.629	16.353***			
	U8	0.750	24.088***			
	U9	0.806	37.269***			
Perceived risk	R1	0.827	23.273***	0.826	0.875	0.584
	R2	0.763	15.117***			
	R3	0.751	14.784***			
	R4	0.741	13.620***			
	R5	0.733	12.239***			

Note: *** $p < 0.01$ ($t_{(0.01;\infty)} = 2.3263$); ** $p < 0.05$ ($t_{(0.05;\infty)} = 1.6449$); * $p < 0.1$ ($t_{(0.1;\infty)} = 1.2816$).

4.2.2. Structural model

The estimated model has a good overall adjustment, the final variable "intention of use" has an R2 coefficient greater than 0.10 (Falk & Miller, 1992).

Tab. 12. Worth of the fit model

Variable	R^2
Intention of use	0.302
Ease of use	0.012
Perceived usefulness	0.000

Moreover, the model has a mediumhigh predictive relevance, as Q2 indicator raises the value of 0.267 (Chin, 1998).

In the structural model, we observe that only two of the seven hypotheses pass the limit of 0.2 in β coefficients. Moreover, only three of the seven hypotheses have been empirically proven, with regard to the statistically significance of the relationship (Table 13).

Tab. 13. Hypotheses

Hypotheses	β standardised	t Bootstrap
Perceived usefulness → Intention of use	0.493	11.211***
Ease of use → Intention of use	0.017	0.339
Ease of use → Perceived usefulness	0.022	0.342
Perceived risk → Intention of use	-0.240	4.437***
Perceived risk → Ease of use	-0.109	1.858**
Social presence → Ease of use	0.007	0.131
Social presence → Intention of use	-0.006	0.122

Note: *** $p < 0.01$ ($t_{(0.01;\infty)} = 2.3263$); ** $p < 0.05$ ($t_{(0.05;499)} = 1.6449$); * $p < 0.1$ ($t_{(0.1;499)} = 1.2816$).

5. CONCLUSIONS

This paper analyzes the purchasing behavior of young university students, particularly their propensity to connect to the Internet, use social networks and make online purchases. Several points for reflection emerge, both theoretical and empirical, that may be useful to scholars and operators.

An interesting evidence is the prevalence of using the Internet for social activities rather than for purchases. In fact, the propensity to purchase online is still very limited and mainly concerns cultural and tourist services rather than physical products. Mobile devices are the main devices for connecting students to the Web and, consequently, the most used for purchasing online; so, companies need to create a good web design to favor e-commerce.

Three main factors emerge, which seem to encourage online shopping: the opportunity to save time and money, the ability to compare products/services, and the possibility to obtain reviews and suggestions from other consumers.

Among the factors perceived as a limit to online purchases there is the impossibility to "touch" the product, as well as the fear of receiving the wrong item and the lack of transparency in the buying procedure. Unlike what has been found in other studies, trust in payment methods is not a limit to online shopping according to the sample analysed in this paper.

In relation to the ways through which online shopping takes place, the preferred channels are mainly the marketplaces (e.g. Amazon); the sample show less interest in the official supplier websites.

Regarding social networks, respondents do not usually use them to buy online, however the high connection of society in this media becomes it in a good vehicle for companies to connect their offer with the demand.

According to the results of the statistical analysis, the intention to use e-commerce (through recommendation) is positively influenced by the perceived usefulness and negatively by the perceived risk. This means that the greater the perceived usefulness, the greater the intention of use and the greater the perceived risk, the lower the intention of use. However, ease of use (through the ability to use devices) does not have a significant direct effect.

Unlike previous studies, this article does not show a significant influence of ease of use on perceived usefulness, although the relationship is positive. It seems that with a greater ease of use, there is a greater perceived usefulness.

Regarding the antecedents of ease of use, the perceived risk has a significant negative effect. This means that the greater the perception of risk, the lower the ease of use, as verified in previous studies.

As regards social presence (level of activity in social networks), this paper does not find a significant influence of this variable on ease of use and on the intention of use. In spite of these non-significant influences, the level of social networks activity has a positive influence on ease of use; but, in contrast to other studies, this study reveals a negative influence on intention of use.

Despite some interesting findings, this research presents at least two limits, which evolve from the sample analysed. The first relates to the territorial concentration of respondents, given that the survey only concerns students from the University of Perugia, the vast majority of whom live in Umbria Region. The second refers to the low spending power of the students, which does not guarantee the sample heterogeneity according to the income parameters (over 91% declares an available income of less than 750 euros per month). Additionally, this behavior could be different in the current context defined by Covid 19. We pretend to turn these limitations into future research lines.

Further research is required in this field with the aim of examining in depth the variables affecting online shopping. What is the role of factors such as previous online purchasing experience and the motivations (social, cultural and economic) that lead people to purchase online? At the same time, an interesting research question could be related to the analysis of the multidimensional nature of the risks associated with online shopping and perceived usefulness. The last future research line is the influence of other variables such as the situation defined by the health crisis by Covid 19.

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Mean Arterial Pressure, Squirrel Search Algorithm,
Model Reference Adaptive Controller

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CONTROLLING THE MEAN ARTERIAL PRESSURE BY MODIFIED MODEL REFERENCE ADAPTIVE CONTROLLER BASED ON TWO OPTIMIZATION ALGORITHMS

Abstract

This paper Presents Modified Model Reference Adaptive Controller (MRAC) to regulate the hight blood pressure. It is based on slate model that represent the mathematical equation that clarifies relationship between blood pressure and vasoactive drug injection. In this work Squirrel Search Algorithm (SSA) and Grey Wolf Optimizer (GWO) algorithms are considered to optimize the controller parameters. the results showed that the suggested controller has good performance and stabilize the mean arterial pressure with small settling time (below than 400s) and small overshoot (below than 1 mmHg) with low amount of error.

1. INTRODUCTION

The rise of blood pressure is one of the diseases that most people suffer from, Blood pressure (BP) is articulated with 2 dimensions, systolic pressure is maximum pressure and diastolic pressure is minimum pressures in arterial system. The systolic BP of living person exists between the range of 110–140 millimetres mercury (mmHg) whereas diastolic pressure exists between 70–90 mmHg mean arterial pressure (MAP) is define as the average of the pressure in the systemic arteries that based on the diastolic pressures and systolic (Singh & Urooj, 2019).

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Controlling the MAP is consider as a relevant problem in many applications such as hypertension control in the cardiac post-surgery healing process, in which the MAP has to be reduced as well as during the surgery anaesthesia. The procedure of the MAP lowering is usually implemented by injecting the patient body by vasodilator drug like Sodium Nitroprusside (SNP) (de Moura Oliveira, Durães & Pires, 2014). SNP is a vasodilator drug, which causes the widening in the walls of arterioles to be reduced, thereby lowering blood pressure it is Quickly acting and solid strong enough to resulting serious hypotension and or cyanide toxicity in case of an Excessive dose (Malagutti, Dehghani & Kennedy, 2013). The procedure of the lowering MAP can be done manually but is subject to human error and can take a long time in clinical environments where staff levels can be a problem and/or timely intervention (Malagutti, 2014). So, an Automatic Drug Infusion System is Helpful Efficient the control of drug infusion in a proper way, the Patient injection system is an integrated system contains of injection materials as per the medical standards, which will be sensing the blood pressure level and Determine the amount of drug required to injecting the human body with the help of automatic pump (Basha, Vivekanandan & Parthasarathy, 2018). In recent years, several researchers developed adaptive control system to regulate the rising of blood pressure like fractional order adaptive regulator which is suggested by Samir Ladaci et al. (Ladaci, 2012). The simulation results show the efficiency of this regulation controlling the MAP in presence of disturbances for different patients' sensitivities. Anderson Luiz etal. (Cavalcanti & Maitelli, 2015) use an adaptive predictive controller and a proportional integral controller with Fuzzy system consideration of two patients simulated, the results showed that the Suggested idea has Good results and stabilize the blood pressure with very small value of settling time and overshoot. Humberto A. Silva1 et al. (Silva, Leão & Seabra, 2018) use the Multi-Model Adaptive Control (MMAC) to regulate the MAP, they developed a procedure to control the blood pressure in the presence of significant time delays and parameters uncertainty. Simple adaptive PI controller suggested by Samuel Justino da Silva1 et al. (da Silva1, et al., 2019) for mean arterial pressure regulation, the controller was evaluated with desktop and Hill simulation through the known MAP parameter set of patients, with successful regulation of MAP in all cases considered.

In this paper, Modified Model Reference Adaptive controller (MRAC) is used to regulate the Mean Arterial Pressure, based on the Squirrel Search Algorithm (SSA) and Grey Wolf Optimizer (GWO) algorithm to tune its parameters. The suggested controller gives better performance and accuracy and more effective in handling the environmental changes and unknown parameter variations. To achieve these goals, since the 1980s, different mathematical models that clarifies relationship between blood pressure and vasoactive drug injection have been investigated, one of them is the Slate model which considered here.

The remaining article is consisting of section 2 discussed the mathematical model of MAP. Section 3 describes the MRAC controller with the suggested modification, while section 4 illustrates the SSA and GWO algorithms. Section 5 contain the results of simulation and comparison between SSA and GWO algorithms. Section 6 is the final conclusion section.

2. MEAN ARTERIAL PRESSURE MODELIZATION

To identify the proper infusion, we need to ascertain the mathematical model and the modelling of blood pressure and this model general denoted as SNP (sodium Nitroprusside) model, the modelling is a complex task in bio medically involves multiple inter connected system's Slate et. al. (1980) (Slate & Sheppard, 1983; Saxena & Hote, 2012) did are search and developed an SNP model with the dynamic infusion for hypertension stabilization based on the related analysis of the patient's data. The concluded model as described below based on the behavioural properties the human system (Basha & Vivekanandan, 2019).

$$\frac{\Delta pd(s)}{I(s)} = \frac{K\, e^{-Ti\, s}\left(1+\alpha e^{-Tc\, s}\right)}{1+\mathrm{T}s} \tag{1}$$

where $I(s)$ is infusion rate, Tc is the time consuming by the drug to transported via the patient's body, the time Ti is the initial transport lag from injection sit, α is the drug fraction recirculation, the constant K is the drug sensitivity, T is the time required for Dispersal and biological transition of the drug (Urooj & Singh, 2019; Jones & Tham, 2005).

3. MODEL REFERENCE ADAPTIVE CONTROLLER (MRAC)

The adaptive controller is control scheme that used widely to design the advanced control systems for accurate performance and very influential to handle the environmental changes and the unknown parameter variations. The adaptive controller include two loops, the internal loop (adjustment of parameter loop) and the external loop (feedback loop).The MRAC is usually used to design an adaptive controller which works based on adjusting the control parameters such that the actual output of the plant follow the output of the desired reference model that has the same input reference signal (Jain & Nigam, 2013). This paper deals with designing of adaptive controller with MRAC scheme using SSA and GWO algorithms for optimizing control parameters. Fig. 1 present the patient's model and MRAC controller diagram. The control signal up represents the rate of infusing drug which is a linear combination of the error feedback $K_d\ e_d$,reference model output $K_m\ Y_m$ and reference model input $K_e\ U_e$. The law of the adaptive controller involves the values of the reference model output " Y_m", tracking error

" e_d", and the reference model input " U_e" with a suitable adaptive gain (K_e, K_m and K_d). The adaptive control equation is given by (Enbiya, Mahieddine & Hossain, 2011):

$$up(t) = K_e\, U_e\,(t) + K_m\, Y_m\,(t) + K_d\, e_d\,(t) \quad (2)$$

The suggested modification is tuning the gains (K_e, K_m and K_d) online using Adaline neural network See Fig. 2.

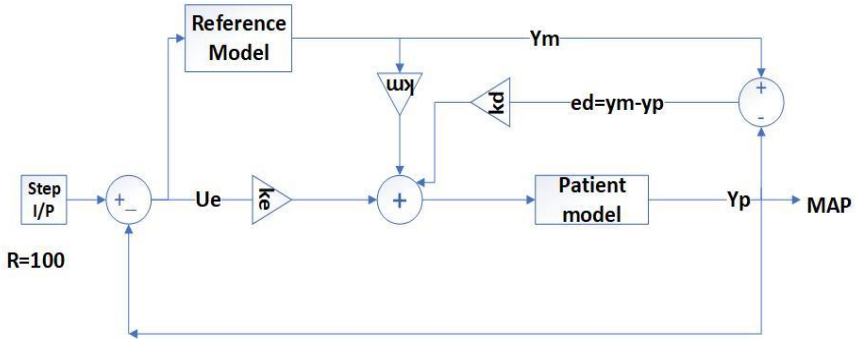

Fig. 1. The block diagram for the patient's model with MRAC

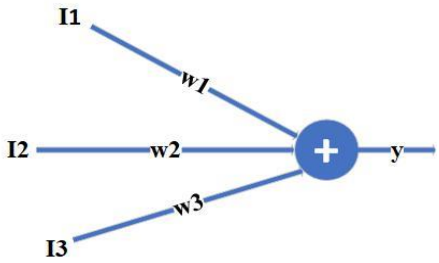

Fig. 2. The ADALINE Network Architecture

The neuron weights W_1, W_2 and W_3will act as the gains (K_e, K_m, and K_d) of the MRAC controller. With the help of some learning algorithm the weights of the neural network are modified to attain the desired goal. The inputs I_1, I_2 and I_3 will act as U_e, Y_m and e_d respectly. These input signals are multiplied with their corresponding weights and act as the input to the single neuron the transfer function of the output neuron is linear function. The least mean square error algorithm adjusts the weights has been given by (Saeed Al-Khayyt, 2017):

$$K_e(t+1) = K_e(t) + \eta_e\, e\, U_e \quad (3)$$

$$K_m(t+1) = K_m(t) + \eta_m\, e\, Y_m \quad (4)$$

$$K_d(t+1) = K_d(t) + \eta_d\, e\, e_d \quad (5)$$

where η_e, η_m and η_d is the learning value, e is the error between the output system and the desired output. note that the value of the basis is considered zero.

The various steps in tuning a MRAC controller using Adaline neural network are as follows:

Step1: Choose random values for the weights.

Step2: Calculate the error which is the difference between the reference input and the output and multiplied with an optimized gain K_{og} to obtain a better closed loop response.

Step3: The gains of MRAC controller are decided by least mean square error algorithm.

The output of the single neuron act as the control signal which regulate the amount infusion rate of SNP. The learning values (η_e, η_m and η_d) and the optimized gain K_{og} are optimized using two algorithms SSA and GWO algorithms.

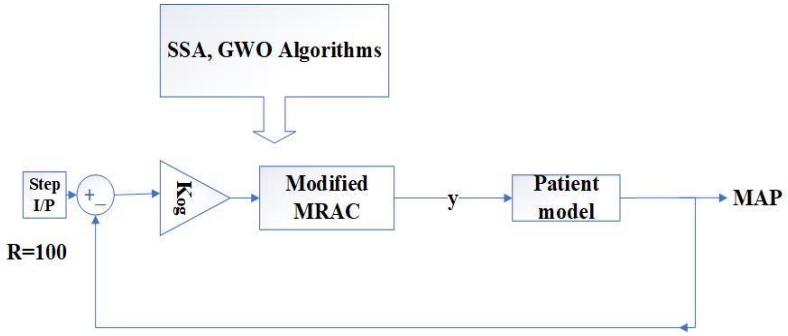

Fig. 3. The suggested controller with patient's model

4. OPTIMIZATION ALGORITHMS

4.1. The Squirrel Search Algorithm

This algorithm (SSA) Suggested et al. in 2019 by Mohit Jain. it was a novel nature-inspired algorithm for optimization, (SSA) algorithm consist of four the search processes of flying squirrels: (i) there are n flying squirrels and n trees and only one squirrel on one tree, (ii) each flying squirrel is tries to find the food so each one searching for food individually, (iv) there are only three types of trees such as normal tree, oak tree and hickory tree (which is the favour tree) in forest only three oak trees and one hickory tree in the forest (Hu, et al., 2019). The following steps explained the operation of this algorithm (Khan & Ling, 2020):

Step 1: Initialization Let that the number of the population is *N*, the upper and lower bounds of the search space are Fsu and Fsl, and start the loop iteration, N individuals are randomly produced according to equation:

$$fsi = Fsl + rand(1, D) - (Fsu - Fsl) \quad (6)$$

Step2: Evaluate the fitness value for each individual based on the least-square error (LSE) criterion. ranking the fitness values of the individuals in ascending order, the squirrels are classified into three types: (i) Fh squirrels located at hickory trees (the best food resource for the squirrels), (ii) Fa squirrels located at acorn trees (takes second place food resource for the squirrels), (iv) Fn squirrels located at normal trees (no food).

