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IN THE NAME OF ALLAH,
THE MOST GRACIOUS,
THE MOST MERCIFUL

Kingdom of Saudi Arabia
Ministry of Education
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Journal of Engineering and Applied Sciences

Editorial

Scientific publishing has brought many challenges to authors. With increasing number of scientific journals, varying scopes and reviewing requirements, and cost of publishing to authors, finding the right journal to publish an article is a decision many authors must bitterly confront and resolve. The publication of scientific findings is an integral part of the life of researchers; and the process of publishing has evolved to become an efficient system of decimating knowledge and collaboration among scientists. Science journals have institutionalized procedures to manage large volume of article submissions per year; in many cases, journals began to define narrower scopes for a dual purpose: managing submissions and delivering outstanding research.

Based on recent studies, the scientific publishing world consists of more than 25 thousands active journals in various disciplines and fields. Science Direct hosts 3,348 journals (as of February 2014). The Directory of Open Access Journals lists in its search engine more than 9,800 open access online journals.

According to recent estimates, the number of scientific journals grows by 3% per year worldwide. With this large number of journals, journals may find it harder to stay afloat.

In its inauguration, the board of editors is honored to introduce to the scientific community the Journal of Engineering and Applied Sciences - JEAS, another scientific journal from Majmaah University. The board has pledged a commitment to JEAS authors and readers to bring the most dynamic and vibrant journal management with better satisfaction.

Dr. Tawfeeq Alkanhal

Contents

Addressing the Challenges in Construction Project Management: The Case of Saudi Arabia

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Abstract
The construction industry in Saudi Arabia is improving its economic conditions and diversifying its investment. However, considering the complex nature of Saudi construction project management, this study explores the challenges facing the industry's management so that measures to deal with these can be taken. A total of 111 construction personnel associated with three different construction projects in Saudi Arabia were recruited to participate in a quantitative inquiry. The findings show that the major problems occurring within the construction are caused by variations between the designs and plans, ineffective communication, unproductive performance, and poor workmanship in the construction projects. Hence, the study provides a better understanding of the problems that can occur during construction projects. It is concluded that changes in the project scope, design and site conditions are the major factors leading to project delay and overrun cost, and the need is emphasized for a strengthening of the administrative, regulation and communication routes among the construction actors to enable the successful completion of projects.

Keywords: Challenges, Construction Industry, Projects, Regulations, Saudi Arabia;
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1. Introduction

In recent times, both professionals and academics have recognized project management as a most challenging task (Langston, 2013). Indeed, given the developments in project management, the results have been less than expected, and concerns have been raised on its effectiveness as a discipline (Mir & Pinnington, 2014). Nonetheless, changing human needs and developments in infrastructure have increased the number of construction projects across the world signifying the contribution of the construction industry to the global GDP (Myers, 2013). Its effective management is therefore, imperative.

Construction projects are recognized as one of the oldest human accomplishments, initially having been achieved by builders, architects, masons and craftsmen (Irefin, 2013). Technological innovation, eco-friendliness, and altered manufacturing concepts have, however, modified construction practices in an attempt to improve them. Simultaneously, the quality and quantity of construction projects are now used as indicators of a country's status as being underdeveloped, developed, or developing (Abdullah et al., 2011).

It is a well-established fact that the nature of the construction industry is highly complex and distinct, making it difficult to complete projects on time and within budget while simultaneously complying with the specifications set for quality (Chia et al., 2014). Performance in the sector is affected by various factors, making planning and regulation difficult (Almahmoud, Doloi, & Panuwatwanich, 2012). The Saudi Government was seen to invest around US 629$ billion in construction projects (Shuaib, 2016), marking an unprecedented growth comprising water supply projects, power stations, hospitals, housing and other facilities. These projects contribute 30-40% to the KSA economy, and hence, the effective management of these projects is essential. Moreover, given that the building price is associated with the rise in oil prices, it becomes even more important to properly manage the underlying difficulties in the sector (Badran, 2012).

The announcement of the Saudi Arabia Vision

2030 by the Kingdom's Deputy Crown Prince for the economic reform of the country has amplified the number of projects (Alshuwaikhat, & Mohammed, 2017). Since the economy is shifting to diversify its revenue resources, investment in housing projects is increasing, and is expected to continue in this vein in the coming years (Intersec Saudi Arabia, 2018). Considering the expanding dynamics, strict timeline, and the sky-rocketing number of housing projects under construction, the identification of the obstacles to timely completion is vital for project management personnel who are aiming to complete their projects within determined timeframes.

The major challenges faced by management teams include delays in project completion, which increase the overrun cost, and disputes that occur during projects. Various studies have endorsed completion delays as a major problem associated with construction projects. Gündüz and AbuHassan (2016) researching in Qatar, Samarghand et al., (2016) in Iran, and Doloi et al., (2012) in India all identified the lack of of labour capacity, inadequate planning, and a shortage of resources as major causes. Since construction projects are large, huge investment is required to overcome these issues, which once they occur, require immediate attention.