Step3: Update the Position (winter strategy). All squirrels try to move to the hickory trees or acorn trees, the positions of each squirrel updated according to the updating equation:

$if \;\; p > pdp$

$$fsi(t+1) = fsi(t) + dg\ Gc\ (fth - fsti) \quad (7)$$

$Random\ location \qquad otherwise$

$if \;\; p > pdp$

$$fsi(t+1) = fsi(t) + dg\ Gc\ (fta - fsti) \quad (8)$$

$Random\ location \qquad otherwise$

where: pdp is the predator appearance probability, Gc is the constant with the value, dg is the gliding distance which can be calculated by this equation.

$$d = \frac{hg}{tan(\Phi)\ sf} \quad (9)$$

where: hg the constant, sf the constant, $tan(\Phi)$ is the angle of gliding which can be calculated as shown below:

$$tan(\Phi) = \frac{D}{L} \quad (10)$$

$$D = \frac{1}{2p\ v\ s\ CD} \quad (11)$$

$$L = \frac{1}{2p\ v\ s\ CL} \quad (12)$$

where p, v, s, CL and CD are all the constants.

Step4: Seasonal Transition whether the season changes is judged according to these equation:

$$S_c^t = \sqrt{\sum_{k=1}^{D} (F_{ai,k}^t - F_{h,k}^t)} \; i = 1,2, \dots, Nfs \tag{13}$$

At the beginning of each iteration, the whole population is in Winter, so all the individuals are updated in the way introduced step (3) When the season turns to summer, the individuals updated location, by these equations:

$$FS_{inew}^{t+1} = Fsl + Le' \, vy(n) \, (Fsu - Fsl) \tag{14}$$

$$Le' \, vy(n) = 0.01 \, \frac{r_a \, \sigma}{|r_b|^{1/\beta}} \tag{15}$$

$$\sigma = \left(\frac{\Gamma(1+\beta) \, sin\frac{\beta\pi}{2}}{\Gamma\left(\frac{1+\beta}{2}\right) \beta \, 2^{\frac{\beta-1}{2}}}\right)^{\frac{1}{\beta}} \tag{16}$$

where: $\Gamma(x) = (x1)!$

Figure 4 illustrates the procedure of SSA algorithm.

4.2. Grey Wolf Optimizer

Mirjalili proposes the GWO algorithm in 2014. It is suggested in order to find prey According to the Gray wolf social hierarchy Hunting practices are the solution to the problem of optimisation. The social hierarchy is represented by splitting the quest agent population into four groups of wolves, i.e., alpha, beta, delta, and omega, based on their fitness. In order to mimic the hunting actions of grey wolves, the quest technique is modelled using three stages that encircle and attack the prey (Precup, et al., 2017).

The GWO comprises the steps established by the revision of the measures (Mirjalili, Mirjalili & Lewis, 2014):

Step1: The initial random grey wolf population, represented by *N* agents' positions in the *D* dimensional search space, is generated. The iteration index is initialized to *t* = 0 and the maximum number of iterations is set to *T*.

Step 2: The performance of each member of the population of agents is evaluated by simulations conducted on the Model Reference Adaptive Control based on the least-square error (LSE) criterion.

Step 3: x^{α}, x^{β}, x^{δ}, which represented alpha, beta, delta positions are identified according to the first three best solutions.

Step 4: The agents are moved to their new positions according to the Equation below.

$$X_{new} = \frac{(x_1 + x_2 + x_3)}{3} \tag{17}$$

x_1, x_2, x_3 calculated from equations below.

$$x_1 = x^{\alpha} - A_1 D_{alpha} \tag{18}$$

$$x_2 = x^{\beta} - A_2 D_{\text{beta}} \tag{19}$$

$$x_3 = x^{\delta} - A_3 D_{\text{delta}} \tag{20}$$

$$A_1, A_2, A_3 = 2a\, r_1 - a \tag{21}$$

r_1 is random value having different value for $A_1,\ A_2, A_3, a$ is variable value.

$$a = 2 - t \left(\frac{2}{T}\right) \tag{22}$$

$D_{alpha}, D_{\text{beta}}, D_{\text{delta}}$ are computed from equations below.

$$D_{alpha} = abs(c_1\ x^{\alpha} - X_{current}) \tag{23}$$

$$D_{beta} = abs\left(c_2\ x^{\beta} - X_{current}\right) \tag{24}$$

$$D_{delta} = abs\left(c_3\ x^{\delta} - X_{current}\right) \tag{25}$$

$$c_1, c_2, c_3 = 2r_2 \tag{26}$$

$r_2$is random value having different value for c_1, c_2, c_3.

Step 4: If all iteration will be finished, stop the search and display the value (alpha position is best solution). Otherwise, repeat step (2) to step (4) before iterations have been finalized.

Figure 5 illustrates the procedure of the GWO.

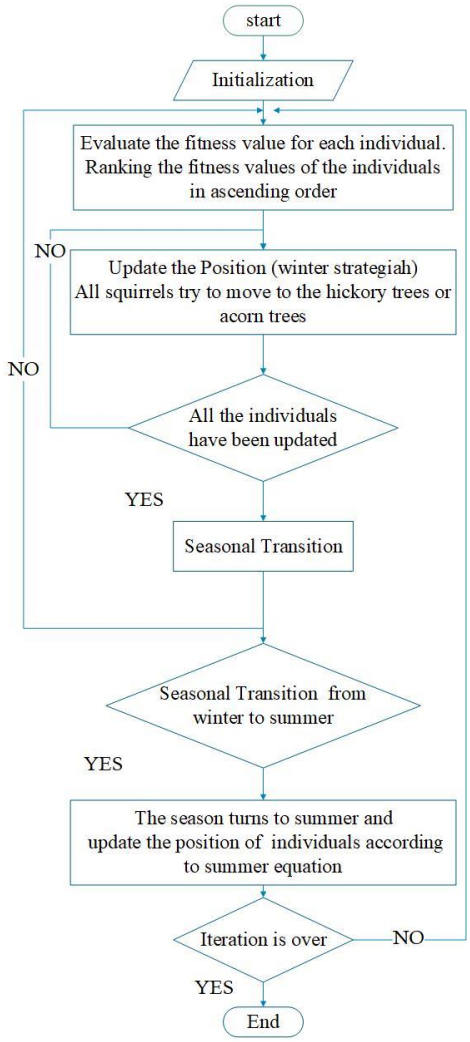

Fig. 4. SSA Procedure

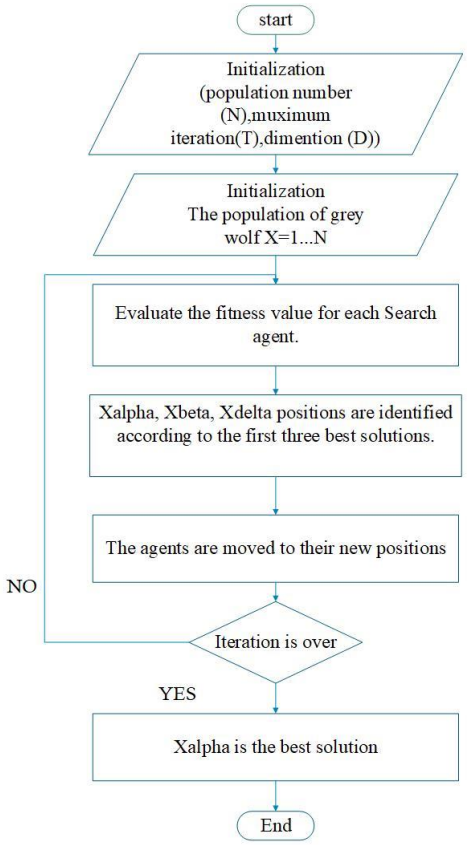

Fig. 5. GWO Procedure

5. SIMULATION AND RESULTS

The simulation results of the suggested controller based on the SSA, GWO algorithms for controlling MAP regulation model have been presented in this section. The control simulated with patient model using MATLAB program. The initial value of the patient MAP is chosen as 140 (mmHg), The control objective is to reduce the MAP to 100 (mmHg) for three cases (sensitive patient, normal patient, insensitive patient) without disturbance, the parameters of MAP model illustrated in Table (1).

The parameters SSA and GWO are considered in this Table (2) Shown. The simulation response of MAP model after regulated it by the suggested controller (Model Reference Adaptive Controller) which tuned by the SSA and GWO algorithms as illustrated in Table (3,4*)* is shown in Figure (6) and Figure (7) respectively. Figure (8) and Figure (9) show the controller signal (SNP Injection).

It is obvious It from Figure (6) and Figure (7) that the controller satisfies the design requirement by making the MAP system follows the desired level with small steady state error (e_{ss}), settling time (t_s), drop time (t_d) and undershoot (M_p) as shown in Table (5).

Table (5) illustrates that the performance of the Modified Model Reference Adaptive Controller optimized with SSA algorithm is nearly similar to the performance of controller when optimized with GWO algorithm.

From the results it can be noted that the controller has less settling time, drop time when optimized with SSA algorithm.

Tab. 1. Model parameters (Nirmala, Muthu & Abirami, 2013)

Model variables	SEN (underneath normal)	NOR (normal)	INS (above normal)
α	0	0.4	0.4
Ti	20	30	60
K	–9	–0.7143	–0.1786
T	30	40	60
Tc	30	45	75

Tab. 2. The SSA and GWO algorithms parameters

SSA parameter	value	GWO parameter	value
Search agent no (S)	20	Search agent no (N)	20
Max iteration (T)	10	Max iteration (T)	15
Dimension (D)	3	Dimension (D)	3
Upper limit (Fsl)	0	–	–
Lower limit (Fsu)	0.5	–	–
predator appearance (Pdb)	0.25	–	–

Tab. 3. Optimal controller parameters (η_e, η_m, η_d)

	η_e	η_m	η_d
SSA Algorithm	0.0019	0.00186	0.00227
GWO Algorithm	0.00218	0.0004	0.0024

Tab. 4. Optimal controller parameter (K_{og})

Optimized Gain (K_{og})		
Case	**SSA Algorithm**	**GWO Algorithm**
Sensitive	–0.0017	–0.0014
Normal	–0.0082	–0.0075
Insensitive	–0.0247	–0.0226

Tab. 5. The evaluation parameters of simulation results for three cases

SSA Algorithm					
Case	M_p **(mmHg)**	t_s **(sec)**	t_d **(sec)**	e_{ss} **(mmHg)**	**SNP (ml/h)**
Sensitive	0.1403	197.9941	119.6477	$1.543 \cdot 10^{-6}$	4.444
Normal	0.03229	249.8644	134.9153	$3.602 \cdot 10^{-5}$	40.02
Insensitive	0.0313	377.4166	205.0418	0.00074	160.5
GWO Algorithm					
Sensitive	0.0026	266.1911	133.4159	$7.492 \cdot 10^{-5}$	4.444
Normal	0.0376	277.2142	158.1251	$3.838 \cdot 10^{-5}$	40.02
Insensitive	0.0528	377.1661	205.3626	0.000689	160.23

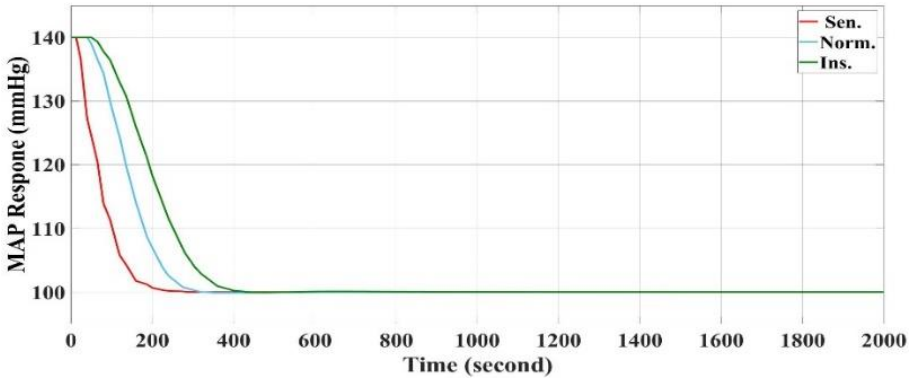

Fig. 6. The response of MAP according to the MRAC optimized with SSA

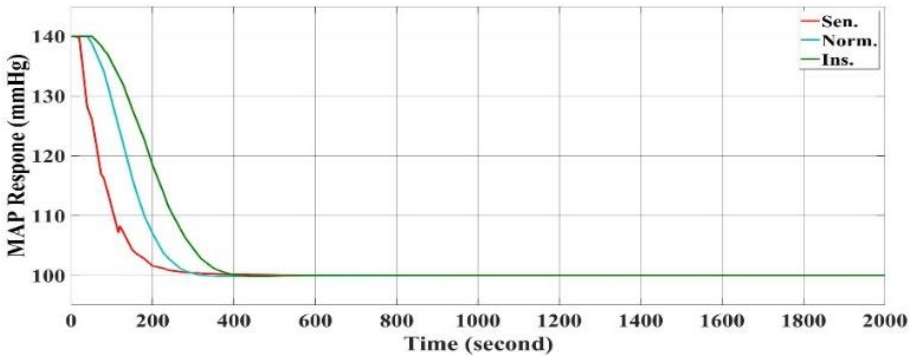

Fig. 7. The response of MAP according to the MRAC optimized with GWO

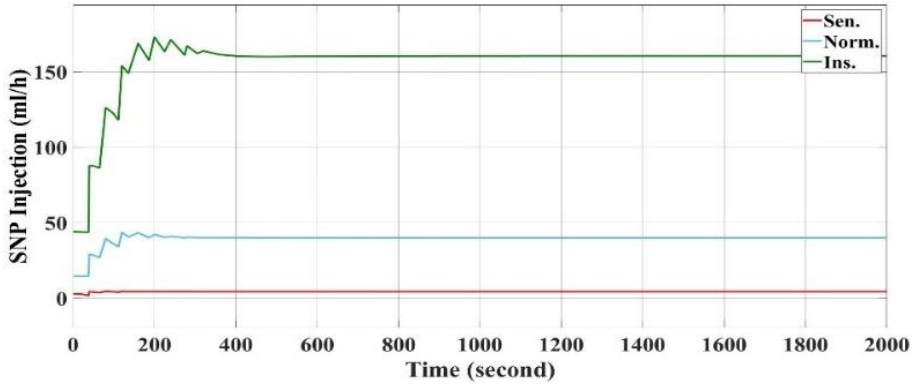

Fig. 8. SNP Injection according to the MRAC Optimized with SSA

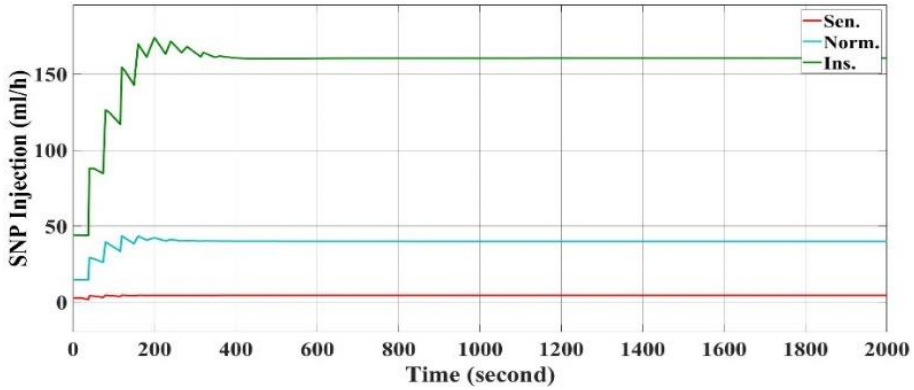

Fig. 9. SNP Injection according to the MRAC Optimized with GWO

6. CONCLUSION

The paper has presented an adaptive single-drug control scheme for MAP control. The suggested controllers designed and evaluated by simulation results for different variations in patients (normal, sensitive, and insensitive). The single drug which is used is the Nitroprusside. The results of the simulation have shown that MRAC is more efficient in regulating the MAP by calculated the infusion rates of the SNP. In order to improve the characteristics of the controller, SSA, GWO algorithms have been applied. For future work we suggest use same controller in multi input multi output system rather than single input single output system to regulate the mean arterial pressure and cardiac output using two drugs: dopamine and Nitroprusside.

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e-Commerce, customer-centric, cinema, e-booking

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A CUSTOMER-CENTRIC APPLICATION FOR A CINEMA HOUSE

Abstract

Imagine a cinema with different branches and because of diverse regions, there may be a need to have different services for such regions. Uniformity is needed for systems like this. In this research, we developed a customer-centric online booking system for a cinema house called FLOW Inc. We used Hypertext Mark-Up Language, Cascading Style Sheet and JavaScript for the front end and MySQL database as the back end; and PHP as the scripting language. The system was implemented using the XAMPP package and Apache as the server. It was successfully tested on a computer system with a 4GB RAM and a CORE i5 processor with a processor speed of 2.16GHz.

1. INTRODUCTION

Over the years in our contemporary world, the cry for autonomy and restructuring in several sectors have been growing wildly, everyone wants to be independent. A child wants to gain freedom as fast as possible, a local government wants autonomy, and states are clamoring for restructuring so that it could be easier to split

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problems and successes according to their knowledge. Although I do not tend to support or oppose autonomy and independence for selfish gains, I believe it could be of help in building a web-based application. Building an e-Commerce system with individual customers in mind as a different entity would mean each unit in an organization solves their problems individually and expertly to soothe customers. A marketing department should know what best to do with its interface better than when a jack of all trades is handling it

With the noticeable growth in the cinema industry in Nigeria and as the Nigerian Communications Commission (NCC) reported that the number of internet users in Nigeria as at December 2018 was about 111.6 million persons (Edubi, 2019). With this statistic, information technology can help customers in this regard through online booking to easily access the cinema services as well as book and make payments online. This system has kicked off in the country already although not much people are using the system because of trust issues (Benedict, 2018) and its irregularities as I once experienced at a top Nigerian cinema house, the system still seems to have a long way to go in order to be widely accepted in this nation.

1.1. E-commerce and e-booking

It has not been so long e-commerce was birthed. It is a very recent occurrence of the late 90s; the journey has been brief but interesting. The early years were a time of explosive growth and extraordinary innovation, beginning in 1995 with the first widespread use of the Web to advertise products. This period was capped in March 2000 when stock market valuations for dot.com companies reached their peak and later began to collapse. A period of reassessment occurred, followed by strong double-digit growth through the current period. The misconception about e-Commerce being just about buying and selling also led to an extensive description of e-Commerce and Kalakota and Whinston (1997), defined e-Commerce as a range of different perspectives. They are:

1. A communication perspective: this is the delivery of information, products or services or payments by electronic means.
2. A business perspective: this is the application of technology towards the automation of business transactions and workflow.
3. A service perspective: this is enabling cost-cutting at the same time as increasing the speed and quality of service delivery.
4. An online perspective: this is the buying and selling of products and information online.

From this definition, it can be seen that most people only see one perspective of e-Commerce and fail to see the other sides of e-Commerce. It also includes some presale and post-sale activities.

E-Booking, on another hand, is making a reservation or appointment for a service via the internet. With the e-booking system, customers can book for show tickets online and pay via the internet beforehand using their credit cards, master cards, etc. After a booking has been made online, the customer will receive a code or serial number which will be unique for entry and also a form or ticket with the code on it will be printed by the user which will also have the passport of the user on it for security against thieves. With the code, the user can also go online to request for another ticket in case the ticket gets lost or stolen. This differs a lot from the traditional queuing for tickets or to book for tickets for very long hours, in this system a traditional database. The details of the e-Booking transaction are automatically recorded in the database on confirmation of payment and as such the database can be easily transferable from one place or computer to another.

There are other times when a customer wishes to make inquiries concerning certain products or service but in the traditional method of e-Commerce, the user would have to make these inquiries in person no matter how busy he or she is. There are periods when the phone lines of the organization might be busy or unavailable when enquiries need to be made making the client still need to come physically to check for the good or product needed. There are also times when lots of customers will come to enquire about certain goods and services at the same time thereby causing long waits before being able to access the customer service.

Thankfully, we have the media but not everyone subscribes to every available channel of the media and even those who do might still miss whatever advert or promotional offer a company puts up for their products or services and this goes a long way to say that people will be ignorant of whatever freebies a company provides to the society and because people will still need to visit the store to find out, it does not help to promote their business as much as they would like. Clients who do not have any of the media facilities might rather go to stores nearby because they are ignorant of the freebie your business offers.

2. RELATED WORKS

Enache, (2018) developed an Event Ticketing Software. The participants can buy tickets or register for free events and planners have information about the guest list. The system also simplifies the registration process for participants and can receive payment before an event and can organize the daily registration process. The project works with a database that runs on the MySQL server while the front end runs on a JavaScript and HTML. The system addressed critical design and implementation issues for an Event Ticketing System and the potential problems for such a fully automated, high-availability system. However, the security of the system is not guaranteed i.e. user details may not be so secure.

Akinyede, et al., (2017) developed an online booking system for a cinema house to cater for the stress that arises as a result of queuing manually in cinemas The hustling and jostling in the cinema houses will also be reduced through the system implementation. The system was implemented with design components such as web browsers, HTML, CSS, JavaScript, PHP, a web server and a relational database (MySQL). The system is also designed to help improve the rate at which people watch movies in Nigeria's cinemas. However, the limitation of this work as interesting as it looked was that there was no room for feature updates or components upgrading.

Kujanpää, (2018) developed a new browser-based online booking system for the Turku University of Applied Sciences Cisco Laboratory. This system was birthed because the current system was out-dated and system functionalities and user interface requirements needed to be updated and to improve the usability and the security of the system. PHP5 and MySQL were used as development tools for the server-side development and Twitter Bootstrap front-end framework including HTML, JavaScript, and CSS for the browser side. It concentrated on how to develop a booking system for a specific situation and how to achieve the best results on the front and back-end. However, the limitation of this work was that the development was to meet a specific need and isn't flexible enough to meet other booking needs in the institution.

Yang, (2012) developed a Homestay online booking and management system. This system was developed for ease of access for global voyagers who need better and cheap accommodation to Homestay via the web and other computers aided tools and to simplify the booking process and to also enable searching and database synchronization. The system uses the first come first principle for customers. The user interacts with the system via the system interface design with PHP to the database design developed with Microsoft Access. This system was developed by using Microsoft Visual Basic. NET. The system was developed in such a way that Customers can; check room availability and homestay information, leave a message for each homestay, book the available room/house through the internet. While Homestay Keepers can update the information of the rooms, answer notes and follow the customers' message. However, the system was designed only for people in a particular region called Kuantan while finance also proved a major threat to the system.

Mateos, et al., (2012) developed a rig booking system designed for the LiLa (Library Laboratory) Portal, a web portal that makes virtual and remote experiments available on the Internet. This system was developed to maximize the student access to the experiments, to schedule access to the remote experiments and to accommodate as many students as possible and to help them organize their activities in the portal. The system runs on an application server and uses a database to persist experiment information and user interactions. It also provides an interface that allows searching, classifying and commenting experiments; and makes the experiments available on the Internet. The system describes a solution

to control access to virtual laboratories and remote experiments using learning objects, it gives schools the flexibility of accessing the system functionalities via their own Learning Management Systems and simplifies interchange. However, there is still a need for improving the metadata-based search functionality to help teachers find the experiments they can include in their courses and there is also still a need for improving the access control to help content providers verifying the users accessing remote experiments through the system.

Hang (2011) designed and implemented a Cinema Online Booking System. This system was developed to ease booking transactions, thereby reducing on-site manpower requirements and to allow the industry to focus on improving other services. The system was developed on JSP (Java Server Pages) and the server-side execution environment required Apache Jakarta Tomcat 5.0, Java 2 Platform, Standard Edition (J2SE), v 1.5, and MySQL 5.0, the client-side was designed with JavaScript. The system enabled High efficiency and Low-cost ticketing network management system. However, the seats to be booked are automatically selected for the user.

Björk (2011) worked on Adapting a Hotel Reservation System to Camping Reservation. This was done to evaluate how to adapt the IBE for camping reservations. The system will also be used by the marketing department to sell the concept of a reservation system to chains of campgrounds. A review of existing reservation systems and a user survey was conducted. IBE (Internet Booking Engine) was proposed for the client-side program while the implementation was done in Java and Wicket, a Java-based web framework developed by the Apache Foundation. Critical design and implementation issues for an Event Ticketing System and the potential problems for such a fully automated, high-availability system was arrived at after the work was done. However, in the system, no features, such as an interactive map of the campground was used and also, the IBM was a little underdeveloped during the project, therefore, causing complications in making changes to the program

Fragidis (2007) developed A Service Model for Customer-Centric Electronic Business. This was done to analyze customer participation in services and considered the value-adding opportunity being offered and prepare a service model for it from the data collated. A conceptual framework was then designed for customer participation in services based on customer needs, the services being offered and its outcomes. A service model was brought forward which would cater to the association of needs, services, and experiences. However, in this model, situational needs (constraints of services) were not catered for – e.g. a four-member family cannot rent a two-seat car or a pet owner cannot go to hotels that do not allow pets and also there was no room for extending the required services (e.g. an elder needing assistance going to the theatre).

3. SYSTEM ANALYSIS AND DESIGN

The system architecture is divided into three (3) tiers namely: Front tier, Middle tier, and Back tier. These also form the components that were used to design the system. The tools used in carrying out this task will be HTML (Hypertext Mark-up Language) which incorporated the CSS (Cascading Style Sheet) and Java Scripts for the front-end design. PHP (Hypertext Preprocessor) will be the programming language that used as the middle tier, which will establish the connection between the backend and frontend of the system. The application backend consists of a MySQL database. This stores all the necessary information about the administrator and users of the system. The application also allows multiple ticket purchases and as such tables were designed to have space for it. Figure 1 describes the main components and architecture model of the system and how they interact with each other.

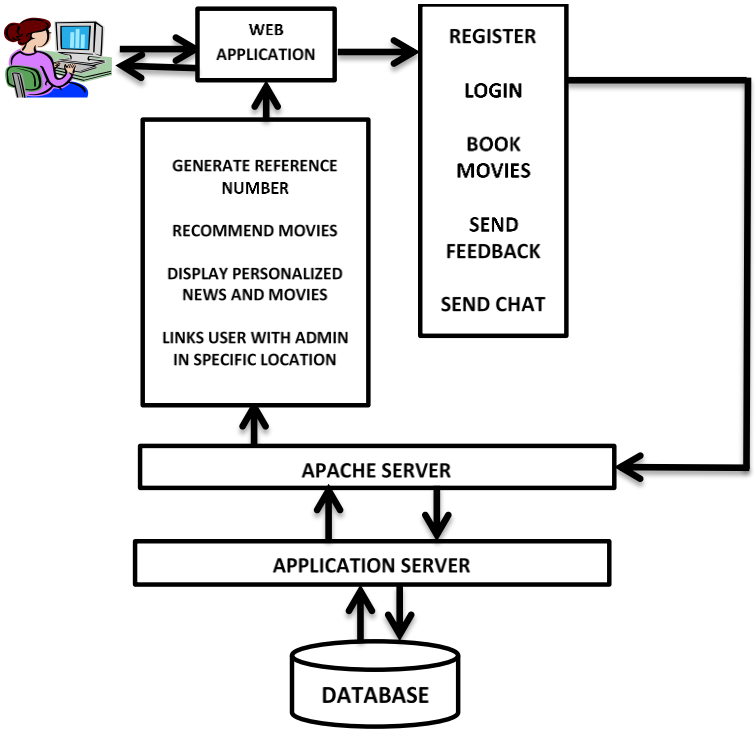

Fig. 1. System Architecture

3.1. Mathematical Model of the System

In integrating the news, promotional updates and movies on the system.

Let the news N_m be such that N_m= $\{N_0, N_1, N_2, N_3 \ldots\ldots N_{k-1}, N_k\}$, let the Promotional offers O_m be such that O_m= $\{O_0, O_1, O_2, O_3 \ldots\ldots O_{k-1}, O_k\}$ and let the uploaded movies U_m be such that U_m= $\{U_0, U_1, U_2, U_3 \ldots\ldots U_{k-1}, U_k\}$.

Where m represents individual movies. Therefore, the total number of uploaded news N:

$$\sum N = N_k. \tag{1}$$

The total number of Promotional offers O:

$$\sum O = N_k. \tag{2}$$

The total number of uploaded movies (U):

$$\sum U = U_k. \tag{3}$$

Every functioning cinema house will have available movies currently showing or that will be shown later. There is no cinema without a movie showing, therefore concerning this, the number of available movies (M) is:

$$M \leq \mathrm{U}: M \geq 1.$$

To get the total sale amount, the following assumptions are made:

S = the total number of seats.

$A_{mk}, k = 1, 2, 3, 4, \ldots, z$ are available seats for each movie.

$A_{mk} = A_{m1}, A_{m2}, A_{m3}, \ldots\ldots A_{mz}$ (where z is the number of the last seat – if the seats in a theatre are 25 in all, then z will be 25):

$$A_m = \sum_{k=0}^{z} A_{m,k}, \tag{4}$$

where A_m – total number of available seats for each movie,

$$UA_m = S - A_m, \tag{5}$$

where UA_m – total number of unavailable seats.

Let the selected seats (SS_m) by customer (c) be $SS_{m,c}$, $c = 1,2,3, \ldots, n$: $SS_{m,c} \in A_{m,k}$. The total number of selected seats for each movie (SS_m) be:

$$SS_m = \sum_{c=0}^{n} \mathrm{SS}_{m,c}. \tag{6}$$

The number of unbooked seats (US_m) will therefore be:

$$US_m = S - SS_m. \tag{7}$$

The seats will be termed as full and un-selectable anymore or customers will be unable to book any more seats if (6) = (4) or if (7) = 0 – i.e. $SS_m = A_m$ or $US_m = 0$.

Unbooked seats mean that the seats aren't filled up by the customers whereas the unavailable seats mean seats that have been either booked by other customers or for some reason are not up for sale in that theatre. There can be several reasons for a seat not to be available in a theatre.

Let the total sale per movie (T_m) be

$$T_m = SS_m * P_m, \tag{8}$$

where P_m, is the price per movie.

4. SYSTEMS IMPLEMENTATION AND RESULTS

The user interface is such that the users would have a wonderful user experience tailored particularly for them. The administrators would also be given power to ensure that the users get what is peculiar to them. The choice of colors, images and the flow of the site is such that they are designed according to standard patterns. For example, the system contains a logo instead of the name of the website so that the header would not be too cumbersome; the top film banners are in a slide bar to make the site look more interesting and dynamic.

The user interface is separated into two, that of the administrator and the customer. The administrator's interface which is entirely different from the customer's interface is used for managing the website majorly. Below are some screenshots of what the website looks like.

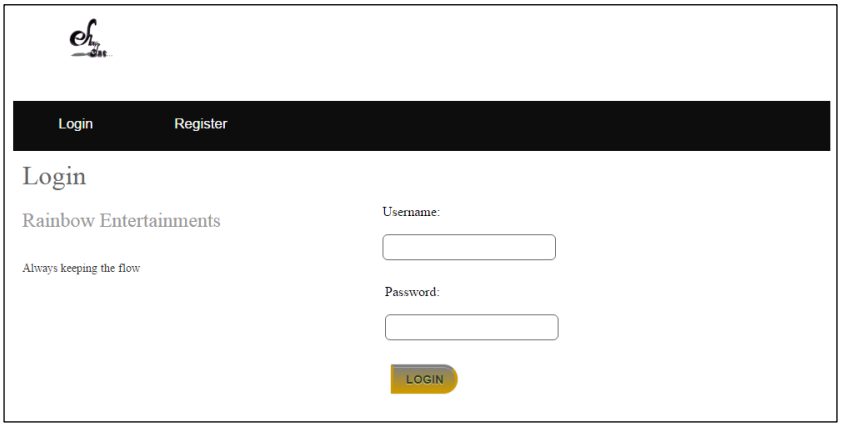

Fig. 2. Login Page of the User

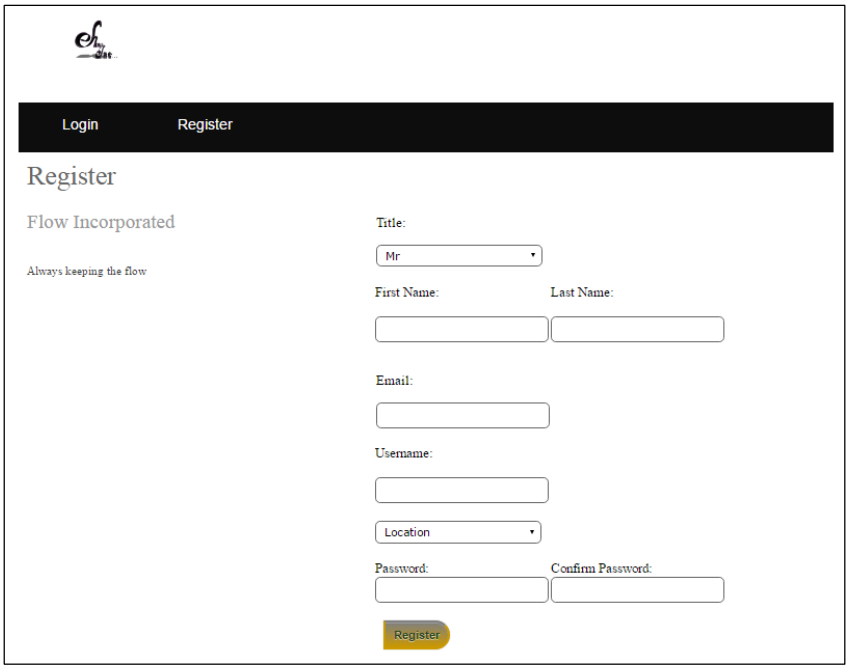

Fig. 3. Register page for the user

This login page in Figure 2 is for the user to log into the system to be able to access information and other activities on the website while the register page for new customers to create an account is shown in Figure 3.

The homepage, which the user will be directed to after successful entry into the website, is shown in Figure 4. It shows the major things which the site entails. It also displays information peculiar to the user. The user will also get to access news and promotional offers from the homepage. The space for searching for a movie is also done on the homepage after which the user proceeds to book.