Construction industry projects are undertaken in four phases, namely: conceptual, designing, engineering, and construction. Continuous evaluation and control can overcome difficulties experienced during these phases (Alhajri & Alshibani, 2018), and the project management team can eradicate all such problems, thereby enhancing overall project efficiency by imposing such evaluation and control. Certainly this is a desired outcome, since the on-time completion of projects within all the quality and technical requirements is what both clients and contractors want (Ruqaishi & Bashir, 2013). According to Khan (2015), the objective of construction teams is to complete their projects on time and with less estimated cost. But challenges to on-time completion are many, as noted by Abd El-Razek et al., (2008) who highlight such delays as resulting from the inadequate experience of the contractor, ineffective and inappropriate planning, delays in payment, ineffective or no intervention by the professional construction management.

Alinaitwe et al., (2013) highlight five critical factors associated with delays in construction industry projects, namely: changes in the project scope, progressive delays in the payment, less control of the project, the increased cost of the project, and the country's political uncertainty and instability. McAnulty and Baroudi (2010) on the other hand, confirmed other researchers' argument that challenges to construction projects are due to the failure in attracting skilled workers, and in retaining those who are recruited. And Rao (2016) has identified problems contributing towards delays as the lack of communication, delays in payment, poor management, variations in price and shortage of materials, and late provision of instruction

The challenges of construction project management are also related to the production capacity of its workers. These are the core elements of construction projects without whom such projects cannot be carried out. Ngwenya and Aigbavboa (2017) also point to the different levels and types of skills required by workers for the proper planning, design and execution of a project. The integration of this diversified workforce brings with it the potential for conflict, and such problems among workers are hindrances to project progress. In this regard, Almannaee (2014) has highlighted issues such as the shortage of both skilled and unskilled labour, lack of experience, safety concerns, extended working hours, and discrimination on the basis of race.

In fact, Memon et al., (2011) cite the problem of being able to source quality workers in construction projects as the topmost concern (Memon et al., 2011), a challenge echoed by Pramanik and Chackrabarti (2013) who also report ignorance of the market conditions and the changing labour market dynamics as further concerns. Likewise, the frequent changes and modifications to construction projects, which affect the working of the project management team are blamed for delays since such variations substantially disrupt the production flow and the smooth working of the project personnel, resulting in a reduction of performance and time delays. These variations appear in the form of infrastructure design, low retention of the labour, and administrative problems among the owners (Lindhard, 2014).

Since the construction industry ranks as the second largest industry in Saudi Arabia, the challenges and problem associated with it are enormous (Andrieu, Ucla, & Lee, 2016). The commonly reported problems result from low wages, shortage of workers, and administrative issues, all of which bring a detrimental influence which combines to make management of the growing number of construction projects in the country much more difficult.

Despite these overwhelming challenges, no previous study has accorded meaningful investigation of the problem and a deep understanding and identification of all the various impediments to effective construction project management is required in order to improve the completion rates, and performance quality. The present study therefore explores the challenges encountered by construction project management in Saudi Arabia with a view to highlighting the problems faced by the construction workforce that are currently preventing the achievement of quality performance.

2. Methodology

A quantitative method was employed to assess the impact of various issues in the construction project management, including the additional costs incurred.

3. Study Sample

A random sampling technique was used to select the participants, 111 construction personnel from three different sites in Saudi Arabia. The inclusion criteria were: individuals having direct involvement in the construction industry, belonging to middle and upper management, and with not more than 20 years of experience. This sample was believed to yield authentic and valid data. Individuals from small construction enterprises were excluded as they were considered to lack experience of the institutional management framework envisaged in the present study. All participants gave their informed consent. The sample size of 111 is acceptable, considering the fact that a smaller number of respondents with adequate understanding of the subject matter is more appropriate than a much larger sample with little comprehension. The assessment of this data allows for the generation of authentic and effective solutions to the problems besetting construction projects.

4. Study Variables

In the present study, the independent variables are the challenges confronting construction project management in Saudi Arabia, and comprise: administrative procedure issues, regulation and contracting issues, unforeseen ground, utilities and project site issues, performance and workmanship issues, supply and procurement issues, variation orders, payment issues, and delays. These were the most common factors identified in the literature. The dependent variables are: the reported project challenges that delay project completion and the additional cost, observed by participants in construction projects.

5. Data Collection

Data was collected via a self-administered questionnaire, designed after conducting the literature review already reported. The questionnaire was prepared on the survey monkey website, and was then shared with individuals involved in three construction projects in Saudi Arabia, which were among the important projects currently underway, and that were facing challenges likely to delay their completion. The questionnaire was comprised of questions that investigated issues hindering the effective management of the construction projects, and was designed to evaluate the respondent's perception of each of the issues encountered, such as increases in the specified cost of the construction project, and the delays in the project handover. Data was gathered on the basis of its frequency, thereby assisting in the knowledge possessed by management about disruption to the smooth running of projects, and subsequently assisting in the effective corrective action taken to place construction projects back on track.

6.Data Analysis

The responses of the participants were analyzed statistically and were illustrated through graphs. The Microsoft Excel tool was used for the purpose of data evaluation.

7.Results

The questionnaire responses were critically evaluated to identify the challenges associated with construction project management. Demographic analysis revealed that the majority of the population was comprised of project owners or clients (36.94%), followed by consultants (29.73%), contractors (21.62%), and others (11.71%) (see Figure 1).

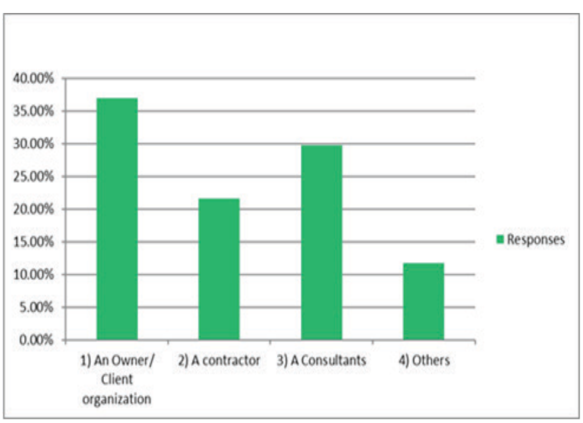

Fig 1. Participants' Characteristics

The experience of the participants and their involvement status in the construction projects appears in Figure 2 which shows that 18.92% of the sample possessed experience of 0-5 years, 27% participants had 5-10 years, 10-20 years, and more than 20 years.

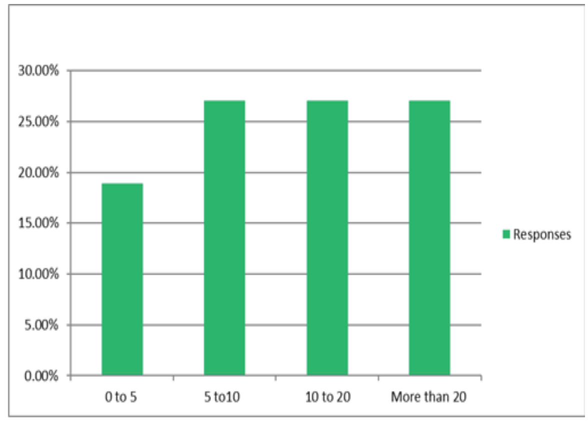

Fig 2. Years of Experience

Figure 3 shows the project budgets, which provides evidence of the scope of these projects. Given the nature of the data, a high budget assists in highlighting the significant issues. In the study, the majority of respondents (36.94%) were involved in projects with budgets of more than 100 million S.R, 24.32% were involved in projects with budgets of less than 10 million S.R, 22.52% were involved in projects with budgets of more than 10 million S.R, while 16.22% were involved in budgets of more than 50 million S.R. This gives some idea of the magnitude of these projects and their complexity, and helps to reinforce the notion that the array of problems faced in projects of such scope can be unique. At the same time, it can be seen that the involvement of the majority of the participants in high budget projects further enhances the scope of the study.

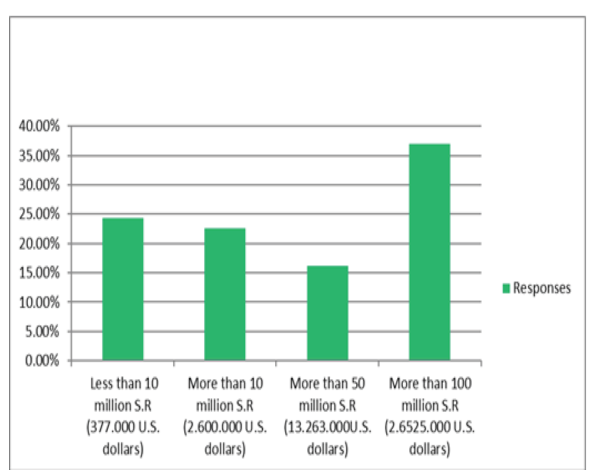

Fig 3. Budget of Projects

Figure 4 highlights the status of the challenges in the construction process resulting from various reasons, showing whether, for instance, the challenge had no impact, was latent, perceived, felt, manifest, or came in the aftermath of the problem. This helped in identifying the status of a specific challenge and the consequences faced by the participants in completing the project on time. The responses showed that in the administrative (project management), procedure issues, the problem perception was highest (28.18%), which was similar in the regulation and contracting issues with a percentage of 23.64%. Similarly, 24.77% of respondents also perceived unforeseen ground, utilities and project site problems as major issues; whereas, performance and workmanship issues were manifested by 29.63%. The manifest percentages were the same in the supply and procurement issues, i.e. 23.36%. The majority of participants (29.63%) manifested the variations orders issues, similar to payment issues (38.89%). The aftermath was highlighted (36.36%) in the form of delay issues.