From Figure 4, a user from Lagos is already getting tailored information about Lagos; if the Location of the user were in Akure, only information about Akure users will be displayed on his or her homepage.

The movie details page in Figure 5 is for viewing basic information about a particular movie selected on the page by the user.

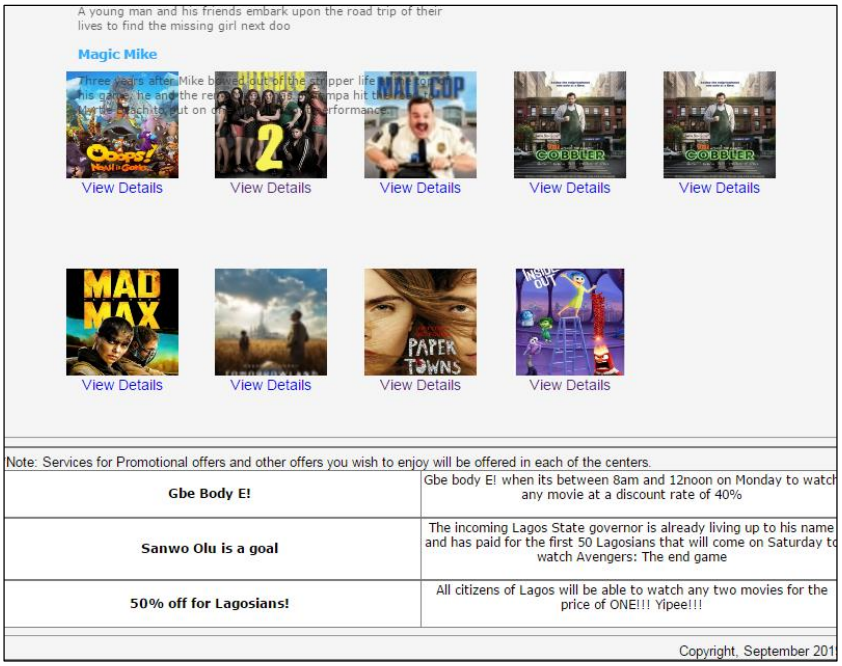

Fig. 4. Homepage for the user

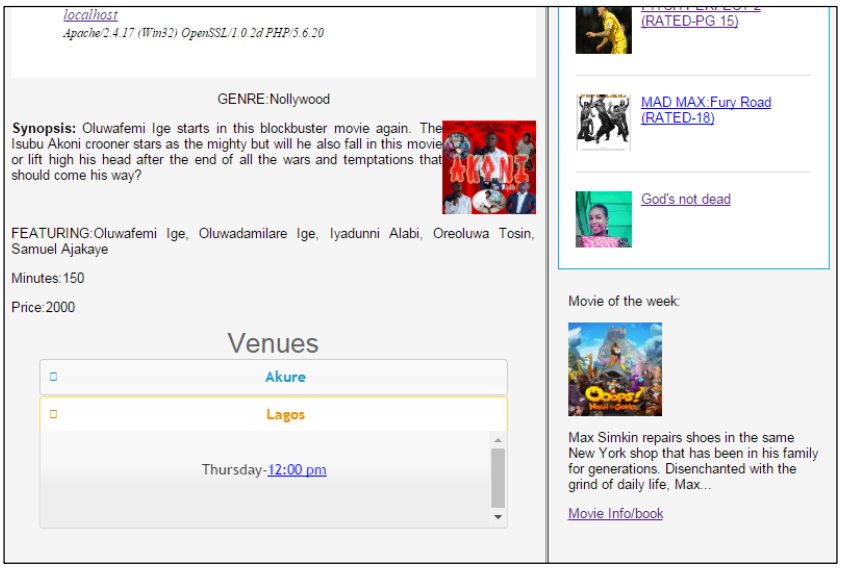

Fig. 5. Movie details and book movie page for the user

Figure 6 shows the admin page which contains several hyperlinks that can be navigated to add movies, add news, upload banners and promotional offers as well as verify reference number. After users have successfully booked a movie, there is a need for verification from the administrators' end. When the user gets to the cinema house, with the reference number on the printed slip or peradventure a snapshot of the booking slip from the website, the administrator can confirm the time, venue and other details of the movie and the customer that booked. Once a customer has been verified, the booking number is marked as verified so that no other customer can use that number anymore.

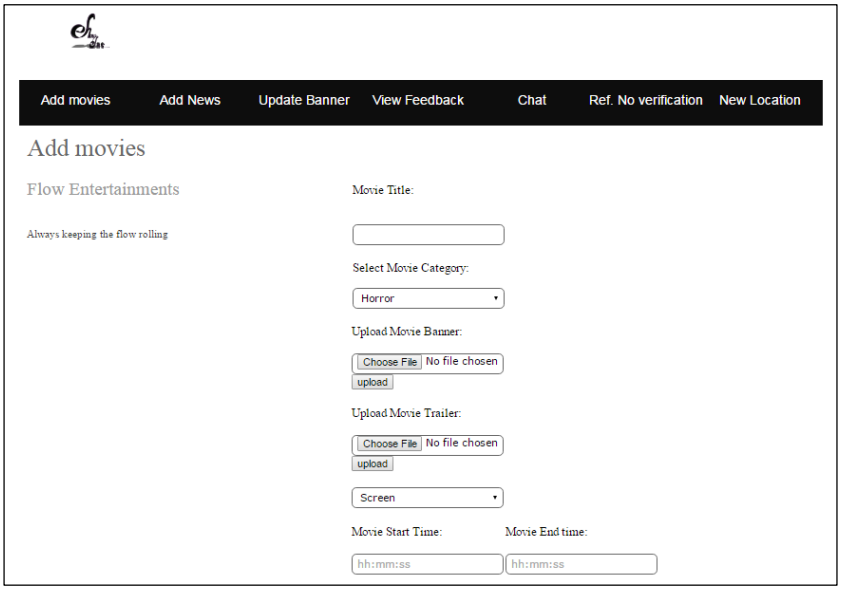

Fig. 6. Admin page

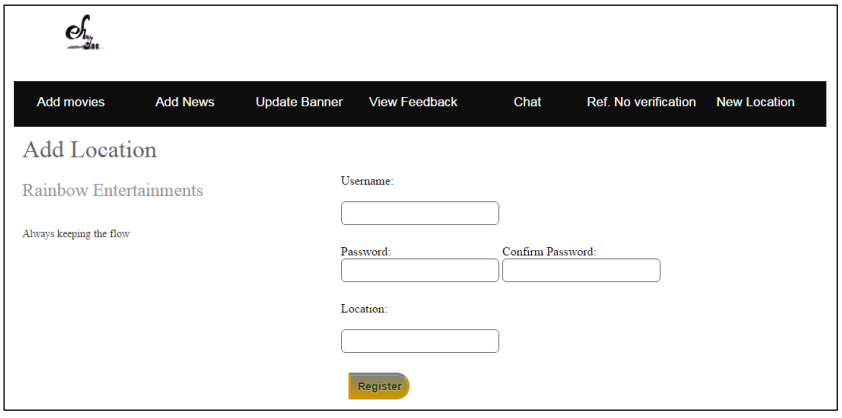

Fig. 7. Add location for overall admin

Movies can be added by the admin of different locations but once a movie is added by a Lagos admin, only people in Lagos can view the movie but a general admin can add movies to all and/or any location while the same scenario plays out for news and banner uploads.

The page that is not for the general admin doesn't have the New Location on the pane meaning only the general or overall administrator can add a new location anytime the cinema is birthed at a new place but as shown in Figure 7, the general admin can add a location in case the company expands.

5. CONCLUSION

It can be said with full assurance that if the system is fully implemented, all the advantages of an online booking system stated in chapter one such as time-saving, 24-hour Working service, access to service from anywhere in the world, check availability and instant collection of all guest payments (i.e. using your own merchant account/payment gateway) and much more will be achieved.

Furthermore, full implementation of this project will further improve the Nigerian cinema booking system, including in other areas of life where bookings or reservations are made, and could also increase the newly found love for movie watching in cinemas, while also helping to cut down cost of servicing extra manpower needed to run report sorting. Future work can be done in the aspect of using support vector machines to make predictions for users who can't decide what to watch.

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Distillation column, Model reduction, PI controller, Fuzzy Inference System, MATLAB tool

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FUZZY CONTROLLER OF MODEL REDUCTION DISTILLATION COLUMN WITH MINIMAL RULES

Abstract

*In this paper the control of a binary distillation column is described. This control is done with fuzzy logic, one with PI- like fuzzy controller and the other with modified PI fuzzy controller, using the minimal rules for fuzzy processing. This work is focused on model reduction of Wood and Berry binary distillation column to get the best performance. It is desired to minimize the rules in order to reduce the computation time to make a faster decision. Comparisons will be made between two versions of fuzzy controllers utilizing reduced rules to verify the outputs. The controlled variables are top composition with high concentration and bottom composition with low. To demonstrate the performance of the fuzzy PI control schemes, results are compared with a classical PI controller and optimal methods, like Differential Evolution (*DE*), Invasive Weed Optimization (IWO). The proposed structure is able to quickly track the parameter variation and perform better in load disturbances and also for set point changes. Then all the processes of the distillation column with it's fuzzy controllers are simulated in MATLAB software as the results are shown.*

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1. INTRODUCTON

Distillation is one of the most common and best understood separation methods, widely used in the process industries, e.g. in partial fractionation of crude oil, separation of noble gases, and production of distilled alcoholic beverages, etc. Hence design and operation of the distillation columns has been studied in many textbooks e.g. (Perry & Green, 2008; Nayef Ghasem, 2014; Gorak & Schoenmakers, 2014). There are many approaches in the controller design for distillation columns. A survey has been published in (Skogestad, 1997) where the focus is on the construction of the SISO loops governed by PID controllers. Design of the stabilizing controllers for unstable distillation columns was given in (Jacobsen & Skogestad,1991). Robust H∞ control of the distillation process was described in Lundstrom, Skogestad & Doyle (1999). Control of the distillation processes based on Model Predictive Control (MPC) was introduced in Cutler & Ramaker (1979). In recent years, multiple fuzzy control setups were independently investigated and verified for different distillation columns mainly on simulation scenarios (Miccio & Cosenza, 2014; Vasickaninová, Bakošová & Mészáros, 2016; Drgona, Takác, Hornák, Valo & Kvasnica, 2017). Fuzzy control provides a formal methodology for implementing a knowledge of human about a system. Since it gives a convenient method for constructing nonlinear controllers via the use of heuristic information, it is a practical alternative for a variety of control applications (Reznik, 1997). Direct fuzzy control of the distillation columns was studied in (Aaron, Antony & Kumaravel, 2018; Fileti, Antunes, Silva & Pereira, 2007), while in (Glankwamdee, Tarathammatikorn & Chattana-anan, 1999) the supervisory fuzzy system for adjusting the parameters of the classical PI controllers is proposed for a binary distillation column.

In this paper a fuzzy logic based control (PI) schemes have been proposed for distillation column. Fuzzy Inference Systems (FIS) are proposed to adjust the manipulated variables (reflux flow rate L) and (steam flow rate V) to get the desired composition of products (top XD) and (bottom XB) for a binary distillation column. To control the top (desired value = 0.98) and bottom (desired value = = 0.02) product composition two separate fuzzy inference systems has been designed. The scheme uses fuzzy rules and reasoning to determine the desired outputs based on the error signal and integral of it (version 1), while (version 2) is modified depends on the error and derivative of it.

The paper is organized as follows. Section II presents a detailed description of the distillation column. Section III is devoted to fuzzy controller synthesis. Experimental results and discussion are presented in Section IV. Robustness analysis is presented in section V and Conclusions are drawn in Section VI.

2. DISTILLATION COLUMN

The distillation column feed tank is carrying methanol and water mixtures. During the process the methanol water mixture can be heated. The light weight molecules rise to the top of the column and weighty components moves downstairs to the column. The separation takes place in a vertical column where heat is added to a reboiler at the bottom and removed from condenser at the top. Figure 1 shows distillation column.

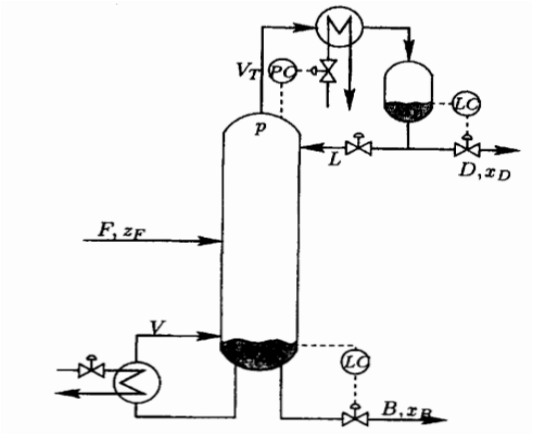

Fig. 1. Shows distillation column

In the present work, Wood and Berry distillation column model is taken for case study. The 2 x 2 MIMO process is presented by Wood and Berry (1973), Hamdy, Ramadan & Abozalam (2018). The process transfer function matrix of the distillation process is given by:

$$\begin{bmatrix} x_D \\ x_B \end{bmatrix} = G\ (s) \begin{bmatrix} L\ (s) \\ V\ (s) \end{bmatrix} \tag{1}$$

where $G(s) = \begin{vmatrix} G_{11}(s) & G_{12}(s) \\ G_{21}(s) & G_{22}(s) \end{vmatrix}$ is the system matrix For Wood and Berry is:

$$G(s) = \begin{bmatrix} \frac{12.8e^{-s}}{16.7s+1} & \frac{-18.9\,e^{-s}}{21\,s+1} \\ \frac{6.6e^{-7s}}{10.9s+1} & \frac{-19.4e^{-3s}}{14.4s+1} \end{bmatrix} \tag{2}$$

Decoupling is used to reduce the control loop interactions. The theory of decoupling control for MIMO processes has been well-established in many textbooks and papers (Luyben, 1970; Liu, Wang, Mei & Ding, 2013). In this work, and due to the advantages of simplified decoupling, so that can be used. The decoupler is:

$$D(s) = \begin{bmatrix} 1 & \frac{-g_{12}}{g_{11}} \\ \frac{-g_{21}}{g_{22}} & 1 \end{bmatrix} \quad (3)$$

The resulting transfer matrix decoupler $T(s)$ is (Luyben, 1970):

$$T(s) = \begin{bmatrix} g_{11}(s) - \frac{g_{12}(s)g_{21}(s)}{g_{22}(s)} & 0 \\ 0 & g_{22}(s) - \frac{g_{12}(s)g_{21}(s)}{g_{11}(s)} \end{bmatrix} \quad (4)$$

Then, according to equation (2) and (4), the diagonal matrix of WB column is given by:

$$\overline{g_{11}}\,(s) = \frac{12.8e^{-s}}{16.7s+1} - \frac{6.237(14.36s+1)e^{-7s}}{228.69s^2+31.89s+1} \quad (5)$$

$$\overline{g_{22}}\,(s) = \frac{-19.4e^{-3s}}{14.4s+1} + \frac{9.745(16.7s+1)e^{-9s}}{228.69s^2+31.89s+1} \quad (6)$$

To simplify the equations (5) and (6), pade approximation (Kalpana, Harikumar, Senthilkumar, Balasubramanian & Abhay, 2017) is used to remove the nonlinear term in equations and after applying some mathematical arrangements, it gets:

$$G_{11WB} = \frac{-1432\,s^4 + 7368\,s^3 + 1843\,s^2 + 155.2\,s + 3.75}{3819\,s^5 + 9491\,s^4 + 3971s^3 + 547.1s^2 + 30.05\,s + 0.5714} \quad (7)$$

$$G_{22WB} = \frac{2093\,s^4 - 2698\,s^3 - 710.1\,s^2 - 59.71\,s - 1.43}{3293s^5 + 3615\,s^4 + 1146\,s^3 + 144.1\,s^2 + 7.747\,s + 0.1481} \quad (8)$$

The diagonal transfer matrix $T(s)$ obtained in equation (7) and (8) are complex since its high order transfer functions. Controller tuning can therefore be difficult. It is then often suggested to approximate them by a simpler transfer functions to facilitate controller tuning, so model reduction techniques is used to reduce the order of these equations. Model reduction is a technique widely used in part of dynamic analysis and design of systems, in this paper, optimization technique, which is Particle Swarm Optimization (PSO) algorithm, can be selected. This algorithm is a biologically inspired algorithm and it is a population based stochastic nature. After applying the steps algorithm for PSO to equ(7) and (8), and select generation count limit = 200, population size = 50, problem dimension = 5, mutation probability = 0.06, number of elites = 2, after exploitation improvement program, the reduced transfer function for applying PSO algorithm to equation (7) is:

$$G_{11rWB} = \frac{0.8498s + 0.5051}{s^2 + 0.9989s + 0.077} \quad (9)$$

The step responses of the reduced order model and the original system are compared in Figure 2.