The study also evaluated the additional costs incurred in construction projects as a result of problems, and Figure 5 provides the graphical representation of the answers in the form of a weighted average. From this it is seen that cost due to variations is highest with a weighted average of 3.32, followed by delay issues (3.03). Performance and workmanship issues (2.73) ranked third for increasing the project cost, before unforeseen ground, utilities and project site issues (2.70). The majority of participants agreed that cost associated with administrative (project management), procedure issues and regulation and contracting issues was lowest i.e., 2.53 and 2.54 respectively.

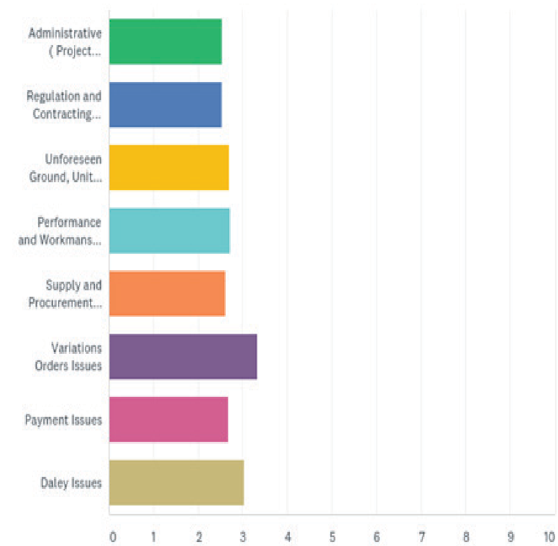

Fig 5. Additional Cost

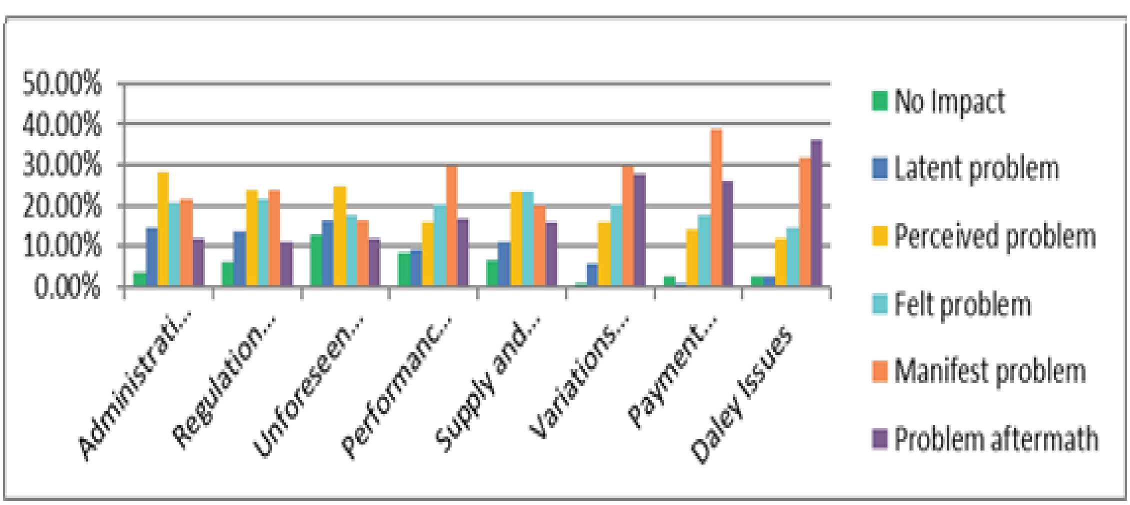

Fig 4. Problem Intensity Level

8. Discussion

The results indicate that challenges in construction project management are not being met, to the detriment of the project planning and budget. Unfortunately, it is usually assumed by the contractor that the client will bear the additional costs, whereas often the client believes this to be the contractor's responsibility. Indeed, Muhammad et al., (2010) found the variation in orders may be due to the owner's change of plans, or to the replacement of the material by the contractor at the suggestion of the consultant. Moreover, Ismail et al., (2012) in their evaluation of construction project management in Iran, show that mistakes in design, modifications to original plans, and different unforeseen site conditions all combine to hamper effective construction project management. The results also indicated that late changes in the project requirement, and efforts to redesign and rework also cause delays and add to overrun costs.

In the present study, it is also clear that administrative inefficiencies resulting in delays in payment also have their knock-on effects, and this has also been found by Sweis et al., (2008) in their research into the Japanese construction industry. The results show that completion delays occur because of the limited financial capability of the contractor which becomes more of a problem when the client changes the orders.

Additionally, Mohammed and Isah (2012) have also highlighted that construction management project often encounters problems during its planning and construction phases, that inevitably involve delay and cost overrun during the preliminary stages. This study supports that finding, and argues for better communication between the construction and finance. managers to ensure payments are made on time.

The effective management of construction projects is also seen to be hampered by the diversified workforce within Saudi Arabia, since the skill sets possessed are varied and often insufficient. Mohamad, Adenan and Abdul Rahman (n.d.) have shown that individual work productivity is linked with the overall productivity of the project, and that the project working capacity is also linked with the payment system as the delays in payment impact upon the work functioning of the involved parties. The analysis of the responses in this study confirms the need to hire competent administrative personnel capable of the timely issuance of payments to maintain the project operational capacity and to retain the workforce.

In the context of additional cost, it is also found in the study that ambiguity surrounding the various tasks within construction projects and who is involved in them, leads to additional cost. This reflects the findings of Pawar and Patil (2014) who highlighted that tasks and duties along with information about the resources must be communicated effectively if a project is to be successful. Pérez Gómez-Ferrer (2017) has added that the use of various tools can increase the project effective and working. Therefore, the utilization of such tools is recommended to assist in overcoming project management problems.

The process of construction is embodied within a set of contractual and other documentation that conveys the needs of projects, included in which are the timescales for completion. However, as shown in this study, challenges occur in relation to delays in payments and continuous change in the building designs. Hence, it is recommended that construction companies focus on the adoption of certain strategies and practices to provide guidance to the associated stakeholders

9. Conclusion

The successful completion of construction projects is highly dependent on the project management team that includes the owner/client, contractors, and consultants. In this study, it emerged that the major challenges facing the project management team lie at the administration level, which is basically responsible for delays in making payments, and therefore, for progression delays. Variation in project designs and planning also causes major complications, hindering teams from completing projects on time. Such delays and their associated overrun costs are commonly experienced in Saudi Arabia, and the study concludes that changes in the project scope and design, and site conditions are the major culprits in this regard. A third problem, which further affects the management of construction projects concerns workmanship and performance, as the competence and overall skill levels of construction workers are insufficient to meet the requirements of large-scale projects.

The study findings confirm that significant effort must be made to overcome the delays and cost overruns, and that clear communication must be established among all parties involved as a first move. It also emphasizes the need for adequate provision of financial resources to ensure the timely delivery of construction projects. With attention to these factors, it will become possible for construction projects to be undertaken harmoniously and within the budget set, and with these good practices in place, the presence of other issues can be mitigated.

It is acknowledged that the findings are limited by the size of the research sample, and future studies can involve bigger populations to expand the scope of a similar investigation. Additionally, it would be beneficial to develop a framework for the management of the challenges in the construction projects, since companies would be facilitated in their efforts to deal with the complications associated with the management of construction projects in the KSA.

Conflict of Interest

The author declares no conflict of interest.

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Flow Pulsatility of Heart Pump: State Space Modeling and Control

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Abstract
In this work, a physiological control strategy using full state feedback (FSF) control method is developed to drive mechanical circulatory support (MCS). This strategy is utilized a validated state space pump model to implement the controller and to track the desired reference flow. The developing strategy is assessed using a software model of the hemodynamical cardiovascular system interacted with left ventricular assist device in different physiological conditions ranging from rest to exercise scenarios. During these scenarios, heart failure disease simulates by changing the hemodynamical parameters of total blood volume, heart rate, cardiac contractility, and systemic peripheral resistance. The results are numerically observed during postural changes. The rate of change in physiological variables showed that the control method can track the reference pump flow with minimal error within acceptable clinical range to prevent suction with lower pump flow (3.35 L/min) and over perfusion with higher pump flow (5.2 L/min).

Keywords: Heart Failure; Cardiac Assist Devices; Full State Feedback; Cardiovascular System, Pulsatility Index.
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1. Introduction

Heart failure (HF) is a serious health condition known as the inability of the heart to pump out enough blood to support the body organs [1, 2]. In the last decade, a large population has attributed to this disease worldwide. In the United States, there are approx. 5.3 million people with HF, yet annually less than 0.05% receive a heart transplant [3]. Similarly, in Australia, the annual prevalence of heart failure is approximately 2% of the population [4]. Continuous intravenous inotrope support has been used as a short-term treatment, and although they may improve symptoms but may worsen mortality. This sets the stopwatch for patients beginning inotropic therapy as survival rates after a year is only 10 to 30% [5].