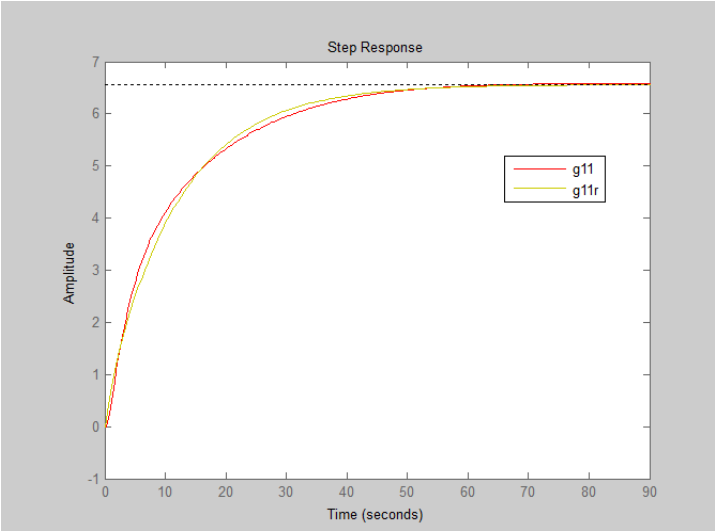

Fig. 2. Step Response Comparison of Original and Reduced Order System *G*11

For transient specifications, the original and reduced systems are compared as shown in Table 1.

Tab. 1. Transient specification comparison between G_{11WB} and G_{11rWB}

Characteristics	G_{11WB}	G_{11rWB}
Ts	48.1	45.8
Tr	27.8	25.8
Mp	0.287%	0%
Ess	6.58	6.56

And for equation (8) is:

$$G_{22rWB} = \frac{0.7324s - 1}{0.7811s^2 + 1.047s + 0.1049} \tag{10}$$

The step responses of the reduced order model and the original system are compared in Figure 3.

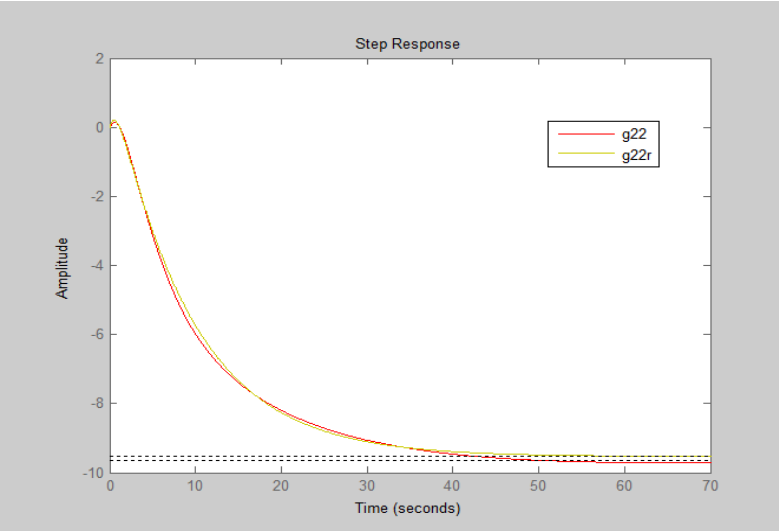

Fig. 3. Step Response Comparison of Original and Reduced Order System *G*22

For transient specifications, the original and reduced systems are compared as shown in Table 2.

Tab. 2. Transient specification comparison between G_{22WB} and G_{22rWB}

Characteristics	G_{22WB}	G_{22rWB}
Ts	39.8	37.2
Tr	22.3	20.2
Mp	0.675%	0%
Ess	-9.72	-9.53

As seen from Figures (2, 3) and Tables (1,2), the reduction models by the proposed method are very close to the original model especially in settling and rise time.

3. DISTILLATION COLUMN CONTROLLERS

There are many control strategies applied to distillation column multivariable system (Jin, Wang & Liu, 2016), (Prodanović, Nedić & Filipović & Dubonjić, 2017), in this work using decentralized decoupling structure control strategy, where the proposed method of control design involves combination of simplified decoupler, and decentralized controller (PI-like fuzzy control and modified PI fuzzy) for each loop. Figure 4 Shows controlled structure block-diagram**.**

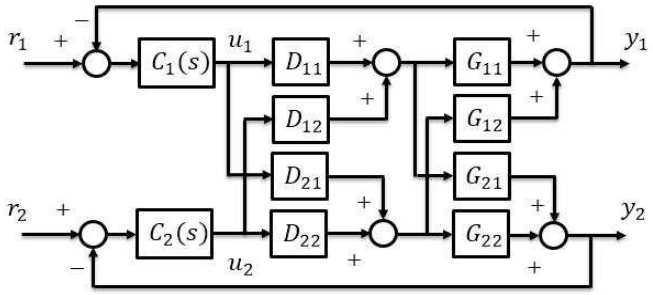

Fig. 4. Block-diagram of the proposed control system

There are many methods for desiging distillation column using fuzzy controller depends on rules minimization procedures (Hung & Benito Ferndndee, 1993; Margaglio, Lamanna & Glorennec, 1997; Farzin & Mirshekari, 2014). In this work using (9 rules) and two versions:

1. **Version 1 (PI-like fuzzy controller PILFC).**

The equation giving a conventional PI-controller is (Reznik, 1997; Avatefipour, Piltan, Reza & Nasrabad, 2014; Javadi &Hosseini, 2009):

$$u(t) = Kp \times e(t) + Ki \times \int e(t)dt \tag{11}$$

where Kp and Ki are the proportional and the integral gain coefficients.

A block diagram for a fuzzy control system looks like Figure 5.

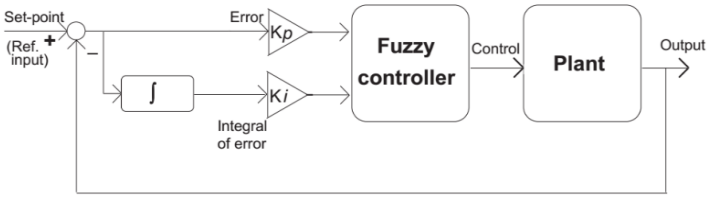

Fig. 5. A block diagram of a PI fuzzy control system (version 1)

2. **Version 2 (Modified PI- like fuzzy controller MPILFC).**

Now the fuzzy controller and the rules table have other inputs. It means that the rules themselves should be reformulated. Sometimes it is difficult to formulate rules depending on an integral error as in Figure 5. Because it may have the very wide universe of discourse, so that this version 2 has the error and the change-of-error inputs and one needs just to integrate the output of a controller. One may consider the controller output not as a control

signal, but as a change in the control signal. The block diagram for this system is given in Figure 6. It is clear that the gain factor Ki is used with the error input and Kp with the change-of-error. The change-of-control output $\Delta u(t)$ is added to $u(t-1)$. It is necessary to stress here that this takes place outside the PI-like fuzzy controller, and is not reflected in the rules themselves.

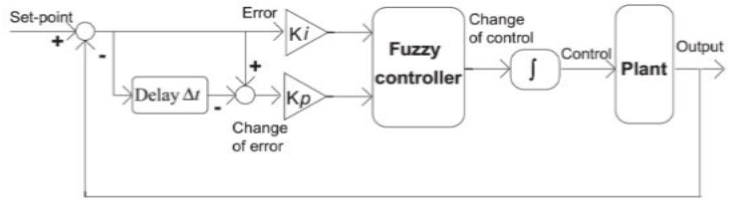

Fig. 6. A block diagram of a modified PI fuzzy control system (version 2)

The structure of FLC contains four main parts (Avatefipour, Piltan, Reza & Nasrabad, 2014) as shown in Figure 7. Fuzzification, inference mechanism, rule base and defuzzification, where fuzzification part is used for converting real input to fuzzy input. The rule-base part contains the expert knowledge in the form of a set of rules.

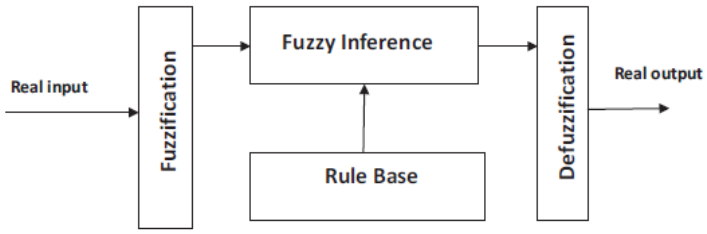

Fig. 7. Shows the fuzzy logic structure

4. RESULT AND DISCUSSION

For selection the optimum values of (Kp, Ki) in fuzzy control for both versions, using the best values (Alawad & Jebar, 2020),which is using optimization methods.

4.1. Case study 1 (G_{11rWB})

By applying the version 1 and version 2 for G_{11rWB} and use the following gains in (Alawad & Jebar, 2020): Kp = 24.501, Ki = 24.601. Figure 8 shows the membership functions of version 1 for two inputs, while Figure 9 shows the output and Figure 10 shows the membership functions of version 2 for two inputs. Figure 11 shows the output.

a) for input1 **b) for input2**

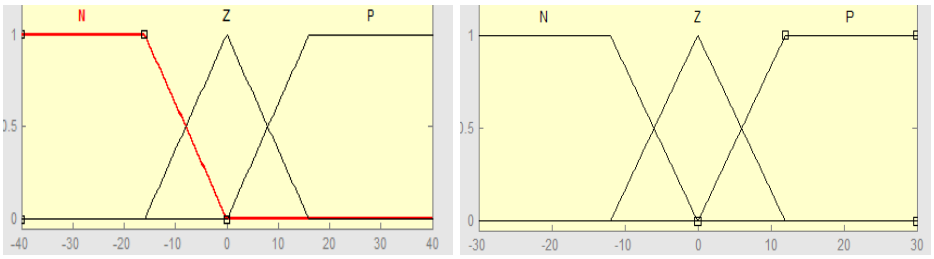

Fig. 8. Membership functions for two inputs (version 1) of G_{11rWB}

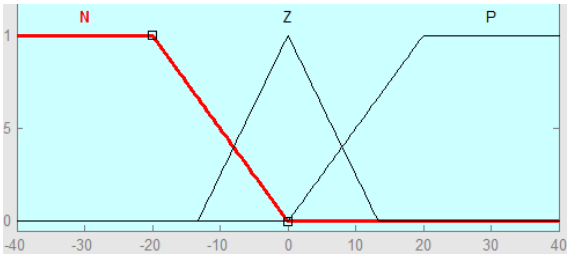

Fig. 9. Membership function for output (version 1) of G_{11rWB}

a) for input 1 **b) for input 2**

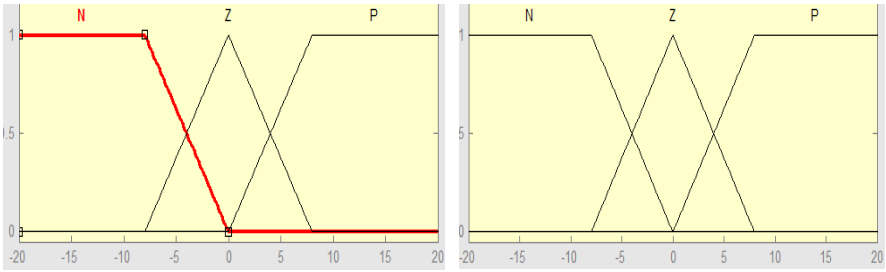

Fig. 10. Membership functions for two inputs (version 2) of G_{11rWB}

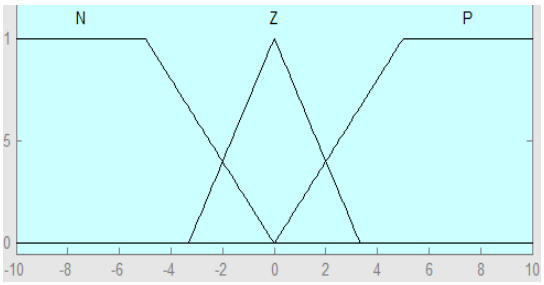

Fig. 11. Membership function for output (version 2) of G_{11rWB}

The fuzzy controllers rule base composed of 9 (3×3) rules as shown in Table 3. Also we use the Mamdani inference system as inference engine and centroid method for defuzzification in the fuzzy controllers.

Tab. 3. Rules for fuzzy control

de \ e	N	Z	P
N	**N**	**N**	**Z**
Z	**N**	**Z**	**P**
P	**Z**	**P**	**P**

The following results are obtained and compared with others controllers using (PI) with optimization techniques (Alawad & Jebar, 2020) and (PI) with fuzzy as shown in Table 4. Figure 12 Shows the step response comparison between all controllers for G_{11rWB}. In the simulation results reported in this work as shown in Figure 12, the controlled variable XD was always considered to have a set-point equal to 0.98.

Tab. 4. Transient response parameters of G_{11rWB} for different controllers

Controller types	Mp%	Ts (minute)	Tr (minute)	Ess
Without controller	0.13	7.72	3.67	0.13
PI-MATLAB	12.4074	46.6524	13.8450	0
PIFC (Alwadie, Ying & Shah, 2003)	0	16.66	9.352	0
PI-DE (Alawad & Jebar, 2020)	2.3725	0.6299	0.0977	0
PI-IWO (Alawad & Jebar, 2020)	7.9654	3.1801	0.3889	0
PILEFC(version1)	2.9279	0.4802	0.0548	0
MPILFC (version2)	0.0922	2.5613	1.2387	0

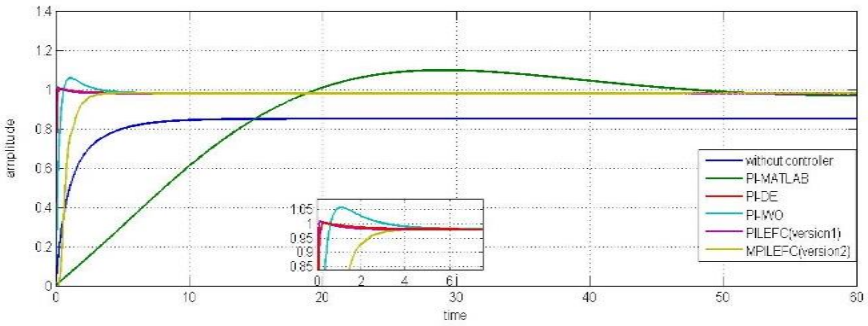

Fig. 12. Step Response comparison between all controllers for G_{11rWB}

As seen from Table 4 and Figure 12. version 1 is better than version 2 in speed response (less Ts and Tr) but with an over shoot (Mp=2.9279%), also version 1 gives a small improvement when compared with optimization method (PI-DE).

4.2. Case study 2 (G_{22rWB})

By applying the version 1 for G_{22rWB} and use the following gains (Alawad & Jebar, 2020) Kp = –0.2717, Kp = –0.028. Figure 13 shows the membership functions of version 1 for two inputs, while Figure14 shows the output.

a) for input 1 **b) for input 2**

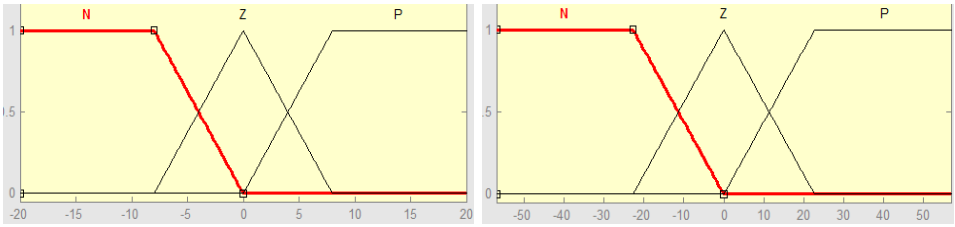

Fig. 13. Membership functions for two inputs (version 1) of G_{22rWB}

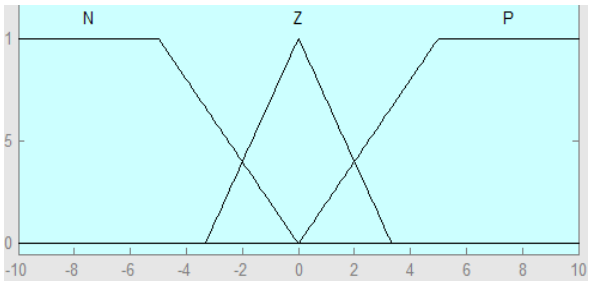

Fig. 14. Membership function for output (version 1) of G_{22rWB}

And by applying the version 2 for G_{22rWB} and use the following gains (Alawad & Jebar, 2020) Kp = –0.2717/2 = –0.13585, Ki = –0.028 × 1.5 = –0.042. Figure 15 shows the membership functions of version 2 for two inputs, while Figure 16 shows the output.

a) for input 1 **b)for input 2**

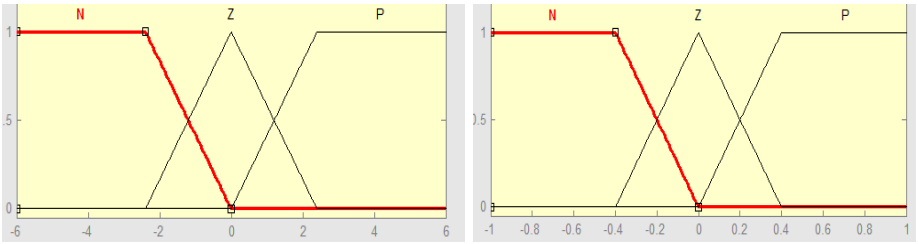

Fig. 15. Membership functions for two inputs (version 2) of G_{22rWB}

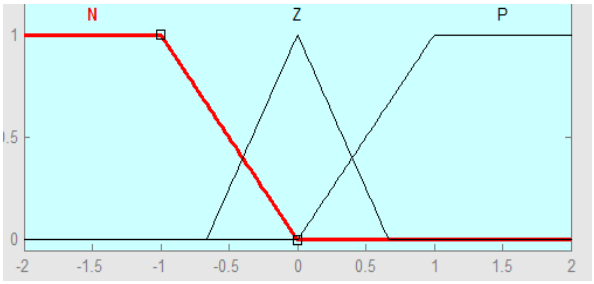

Fig. 16. Membership function for output (version 2) of G_{22rWB}

The following results are obtained and compared with others controllers (Alawad & Jebar, 2020; Alwadie, Ying & Shah, 2003) as shown in Table 5. Figure 17 shows the step response comparison between all controllers for G_{22rWB}. In the simulation results reported in this work as shown in Figure 17, the controlled variable XB was always considered to have a set-point equal to 0.02.