Heart transplantation is the only solution for those people suffering from this disease. However, the shortage of donor's hearts has forced mechanical circulatory support (MCS) to mitigate the sever of a heart failure condition. MCS has proven to produce more favorable outcomes in end-stage HF patients than optimally medically treated heart failure patients [6]. For this reason, it is expected that the use of MCS must increase significantly, with the indications widening to include both bridge to recovery (BTR) patients and destination therapy (DT) patients not previously considered transplant candidates. Many devices exist to support the circulation of an HF patient, with the main distinguishing feature relating to their mode of outflow, i.e. pulsatile or continuous. Although a nearly physiological pulsatility in the middle cerebral arteries was developed in patients with the continuous axial ventricular support, the debate continues regarding the benefit of maintaining flow pulsatility [7].

These mechanical devices are shown in Fig. 1, fall into two categories of ventricular assist devices (VADs); of constant flow rotary and pulsatile flow [8, 9]. The new generation of VADs hydrodynamic and/or magnetic suspension systems levitates the impeller giving a system with no mechanical parts to fail and a life expectancy of 10 to 15 years [10]. The clearance gaps of magnetic systems are generally larger than hydrodynamic bearing pumps giving lower shear rates associated with blood-washed bearings, reducing the risk of damage to blood components that trigger thrombus formation.

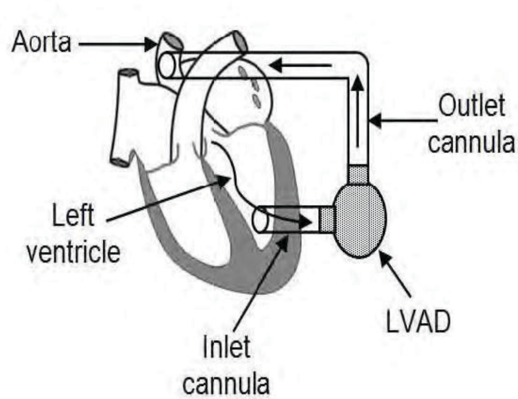

Fig. 1. Schematic diagram of the left ventricular assist device connected with the human heart.

These new generations of VADs without mechanical contact bearings are available in axial and centrifugal forms [11]. Recent investigations into these two types of VADs indicate that patients have a higher chance of survival with rotary or constant flow support, as they allow higher reliability, reduced sepsis and decreased the incidence of the right heart and end-organ failure. However, constant flow supports and ability to provide optimal safety is still with high concern because of devices' small size, reduced implantation procedural time and decreased device complexity [12].Naturally, as the VAD and controller will eventually be implanted in human and their life span highly depend on the appropriateness of pump control, we must have great certainty in the robustness of control algorithms [13]. The ability to control the speed of continuous flow or VADs may enable the generation of simulated pulses, however till date circulatory support is conventionally provided at a constant mean rotational speed in-spite of the sensitivity to left ventricular and aortic pressure, invariably reduces pulse pressure [14, 15].

In general, these types of devices require precise control and using sensors to measure flow and pressure are nor reliable due to clinical issues such as routine calibration and blood clotting [16]. These concerns regarding implantable sensor reliability have driven the search for sensorless and non-invasive sensor-based approaches to identify an analogue of cardiac preload. We now believe that a non-invasive technology has advanced to a level where it can be considered for long term implantation, combined with sensorless signals, to form a robust control system giving physiological behavior to rotary blood pumps. In this work, we developed and validated the physiological control algorithm for VAD using FSF technique to track the error states between the measured and estimated flow of VAD. Non-invasive signals of current and voltage in combination with modeled estimator of flow are used as a part of the design [16]. The methodology is proposed to evaluate the merits of controller involving the flow estimator in a range of identical simulation scenarios.

2. Materials and Methods

2.1 Pump flow pulsatility control strategy

Pulsatile MCS has the advantage of producing physiologic pressure and flows within the cardiovascular system [8]. This may be beneficial to improve micro-circulation and prevent complication in the gastrointestinal circulation. However, the excessively large size and unreliable mechanical function of such devices are far out way the benefits that pulsatile flow may provide. Rotary pumps overcome these issues by offering smaller and more reliable devices [17].

In this research, the parameter of the pulsatility index (PI) is used as a control target. This index is validated that represents the ventricular preload or left atrial pressure. where PI increases, so too preload dose, and vice versa [18]. The state of ventricular collapse can be induced by excessive decreases of PI. Thus, PI index is a valuable indicator for sustaining the pump responds to change in preload and afterload conditions for patients suffering from HF disease by providing the highest possible flow rate to prevent suction [8].