Tab.5. Transient response parameters of G_{22rWB} for different controllers

Controller types	Mp%	Ts (minute)	Tr (minute)	Under shoot	Ess
Without controller	N/A	N/A	N/A	N/A	N/A
PI-MATLAB	9.4941	26.3414	6.0747	3.7694	0
PIFC (Alwadie, Ying & Shah, 2003)	0.5	25.732	15.83	0	0
PI-DE (Alawad & Jebar, 2020)	0	7.7918	4.3258	6.2333	0
PI-IWO (Alawad & Jebar, 2020)	17.9261	11.3792	1.7423	12.1463	0
PILEFC (version1)	7.2023	7.3392	1.9995	10.3027	0
MPILFC (version2)	4.0792	10.1798	5.5103	0	0

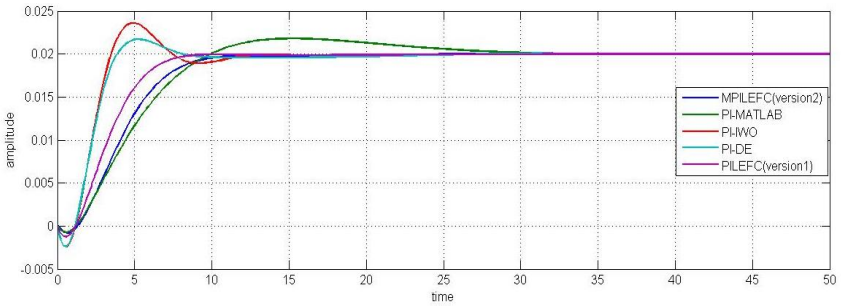

Fig. 17. Step Response comparison between all controllers for G_{22rWB}

As seen from Table 5 and Figure 17 version 1 is better than version 2 in speed response (less Ts and Tr), but over shoot (7.2037%) and under shoot (10.3027%) is not best when compared with PI-DE .The system G22rWb is not appear in Figure 16, because the system is unstable.

5. CONCLUSIONS

Two advanced controllers were developed in this paper, i.e., version1 and a version 2 fuzzy logic controller and their performances compared in simulation for a case study, i.e., a Wood and Berry binary distillation column, which is characterized by high nonlinearities and parameter uncertainties in the underlying mathematical model. Triangular membership functions are used to represent the input and output variables

The performance and the control synthesis of the fuzzy control approaches are moreover compared with classical PI controller, FPI, (DE) and (IWO) optimization methods. All the simulation results confirmed the robustness and the effectiveness of the fuzzy control action, with evident advantages for the (version 1) fuzzy controller, but the main disadvantage it may have the very wide universe of discourse. In distillation columns, tight composition control of products with 98% purity level is not achievable with classical PID controllers only due to sensitivity to disturbance. This work focuses on one of the most extended forms of conventional decoupling called simplified decoupling. The simplified decoupling technique has the simple decoupler form, but controller cannot be designed directly from the decoupled process model without using the model reduction technique.

Generally, (PILFC) is better than (MPILFC),in transient response specifications (Mp%, Ts, Tr), when compared with (MPILFC), this is clear for minimum-phase system G_{11rWB}, but with The non-minimum phase system G_{22rWB}, the proposed (MPILFC) is better in average values of transient response, when compared with (PILFC).

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Wall Climbing Robot, Multi Criteria Decision Analysis,
Cleaning Robot, Quality Function Deployment

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EVALUATION OF ROBOTIC CLEANING TECHNOLOGIES: PRESERVING A BRITISH ICONIC BUILDING

Abstract

The engineering building of the University Leicester built-in 1963 has been a British icon for decades now. Applications of Robotic technologies are uprising nowadays, which provides a contingency to manipulate the benefits of robotics for executing challenging and precarious facade cleaning processes. This paper surveys the facade cleaning robotic technologies exist in the market. It exhibits the comparative analysis of four notorious robotic facade cleaning solutions namely Sky Pro, Gekko, BFMR (Building Façade Maintenance Robot) and Sirius_c. The comparison is executed using Multi Criteria Decision Analysis (MCDA) and Quality Function Deployment (QFD) techniques. This study analyses the performance of the robots based on the critical parameters such as water consumption, cleaning efficiency, cleaning dimensions and ease of implementation. Although none of these robotic solutions are implemented off the shelf, some adaptation on these solutions is necessary for the development of robotic techniques work successfully in real time. This paper proposes a hybrid robotic solution combining the vacuum pump adhesion and wheeled locomotion for the effective cleaning of the complex external building structure based on the MCDA and QFD analysis. It highlights the significant future research directions in this field.

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1. INTRODUCTION

After gaining its Royal charter in 1957, the University of Leicester chose Leslie Martin for preparing the master plan for the 9-acre site near the edge of the Victoria Park. Martin was influential in the expansion of university and wanted to use the awkward triangular-shaped corner at the boundary of site for accommodating department of engineering premises (Berman, 2010a). The site was small relative to the space required for the facilities that were meant to be a part of the Engineering building, and this played an essential role in determining the design of the building (Berman, 2010b). Over time, the ability to maintain the condition of the building has become increasingly difficult, and one issue in preserving the state of the building is the cleaning problem. The process of cleaning the external surfaces of the building has been stopped after the health and safety issues that arose during the cleaning operation carried out by maintenance workers. Due to the stoppage of maintenance activities such as cleaning of exterior surfaces, it is becoming increasingly difficult to preserve the condition of this British Icon. The building being Grade-2 has several restrictions on the changes that can be made with the structure in order to keep its historical heritage and iconic image across the world intact.

The recent advancement in technology has opened a wide range of applications for robots. In several countries, climbing robots are currently in use for cleaning high-rise buildings (Breaz, Bologa & Racz., 2017; Zhu, Sun & Tso, 2002) reducing the risk in human workers. For this reason, significant research is carried out in the field of mobile robotics, which has led to the development of climbing robots all over the world (Panchal, Vyas & Patel, 2014). However, most of the robots currently in use are mounted to the building structure and are highly expensive with high maintenance cost (Gudi & Bhat, 2016).

This work seeks to assess the challenges associated with the implementation of robotic cleaning methods. Few market alternatives are compared for their potential implementation for the engineering building based on the information gathered through the literature survey. The evaluation of the robotic technologies is carried out based on some critical parameters for cleaning the façade of the building efficiently. To resolve the façade cleaning problem of the engineering building, symbol of British Icon of University of Leicester, shown in Figure 1, this study explores the possibility of robotic solutions that could help preserve the condition of the building without making significant changes to the structure of the building to retain its historical heritage and iconic look. The remainder of the paper is structured as follows: Section 2 presents the detailed survey of cleaning robots available in the market along with the multi criteria decision making method utilized for selection of the robot. This section also presents QFD (Quality function Deployment) which provides a base for product development. Section 3 presents the proposed system design based on the findings and Section 4 concludes the findings of this paper.

Fig. 1. Engineering Building, University of Leicester, United Kingdom

2. SURVEY ON CLEANING ROBOTS

Manual facade cleaning of buildings is susceptible accident due to the irregular shape of the building, tangled rope, sudden gust, crash against the building, breaking of wire, unfit posture, lousy equipment, and heavy weight. Robots are being widely adopted to reduce the interference of labour for extremely unsafe and dangerous jobs. Climbing robots are useful for a variety of applications including cleaning buildings safely and efficiently. Some cleaning systems are already in commercial use for cleaning buildings (Mahajan & Patil, 2013). The major stumbling block is that these climbing robots are not well suited to complex structures as most systems are mounted to the building and are very expensive to develop, and the payback often takes a long time.

The cleaning method deployed by the robot depends on the type of cleaning required by the building for its maintenance. The wall cleaning is classified as regular cleaning (light soiling), occasional cleaning (medium soiling) and stubborn dirt cleaning (heavy soiling). Typically, robots execute all the above cleaning methods individually but cannot do them together through one integrated system, as not all capabilities can be housed in a single unit for the real-world environment. It is difficult to set up an array of performance requirements for such robots, which adds uncertainty in designing a platform while making optimal trade-offs between competing design criteria (Nansai & Mohan, 2016). The identification and understanding of desirable characteristics of cleaning robots facilitate to set clear technical goals and well-defined design trade-off boundaries (Nansai & Mohan, 2016).

The three functional requirements are 1) locomotion method, 2) adhesion method and 3) actuation mechanism (Guo, et al., 2015). Adhesion system allows the robot to adhere on the surface of the climbing wall/façade properly without falling.

The types of adhesion methods are broadly illustrated in Figure. 2. The magnetic adhesion method is used for walls and surfaces with high levels of magnetic permeability (Nansai & Mohan, 2016; Sahbel, Abbas & Sattar, 2019). This method is not suitable for cleaning non-ferromagnetic surfaces, which reduces its scope for use in wide variety of applications. Pneumatic method allows suction by creating a vacuum between the surface of the robot and the wall, which allows the two surfaces to adhere to each other. Suction cup adhesion works on smooth surfaces, such as glass surface (Rathod, et al., 2017). This method uses suction cups to adhere to the surface and is best used in combination with a leg-based locomotion mechanism (Nansai & Mohan, 2016).

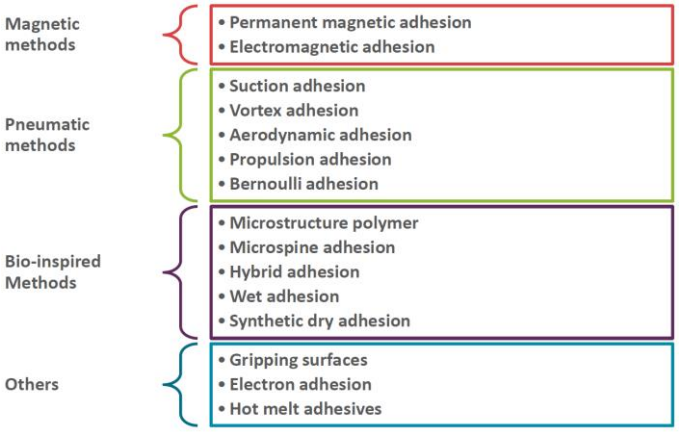

Fig. 2. Types of Adhesion methods used for wall climbing robots

Air leaking is one significant issue with this mechanism, which can reduce the negative pressure that allows adhesion with the wall (Qian, Zhao & Zhuang, 2006). The other drawback of this technology is that it allows slow-moving speeds, which reduces the efficiency of the robot because there is a time delay due to variation in suction pressure in the cups while engaging and disengaging (Nansai & Mohan, 2016). Bio-Inspired Adhesion system is inspired by living organisms that can traverse over vertical surfaces. In this method the climbing behavior of the animals is imitated by the robots (Nansai & Mohan, 2016). This system does not require bulky components to function thus the robots are lightweight. The major drawback in this system is that it cannot carry heavy payloads, thus it provides less productivity.

Locomotion system of the robot provides the mobility and the ability to tackle obstacles in the way of the robot. The locomotion methods can be classified into five major types. as shown in Figure 3. The sliding locomotion mechanism helps the robot to move and operate by a sliding movement, which is straightforward and easy to operate compared to other mechanisms. The sliding mechanism has drawbacks such as limited ability to cross obstacles, low speed, and large components.

The wheeled mechanism allows operation at high speeds with a comparatively low power requirement along with excellent mobility. The major flaw with this mechanism is the ability to tackle obstacles, which is limited due to the manner in the robot, gets unsettled while traversing obstacles (Nishi, Wakasugi & Watanabe, 1986).

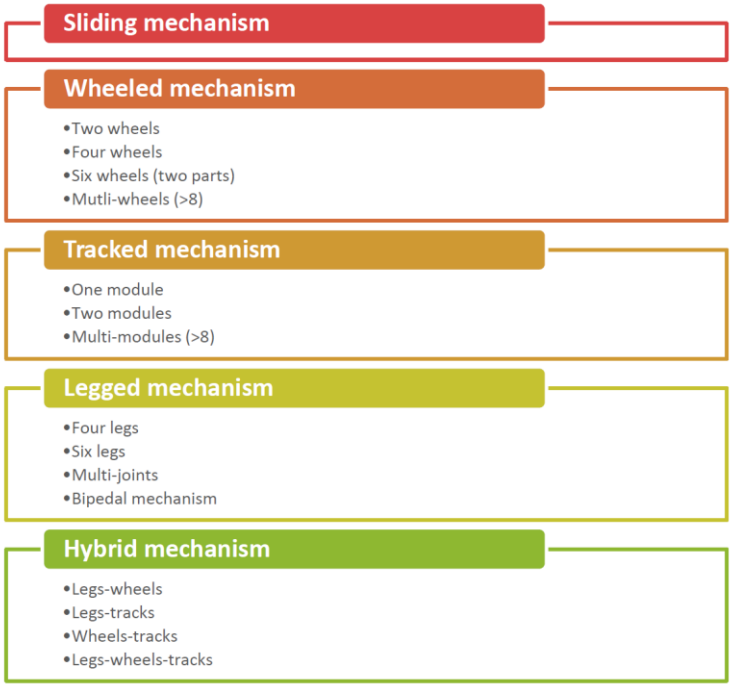

Fig. 3. Types of Location methods available for Wall Climbing Robots

Tracked robots are well suited to soft terrain with impediments because the contact with the ground is considerable. They are slow and require more energy compared to wheeled mechanism robots (Silva, Machado & Tar, 2008). Legged robots have higher mobility in different kinds of structured environments and uneven surfaces (Dissanayake, et al., 2018). Due to the discontinuous movement of the legs, they are relatively slow and consume more energy when compared to the wheeled mechanism. The legged robots have higher stability, robustness, adaptability, flexibility, and efficiency when compared with all the other systems.

Hybrid systems are different combinations of wheeled/legged/tracked mechanisms. They try to combine the advantages associated with all the systems. However, they make the resultant system complex and cumbersome, which make it difficult to operate and manage. In this paper the locomotion methods are compared to assess their suitability for the engineering building. The criteria for comparison are complexity, speed (irrespective of the locomotion method), risk,

stability, and suitability. Most common actuation method is by using electric motors, which account to about 90% (Nansai & Mohan, 2016). There are three primary actuation mechanisms, i.e., hydraulic actuators, electric motors, and pneumatic actuators. Hydraulic actuators have one disadvantage, they require fluid reservoir to function, which adds weight to the system, and any fluid leak will lead to failure of the system. Pneumatic actuators require a compressor, which pressurizes air for actuation and this system is useful for large systems rather than compact systems.

The objective of this paper is to identify the suitable adhesion, locomotion and actuation method for facade cleaning on the British icon. It analyses the methods in the direction of proposing hybrid solutions in order to develop effective facade cleaning robot for the British iconic building.

2.1. List of building cleaning robotic solutions

This study focuses the technology discover on the existing robotic solutions in the market for building exterior cleaning. Apart from the mentioned robotic solutions, there many other solutions that currently available or are in development. All these solutions are not discussed because there is not enough information about all the solutions. Therefore, analyzing those solutions without important details would be difficult and prevent a clear picture from emerging from the analysis. However, the list of other available solutions is given in the Table 1.

Some of these robots are utilized for a variety of purposes, but fundamentally they are all climbing robots which are used for different applications. It is noteworthy that most of these robots are not capable of tackling obstacles. The other pattern noticeable is that most them work on vertically smooth façades and not on inclined surfaces. Japan is one country which is heavily involved in developing robotic cleaning. Most of the solutions on this list currently in R&D and are ready for implementation at any level. Most robots use rail-guided kinematic system, which shows that most developed it is the most developed mechanism out of other alternatives.

Tab 1. List of available cleaning robotic solutions (Gambao, Hernando & Surdilovic, 2008)

S. No.	Robot (source/company)	Country of origin	Application	Locomotion (Direction)	Obstacle Avoidance
1	Wall painting Robot by Taisei (Sakamoto, 1990)	Japan	Painting/ coating	Rail Guided (Vertical)	No
2	Tile inspection Robot by Taisei	Japan	Inspection	Cable Driven (Vertical)	No
3	KFR2 by Kumagai Gumi co Ltd (Tokioka, et al., 1992)	Japan	Coating	Cable Driven (Vertical)	No
4	SB Multi Coater	Japan	Coating	Rail Guided (Vertical)	No
5	Gekko	Switzerland	Cleaning	Cable Driven (Vertical)	Yes
6	Sirius_c	Germany	Cleaning	Rail Guided (Vertical)	Yes
7	Vacuum Suction	Japan	Cleaning	Vacuum (Vertical)	No
8	Canadian Crab	Japan	Cleaning	Vacuum cup with Cables (Inclined)	Yes
9	Robosoft	France	Cleaning	Rail Guided (Horizontal & Vertical)	No
10	Fraunhofer Institute robot Leipzig Glass Hall	German	Cleaning	Wheels with Cable (convex)	No
11	Automatic Window Cleaning Robot by Mitsubishi (Gambao & Hernando, 2006)	Japan	Cleaning	Rail Guided (Vertical)	No
12	Comatec	France	Cleaning	Vacuum Cups (Inclined)	No
13	CSIC	Spain	Cleaning	Air suction (Vertical)	No

2.2. Comparison of available robotic solutions

Market available robotic solutions are compared for their potential suitability for implementation for the engineering building. The comparison is based on the specifications and technology used in the robots. Water consumption, cleaning efficiency, cleaning width, weight of the robot and robot dimension are the parameters taken for comparison. It aims to find the efficient robotic solution for cleaning the engineering building of the University.

The renowned robots such as Gekko, Serbot, Skypro, BFMR (Building Façade Maintenance Robot) and Fraunhofer are evaluated. These four robots are identified since they have distinct design features. The Sky Pro robot is designed by skyprocy for cleaning building façade using a cable-driven method. Serbots's Gekko Façade Cleaning Robot is the first commercial robot, which can climb vertical surfaces. The robot can be controlled on vertical surfaces in all directions. The company claims guaranteed high-quality cleaning due to the use of a rotating brush combined with demi-water. Sirius_c by Fraunhofer is supported by crane (cable-driven system), which is installed on the roof. This system is equipped with the advanced sliding frame mechanism, which helps the cleaning unit move in the vertical and horizontal direction in a relatively small area for cleaning work (Elkmann, et al., 2005). BFMR consists of both horizontal and vertically operating robots. The horizontal robot cleans the windows along the horizontal rail. The vertical robot cleans upwards through rail extensors and rail brakes. The rail brakes hold the robot securely, improving the safety of the system considerably (Moon, et al., 2015).

Table 2 presents the specifications of the four robots compared in this paper. Each performance factors are assigned with a score value from 1–5 based on their raw values. The scores are listed in the Table 3 in the next section.

Tab 2. Specifications of the four Robotic Solutions

Robot – manufacturer	Water consumption (L/h)	Cleaning efficiency (m^2/h)	Cleaning width (m)	Weight (kg)	Dimension (m)
Sky pro	300	600	2.4	225–360	3.35 m (overall width)
Gekko	90	400	1.383	79	1.217 × 1.387 × 0.419
BFMR	11	400	1.6	300	1.6 × 1.9 × 0.545
Sirius_c (Fraunhofer)	1.5	200	1.5	200	1 × 1.5

2.3. Multi-Criteria Decision Analysis (MCDA)

Multi-Criteria Decision Analysis, or MCDA, is a valuable tool that we can apply to many complex decisions. It is most useful to solving problems that are characterized as a choice among alternatives. Table 3 shows the raw scores (5-point scale) assigned to each alternative based on the five parameters. The performance comparison depicts that Sky pro robot's performance is ahead of the field with respect to all the five parameters. Next to Sky pro, Gekko robot provides better performance. BFMR robot stands in third position. Sirius_c robot places least in

the evaluation queue. Comparison of different parameters helps to determine the best robot in the particular criteria, but it does not help to choose the best alternative solution. However, the limitation of MCDA is the use of assessor's judgement to assign weights and score each alternative. To choose the best alternative, the criterion must be given some context by assigning weights to the importance of each criterion. Weights vary from criterion to criterion due to their varying influence on the operation. Each alternative is given scores based on the listed criterion, and the total weighted score is calculated by applying the percentages to the score to get the weighted score, which is then added to give the total weighted score. The total weighted score helps to decide, which takes into consideration the context behind each comparison criterion. The raw scores indicate that Gekko is ahead of its competing solutions followed closely by Sirius_c. However, the weighted scores can change the pecking order. The weighted score is given in Table 4.

Tab. 3. MCDA scores of the four robots

Criteria	Weightage	Sky Pro	Gekko	BFMR	Sirius_c
Water Consumption	5%	3	5	5	5
Cleaning Efficiency	30%	5	4	4	2
Cleaning Width	15%	4	2	3	3
Weight	10%	2	5	3	4
Dimensions	10%	1	3	2	1
Implementation	30%	2	2	1	2
Total (Raw scores)	100%	17	21	18	20

The weighted scores give a clear picture of the performance of the robots based on the important criteria for the implementation of the robot. Although Sky Pro and Gekko have the same weighted score of 3.15, Gekko is the most developed product in the market and the first robot to climb vertically for cleaning façade systems. Water consumption is given a weight of 5% because it is an environmental concern, but not a technical issue. Cleaning efficiency and implementation have a weight of 30% each due them being the most critical selling points for each of the robots. Sirius_c has a high raw score of 20, but it falls short eventually due to performing poorly in the cleaning efficiency, which is very important for a cleaning robot. Sky pro has lower raw score than Gekko, but it has the most superior cleaning efficiency and closely matches in other areas thus it scores joint-highest weighted score with Gekko. However, due to lack of information and Gekko's market presence makes it a better proposition compared to Sky Pro. The scoring system is developed based on the literature survey and understanding of the technologies developed during the comparison phase earlier.

Tab. 4. MCDA weighted scores of the four robots

Criteria	Weightage	Sky Pro	Gekko	BFMR	Sirius_c
Water consumption	5%	0.15	0.25	0.25	0.25
Cleaning efficiency	30%	1.5	1.2	1.2	0.6
Cleaning width	15%	0.6	0.3	0.45	0.45
Weight	10%	0.2	0.5	0.3	0.4
Dimensions	10%	0.1	0.3	0.2	0.1
Implementation	30%	0.6	0.6	0.3	0.6
Total (Raw scores)	100%	3.15	3.15	2.7	2.4

2.4. Implementation and Adaptation

The literature survey makes clear that the current technologies in its existing state cannot be used to implement robotic cleaning for the engineering building because of the drawbacks associated with each mechanism and solutions available. However, since all the robots compared in this paper use cable-driven rail system in combination with vacuum suction, an adaptation idea is presented without considering the difficulty of execution and load calculations for the idea.

The problems associated with the implementation of robotic solution are listed below:

1. For the building facade area, there is no point above it which can allow the support system of cable-driven robots to be placed.
2. The building being grade-2 does not allow any significant structural changes, which make it challenging to adapt the building for robot cleaning.
3. The problem area has its façade in varying angles both in the horizontal and vertical direction.
4. The frame and the changes in the angle of the façade make it challenging to place the support system, and for robots using housed adhesion and locomotion, it is tough to traverse this area.

The solution proposed to solve the above listed problems is to develop is a temporary platform on which the support system can be placed. The temporary platform should be easily removed after cleaning and is easy to install without any structural changes to the building. The platform should be able to bear load 500–600 kg to bear the weight of the robot and its support system. The support system must have the ability to move forward and backwards or extend so that the robot can clean the surfaces in different depths. The support system must have the ability to rotate on its Z-axis to cater to changes in the angle of the façade. Since designing a robot for a particular purpose is complicated, the system has to be divided into subsystems. The primary subsystems required to execute the desired functions

based on the extensive literature survey are Adhesion system, Energy autonomy system, Locomotion system, Actuation system, Sensors and control system, Payload storage (water storage), Cleaning system.

2.5. Concept/Technology Prioritisation using Quality Function Deployment (QFD)

QFD provides a base for product development, and it is not the final step before detailed design execution. The QFD for developing Cleaning robot for engineering building is developed using MS excel, and the four robots considered in this paper are also considered to compare each other to make the case stronger. QFD is large and is presented in two segments. This section of the QFD the customer requirements are presented on the left side of the diagram. The importance of each requirement is marked from 0 to 10 and weight is given for each requirement. On the top side, product characteristics/technical requirements are presented. The right corner presents a comparison of robots in different areas of customer requirements. Black dots represent a strong relationship between the stated requirement and the technical component while calculating this receives a score of 9. Inverted triangles represent weak relation and get a score of 1 and the circles without shading to represent medium relation and gets a score of 3. Empty section means no relation between the customer requirement and technical component. The competing robots are marked between 0 to 5 based on the perceived customer response to the product. The comparison of the market robots shows that Gekko robot can get a high score in almost all areas. The next segment of the QFD presents the calculations based on the relationship matrix.

Figure 4 exhibits a small segment of QFD which calculates the technical importance of each functional requirement based on their relationship with customer requirements. From this calculation, with 17% adhesion is the most important technical component of the cleaning robot. The other significant technical areas include locomotion and cleaning with 11% and 7% respectively. Figure 5 shows the customer competitive comparison between the market robots.

Relationships	
Strong	●
Moderate	○
Weak	▽

Row #	Weight Chart	Relative Weight	Customer Importance	Maximum Relationship	Customer Requirements (Explicit and Implicit) \ Functional Requirements	weight	Dimensions	locomotion	adhesion	power source	sensors	electronic	payload	Materials
1	▮▮▮▮	10%	10	9	cleaning		○	▽	○	○	▽	●	●	
2	▮▮	6%	6	9	semi-automated operation	○		○	●		●	●		
3	▮▮▮	8%	8	9	reliable	▽		●	●	●	●	○		●
4	▮▮▮	9%	9	9	safe	●	●	●	●	●	○	▽	○	○
5	▮	5%	5	9	portable (not too big)	●	●	▽	○	○	▽		●	○
6	▮	4%	4	9	speed (time taken to clean)	●	●	●	●				●	
7	▮▮▮	8%	8	9	Ability to tackle complex design	○	●	●	●		○			
8	▮▮	6%	5	9	Aesthetics		●			○			○	▽
9	▮▮▮	9%	9	9	No major changes to structure	▽	●	○	●					
10	▮▮▮	8%	8	9	Prevent damage to the strucutre	○	▽	○	●					
11	▮▮	7%	7	9	cheap			○	○					●
12	▮	5%	5	9	time to implement			●	●		○			▽
13	▮	5%	5	9	impact resistant	▽			●					●
14	▮▮▮	8%	8	3	weather proof			▽						○

Fig. 4. QFD segment 1

Customer Competitive Assesment						
Our Product (theoritical design)	Sky pro	Gekko	BFMR	Fraunhofer	0 1 2 3 4 5	Row #
4	5	3	3	2		1
4	3	3	3	3		2
3	3	3	3	3		3
4	2	4	3	3		4
3	1	2	2	3		5
3	5	4	4	2		6
4	1	1	1	1		7
3	2	3	1	1		8
4	2	2	2	2		9
4	2	3	2	3		10
1	1	2	2	1		11
0	3	4	1	2		12
3	2	4	2	2		13
4	4	4	4	4	Our Product Competitor #1 Competitor #2	14
						15

Fig. 5. QFD segment 2

In this comparison, Gekko from Serbot comes out on top by consistently getting high scores in different technical areas. The crucial findings from QFD are:

1. Adhesion system is the most vital technical system of the robot.
2. Gekko from Serbot is the most developed product in the market and is currently the best solution.
3. Locomotion system and cleaning system is also essential for the development of competent cleaning robot.
4. The autonomous operation, time to implement and water consumption of the robots are not critical factors for the development of a competent cleaning robot.

3. PROPOSED SYSTEM DESIGN

The proposed system design consists of the selected solutions for the subsystems based on the MCDA and QFD analysis performed in the previous chapters. In addition to the findings from the QFD analysis, the following tasks involved in the cleaning process of the windowpanes and glass façade in the British icon, such as:

1. Safe navigation over the area of interest
2. Provide necessary adhesion for the robot to adhere to the surface
3. Spray Washing and Wiping liquids
4. Brush, Wash and Wipe the surface to remove the marks and dust in the surface is to be considered.

Further, set of attributes is also considered as constraints in the design of the cleaning robot. The constraints are minimization of cleaning time, slippage, energy consumption, payload, noise level and maximization of adhesion force, area coverage, dust removal, information gathering and safety.

Based on the literature survey, QFD and additional constraints, a simple block diagram and structural design of the proposed cleaning robot system is illustrated in Figure 6 and Figure 7.

Even though, the best choice of adhesion mechanism and system for locomotion would be the vacuum pump adhesion and legged mechanism, observed from the literature, it is proposed to use the wheeled mechanism combined with the vacuum suction adhesion as shown in Fig. 7 for providing the necessary adhesion and locomotion to satisfy the design constraints. The legged mechanism is not considered because of the speed of the mechanism, as it is slow and inefficient. The wheeled mechanism illustrated in the proposed design, can traverse obstacles, and uses 8 wheels and 6 motors for having necessary locomotion. A self-transition mechanism is also proposed in the design where two parts of the robot is connected through an active hinge, so that the robot can negotiate corners and traverse from one pane to another pane.

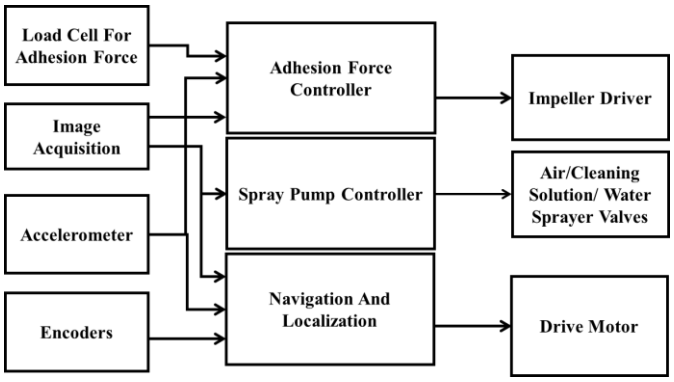

Fig. 6. The proposed system block diagram

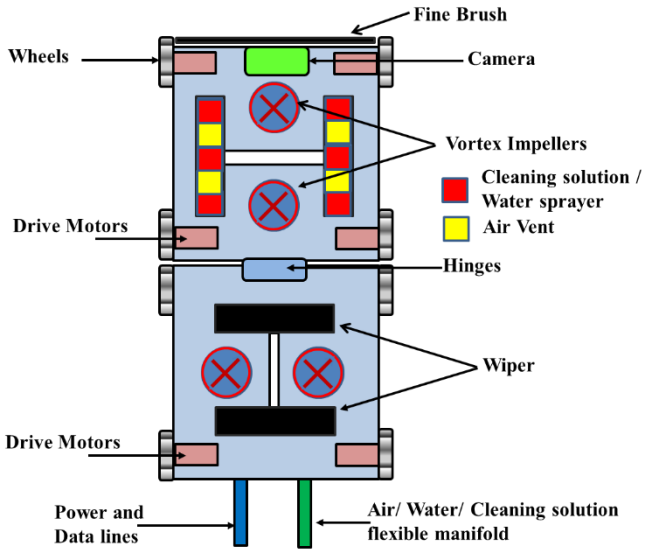

Fig. 7. The proposed model of the Robot

In order to provide the necessary adhesion to the surface, 4 impellers – 2 on either section of the robot is proposed, such that it produces the necessary vacuum suction force for added adhesion, which will increase the safety of the system. Sprayer nozzles for spraying Air, cleaning solution and water is added along with the brushes as shown in Fig. 7. A fine brush is proposed to have at the front of the robot to remove the dust that are fugitive could be swept before cleaning operation. Image acquisition system is also proposed to have in the robot, in order to facilitate the inspection of panes in addition to the cleaning process and to effectively maneuver the area. The robot is planned to be operated from the base where, the pump, power source and controllers as illustrated in Fig. 6. Accelerometer and Load cell sensors

could be used for the adhesion force feedback and tilt of the system to control the robot for safety and efficient operations. For safety reasons, a support system where a cable is used to attach the robot to the platform is a must requirement as it mitigates the problem of robots falling due to the failure in adhesion with the surface. This study uses this finding as a baseline for initiating a mission to implement robotic cleaning for the engineering building.