2.2 Mean pulsatile flow estimator

An estimator model is developed to estimate mean pulsatile flow based on the input signal of the pulsatility index of current (PI_I). The proposed model is constructed using the dog's data collected from real experiments [14]. For system modeling, A state space structure model with observability canonical form is configured. Subspace system identification 4SID method is used for parameters estimation [19]. (PI_I) is modeled to estimate the parameter of mean pulsatile flow (Q_p). The system states were tracked online using a constant forgetting factor method, in this study, it equals to 0.98. This factor accommodates the variations of parameters and the change of preload, after load, and heart contractilities. In the case of sudden changes of a venous return due to body posture when the body is straining or coughing, an updated forgetting factor is needed to allow fast track of the system parameters. Therefore, the estimated parameters were minimized at each time step (t) using the following least squares cost function:

$$V(Q_p, \bar{Q}_p) = \frac{1}{2}\sum_{i+1}^{t} x^{t-i}(Q_p - \bar{Q}_p)^2 \quad (1)$$

In the system algorithm, the best fits between measured and estimated model output were 99.55%. The results of the correlation coefficient (R^2) and the mean absolute error (e) between measured (Q_{meas}) and estimated values of (Q_p) were calculated by giving the following equations as:

$$R^2 = \frac{\sum_{i=1}^{N}(Q_{meas}(k) - \bar{Q}_{meas}(k)(Q_{est}(k) - \bar{Q}_{est}(k)}{(\sum_{i=1}^{N}(Q_{meas}(k) - \bar{Q}_{meas}(k))^2 \sum_{i=1}^{N}((Q_{est}(k) - \bar{Q}_{est}(k))^{1/2}} \quad (2)$$

$$e = \frac{1}{2}\sum_{i=1}^{N}(Q_{meas}(k) - \bar{Q}_{est}(k))^2 \quad (3)$$

where N is the length of data, and is the average values of the measured and estimated pump flow respectively. Table 1 is illustrated the values of the model correlation (R), slope (S) and means absolute error (e) at two different speed.

The estimator model has been carefully evaluated to estimate mean pulsatile pump flow (Q_p). For this model, dog's data are used to simulate the status of the cardiovascular system in terms ofhealthy, exercise and HF by observing the parameters of end-diastolic left ventricular pressure with the cardiac output as shown in Fig. 2.

Table 1: Values of the model correlation (R), slope (S) and mean absolute error (e).

System identification results					
Trail 1 @ speed (ω) = 2900 rpm			Trail 2 @ speed (ω) = 2100 rpm		
R^2	S	e (L/min)	S	R2	e (L/min)
0.9955	1	0.0863	1	0.9955	0.1418

The frequency response of the state space estimator model is shown in Fig. 3. Linear regression analysis between and are obtained from the experiment, is illustrated in Fig. 4.

The results of system modeling are the state space model which can be represented as:

$$x(k+1) = Ax(k) + \Delta Ax(k) + Bu(k) + \eta(k)\; y(k) = Cx(k) \quad (4)$$

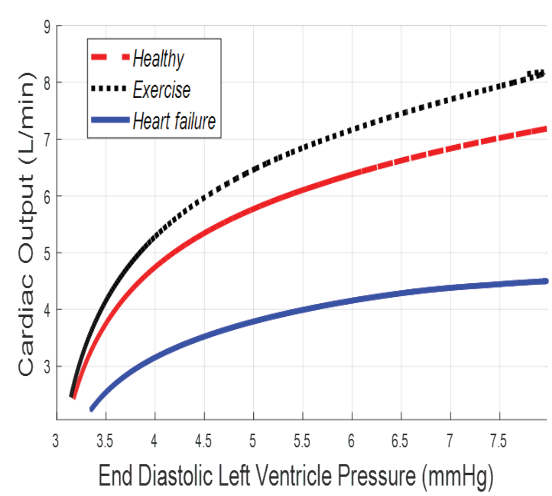

Fig. 2. Cardiac output vs end-diastolic left ventricular pressure.

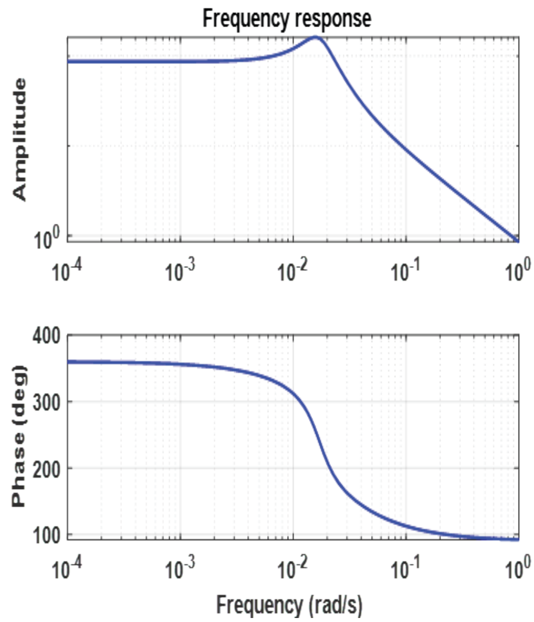

Fig. 3. The frequency response of the state space model.