4. CONCLUSIONS

The engineering building of the University Leicester is not currently fit for robotic cleaning due to its complex architecture and restriction on structural changes. The robots cannot traverse the problem area of the building, as the adhesion and locomotion technologies are not capable to safely navigate obstacles like the frame of the façade. Through extensive literature survey, all functional technologies of the cleaning robots are compared in detail. This paper compares the available market solutions and refines a simple system design for developing completely new robotic cleaning system. The most crucial assumption made during this evaluation study is that all technologies would perform in real-life scenarios as they perform in theory and there would be no hindrance from any unknown external factors. The gap in information available is plugged by referring to similar studies and technologies that are like the missing information. Therefore by comparing the available robotic solution through Multi-Criteria Decision Analysis (MCDA) and Quality Function Deployment (QFD) and also considering the tasks and requirements of the cleaning robots, a design prototype is formulated and proposed, which uses the wheeled mechanism combined with the vacuum suction adhesion for providing the necessary adhesion and locomotion. Our future scope of this research is to develop a cleaning robot prototype as illustrated in the proposed system and to investigate its performance by deploying it for Preserving the said British Icon in University of Leicester, United Kingdom.

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Performance Analysis, MIMO, Rician Fading Channel

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PERFORMANCE ANALYSIS AND EVALUATION OF MASSIVE MIMO SYSTEM

Abstract

This article examines the performance of massive MIMO uplink system over Rician fading channel. The performance is estimated regarding spectral efficiency versus number of base station antennas utilizing three plans of linear detection, maximum-ratio-combining (MRC), zero forcing receiver (ZF), and minimum mean-square error receiver (MMSE). The simulation results reveal that the spectral efficiency increments altogether with expanding the quantity of base station antennas. Additionally, the spectral efficiency with MMSE is superior to that with ZF, and the last is superior to that with MRC. Furthermore, the spectral efficiency diminishes with expanding the fading parameter.

1. INTRODUCTON

Multiple Input Multiple Output (MIMO) innovation is a point-to-point communication links with different antennas at both the transmitter and receiver. The utilization of various antennas at both transmitter and receiver give an enhancements for data rate, in light of the fact that the more antennas, the more autonomous data streams can be conveyed; an enhancements for unwavering quality, on the grounds that the more antennas, the more possible ways that the radio signal can spread over, and an enhancements for energy efficiency, on the grounds that the base station can center its emitted energy into the spatial bearings where it realizes that the terminals are found (Marzetta, 2010).

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An upgraded type of point-to-point MIMO innovation is multiuser MIMO (MU-MIMO) which empowers different autonomous radio terminals to get to a system improving the communication abilities of every individual terminal. MU-MIMO varies from point-to-point MIMO in two regards: first, the terminals are ideally isolated by numerous wavelengths, and second, the terminals can't team up among themselves, either to transmit or to receive data (Ngo, 2012; Ngo, Larsson & Marzetta, 2013).

These days, MU-MIMO systems are utilized in new generation wireless innovations, because of that wireless innovation improvement is continuous, the quantities of users and applications increment quickly. At that point, wireless communications require the high data rate and connection dependability simultaneously. Thusly, MU-MIMO upgrades need to think about 1) giving the high data rate and connection unwavering quality, 2) bolster all users in a similar time and frequency asset, and 3) utilizing low power utilization. Practically speaking, the interuser interference has a solid effect when more users access to the wireless connection. Convoluted transmission techniques, for example, interference cancellation ought to be utilized to keep up a given wanted nature of administration. Because of these problems, MU-MIMO with exceptionally enormous antenna arrays (known as massive MIMO) is proposed. With a massive MU-MIMO system, we mean a hundred of antennas or all the more serving many users. The channel vectors are about orthogonal, and afterward the interuser interference is diminished significantly. In this way, the users can be served with high data rate all the while (Yang & Marzetta, 2013; Pakdeejit, 2013).

2. SYSTEM MODEL

The model of massive MIMO system investigated here comprises of uplink system model, channel model (Rician fading channel), and linear detection plans. These three sections are examined in subtleties in the following sections.

2.1. Uplink system model

A solitary cell uplink system is deemed here, where there are *K* mobile users and one base station (BS). Every user has one transmit antenna, and the BS has *M* receive antennas apparatuses as appeared in Fig. 1. The received signal at the BS is (Pakdeejit, 2013; Lu, et al., 2014):

$$y = \sqrt{p_u} \sum_{k=1}^{K} h_k x_k + n \quad (1)$$

$$y = \sqrt{p_u} Hx + n \quad (2)$$

Where $\sqrt{p_u}x_k$ is the transmitted signal from the *k*th user (the median power transmitted by every user is p_u), $h_k \in \mathbb{C}^{M\times 1}$is the channel vector between the *k*th user and the BS, $n \in \mathbb{C}^{M\times 1}$ is the additive noise vector, $H \triangleq [h_1 \quad ... \quad h_K]$ is channel matrix given underneath, and $x \triangleq [x_1 \quad \cdots \quad x_K]^T$. It is expected that the components of h_k and n are (independent identically distribution) i.i.d. Gaussian distributed with zero mean and unit variance (Lu, et al., 2014).

$$H = \begin{bmatrix} h_{11} & h_{12} & ... & h_{1K} \\ h_{21} & h_{22} & ... & h_{2K} \\ \vdots & \vdots & \ddots & \vdots \\ h_{M1} & h_{M2} & ... & h_{MK} \end{bmatrix} \tag{3}$$

The BS will coherently distinguish the signals transmitted from *K* users by utilizing the received signal vector *y* together with information on the channel state data (CSI). This CSI must be assessed. The channel gauge can be acquired from uplink training.

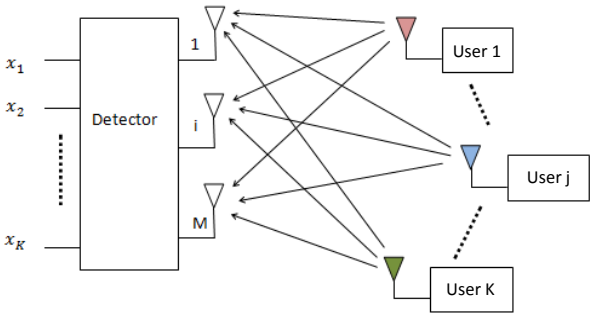

Fig. 1. Massive MIMO uplink system model (Lu L. et al., 2014)

It is expected that the channel remains steady over *T* symbol duration. During every coherence interval, there are two phases (see Fig. 2). In the first phase, a section τ of the coherence interval is utilized for uplink training to evaluate the channel of every user. In the second phase, all *K* users at the same time transmit their data to the BS. The BS at that point identifies the transmitted signals utilizing the direct gauges obtained in the first phase.

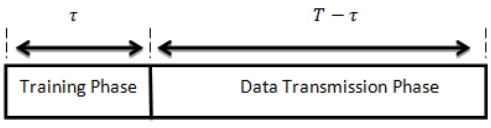

Fig. 2. Uplink transmission protocol (Lu, et al., 2014)

2.2. Rician fading channel

A likelihood density capacity of the signal received in the line-of-sight (LOS) condition follows the Rician conveyance. In the LOS condition where there exists a solid way which is not dependent upon any misfortune because of reflection, diffraction, and scattering, the amplitude of the received signal can be distinct as $X = a + W1 + jW2$ where a represents the LOS part, while, $W1$ and $W2$ are the i.i.d. Gaussian random variables with a zero mean and variance of σ^2 as in the non-LOS condition. It has been realized that X is the Rician random variable. At that point, the channel coefficient of Rician fading channel is given by (Ciuonzo, Rossi & Dey, 2015):

$$h_{Rician} = a + c + jd \tag{4}$$

Where $a = \sqrt{\frac{\mathcal{K}}{\mathcal{K}+1}}$, $c \sim \mathcal{N}\left(0, \frac{1}{2(\mathcal{K}+1)}\right)$, $d \sim \mathcal{N}\left(0, \frac{1}{2(\mathcal{K}+1)}\right)$, and $\mathcal{K}$ is the ratio of the power in the LOS part to the power in the other (non-LOS) multipath parts. The fading parameter $\mathcal{K}$ which is typically given in is a proportion of the seriousness of the fading, a little $\mathcal{K}$ suggests extreme fading, while, an enormous $\mathcal{K}$ infers milder fading.

2.3. Linear detection

To get ideal performance, the maximum likelihood (ML) multiuser discovery can be utilized by the BS to identify all signals transmitted from k user, expecting that the BS has impeccable CSI information. The multifaceted nature of ML is high, so the BS can utilize linear detection plans to minimize the decoding complexity. Nonetheless, these plans have lower detection unwavering quality contrasted and ML detection, however when the quantity of BS antennas is huge, linear detectors are about ideal. Three plans of linear detection are considered, maximum-ratio combining (MRC), zero-forcing receiver (ZF), and minimum mean-square error receiver (MMSE) as portrayed beneath (Ciuonzo, Rossi & Dey, 2015).

2.3.1. Maximum-Ratio Combining (MRC)

With MRC, the BS maximizes the received signal-to-noise ratio (SNR) of each stream, neglecting the effect of multiuser interference. Accordingly, to recognize the transmitted signal from the *k*-th user, the received signal *y* is multiplied by the conjugate-transpose of the channel vector *h_k*, as follows (Fatema, et al., 2018):

$$\tilde{y}_k = {h_k}^H y = \sqrt{p_u}\|h_k\|^2 x_k + \sqrt{p_u}\sum_{i\neq k}^{K} {h_k}^H h_i x_i + {h_k}^H n \tag{5}$$

The received signal-to-interference-plus-noise ratio (SINR) of the *k*-th stream for MRC is given by:

$$SINR_{mrc,k} = \frac{p_u \|h_k\|^4}{p_u \sum_{i \neq k}^{K} |h_k{}^H h_i|^2 + \|h_k\|^2} \quad (6)$$

The achievable rate of *k*-th user with MRC is given by

$$R_k{}^{MRC} = log_2\left(1 + \frac{p_u \|h_k\|^4}{p_u \sum_{i \neq k}^{K} |h_k{}^H h_i|^2 + \|h_k\|^2}\right) \quad (7)$$

Hence the spectral efficiency with MRC is given by

$$R^{MRC} = K * R_k{}^{MRC} = K * log_2\left(1 + \frac{p_u \|h_k\|^4}{p_u \sum_{i \neq k}^{K} |h_k{}^H h_i|^2 + \|h_k\|^2}\right) \quad (8)$$

MRC is a very simple signal handling since the BS just increases the received vector with the conjugate-transpose of the channel matrix *H*, and afterward identifies each stream independently. All the more critically, MRC can be executed in a distributed way. Also, MRC can accomplish a he same array gain as in the case of a single-user system at minimum SNR, however MRC performs ineffectively in interference restricted situations since it disregards the effect of multiuser interference.

2.3.2. Zero-Forcing Receiver (ZF)

Rather than MRC, zero-forcing collectors (ZF) consider the interuser interference; however disregard the effect of noise. With ZF, the multiuser interference is totally nulled out by anticipating each stream onto the orthogonal space of the interuser interference. All the more accurately, the received vector is multiplied by the pseudo-reverse of the channel matrix *H* as (Fatema, et al., 2018; Chopra, et al., 2018):

$$\tilde{y} = (H^H H)^{-1} H^H y = \sqrt{p_u} x + (H^H H)^{-1} H^H n \quad (8)$$

The received SINR of the *k*-th stream is given by:

$$SINR_{zf,k} = \frac{p_u}{[(H^H H)^{-1}]_{kk}} \quad (9)$$

The achievable rate of *k*-th user with ZF is given by

$$R_k{}^{ZF} = log_2\left(1 + \frac{p_u}{[(H^H H)^{-1}]_{kk}}\right) \quad (10)$$

Hence the spectral efficiency with ZF is given by

$$R^{ZF} = K * R_k{}^{ZF} = K * log_2\left(1 + \frac{p_u}{[(H^H H)^{-1}]_{kk}}\right) \quad (11)$$

ZF is a basic signal preparing and functions admirably in interference constrained situations, however since ZF ignores the effect of noise; it works ineffectively under noise restricted situations. Compared with MRC, ZF has a higher execution multifaceted nature because of the calculation of the pseudo-converse of the channel gain matrix.

2.3.3. Minimum Mean-Square Error Receiver (MMSE)

It is realized that the MMSE receiver expands the received SINR. Consequently, among the MMSE, ZF, and MRC receivers, MMSE is the best; the received SINR for the MMSE receiver is given by (Fatema, et al., 2018; Chopra, et al., 2018):

$$SINR_{mmse,k} = p_u {h_k}^H \left(p_u \sum_{i \neq k}^{K} h_i {h_i}^H + I_M\right)^{-1} h_k \quad (12)$$

The achievable rate of *k*-th user with MMSE is given by:

$${R_k}^{MMSE} = log_2\left(1 + p_u {h_k}^H \left(p_u \sum_{i \neq k}^{K} h_i {h_i}^H + I_M\right)^{-1} h_k\right) \quad (13)$$

Hence the spectral efficiency with MMSE is given by:

$$R^{MMSE} = K * {R_k}^{MMSE} = K * log_2\left(1 + p_u {h_k}^H \left(p_u \sum_{i \neq k}^{K} h_i {h_i}^H + I_M\right)^{-1} h_k\right) \quad (14)$$

Where $\boldsymbol{I_M}$ is the identity matrix of size *M*.

3. SIMULATION RESULTS

A progression of PC simulation tests are done to consider the system performance. The performance is estimated by drawing the spectral efficiency versus the number of BS antennas using MRC, ZF, and MMSE. The quantity of users is picked to be $K = 2$ and $K = 0$ dB & -40 dB. Moreover, the SNR is set at 0 dB. Fig. 3 and Fig. 4 demonstrate that the spectral efficiency increments as the quantity of BS antennas increments for $K = 0$ dB & -40 dB respectively. Additionally, the spectral efficiency with MMES is superior to that with ZF, and the last is superior to that with MRC for $K = 0$ dB & -40 dB. Besides, by comparing between Fig. 3 and Fig. 4, it can reasoned that the spectral efficiency for $K = -40$ dB is superior to the spectral efficiency for $K = 0$ dB.

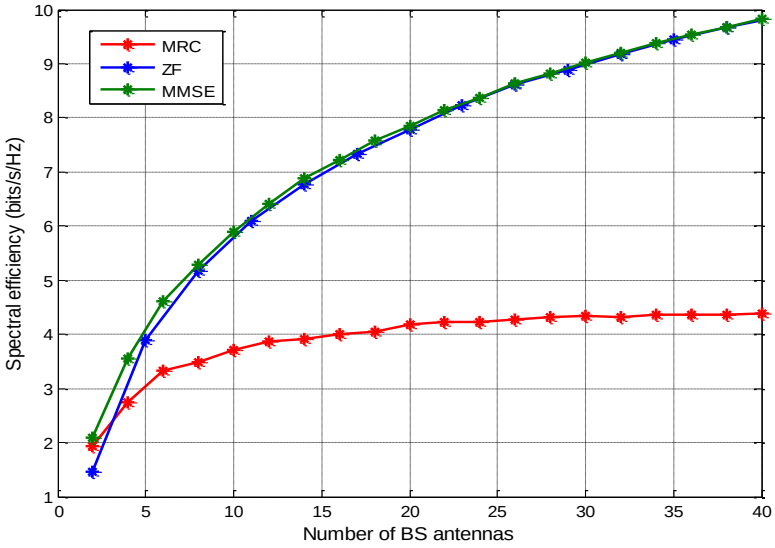

Fig. 3. The spectral efficiency versus the number of BS antennas for MRC, ZF, MMSE and $\mathcal{K}$ = 0 dB

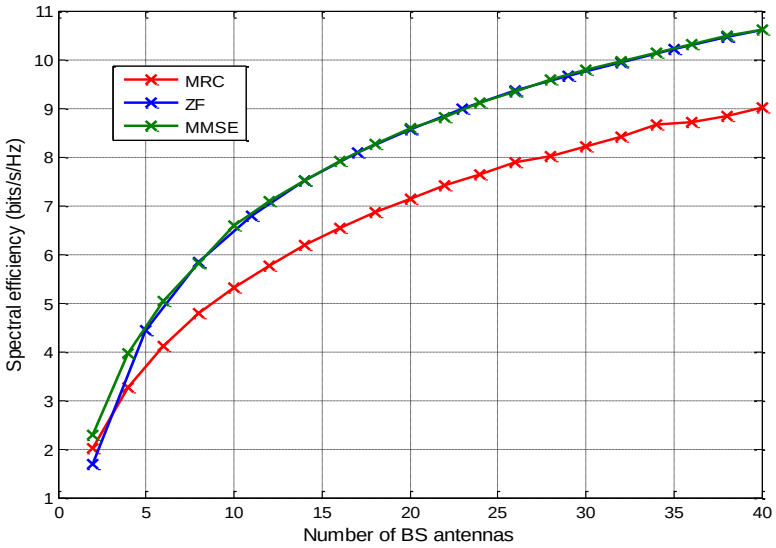

Fig. 4. The spectral efficiency versus the number of BS antennas for MRC, ZF, MMSE and $\mathcal{K}$ = -40 dB

4. CONCLUSION

The performance of massive MIMO uplink system was estimated over Rician fading channel, utilizing MRC, ZF, and MMSE linear detection plans. The outcomes reveal that the performance improved altogether with expanding the quantity of BS antennas for various estimations of *K*. Additionally, the performance with MMSE is superior to that with ZF and the last is superior to that with MRC for various estimations of *K*. Moreover, as *K* expands, the spectral efficiency diminishes.

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