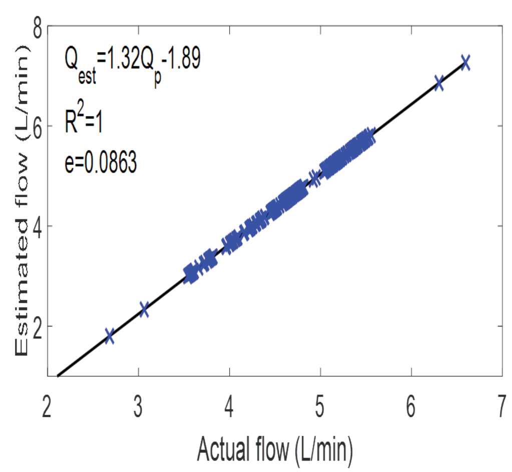

Fig. 4. Linear regression plot between estimated versus measured flow for trail one.

Where $x(k)$ is representing the system states, ΔA is system parameter variations, $u(k)$ is the control input, $\eta(k)$ is the system noise and $y(k)$ is the system output.

2.3 Controller design

Full-state feedback control is introduced in combination with pulsatile flow estimator model, VAD model, and designed the reference signal as shown in Fig. 5 [20]. To design the control law , $u(k)$ the poles of eigenvalues (A) for the closed-loop system are modified to determine $(SI - A_{sf})$, where S is the Laplace variable.

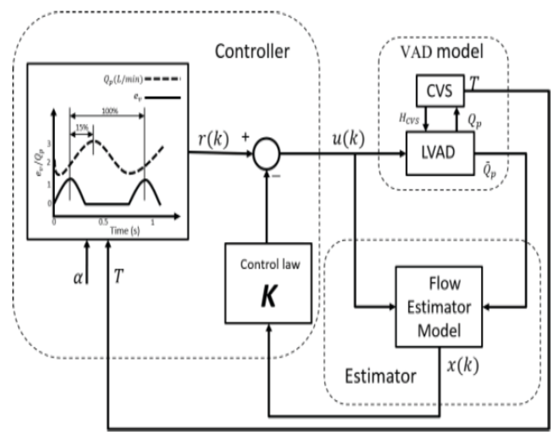

Fig. 5. Block diagram of the human cardiovascular system in combination with the controller, estimator, and reference input.

We assume that the input control of full-state feedback form is given by:

$$u(k) = r(k) - Kx(k) \qquad (5)$$

where $r(k)$ is the reference input and $k = [d_1 \quad d_2]$ is the state feedback gain. The closed loop of system dynamicsfor the state space model can be written as:

$$x(k+1) = Ax(k) + \Delta Ax(k) + B(r(k) - Kx(k)) + \eta(k) \quad (6)$$

$$x(k+1) = Ax(k) + \Delta Ax(k) + Br(k) - BKx(k) + \eta(k) \quad (7)$$

$$x(k+1) = (A + \Delta A - BK)x(k) + Br(k) + \eta(k) \qquad (8)$$

where, $A_{sf} = (A + \Delta A - BK)$, and we assume the terms of ΔA and $\eta(k)$ are bounded with upper and lower limits. The stability of the model with controller design is studied and Fig. 6 indicates that the pole-zeros of the model estimator are located within the unit circle. In addition, the system state response is given in Fig. 7 where the states quick converge to zero. In this method, the controller is designed to track the reference input “flow” in terms of the time-varying of elastance function at systolic and diastolic period [21]. Therefore, the reference signal $(r(k))$ is considered as:

$$r(k) = \alpha + \delta \sin(\frac{2\pi t}{T} + \emptyset) \quad (10)$$

where α = constant > 0, δ= constant,$\delta > \alpha$, and T is the heart period.The second part of $r(k)$ is sinusoidal periodic function and is chosen to achieve the variation of pump flow in elastance function at systolic and diastolic period.

Table 2: Heart failure conditions at rest and exercise scenarios; TBV: total blood volume; LVC: left ventricular contractility; RVC: right ventricular contractility; SPR: systemic peripheral resistance; HR: Heart rate

Parameter	HF simulated conditions	
	Rest scenario	Exercise scenario
TBV (L/min)	decreased by 500 ml	increased by 500 ml
LVC (mmHg.mL^{-1})	normal	increased by 20 percentage
RVC (L/min)	normal	increased by 20 percentage
SPR (mmHg.s/mL)	normal	decreased by 15 percentage
HR (bpm)	10 bpm	30 bpm

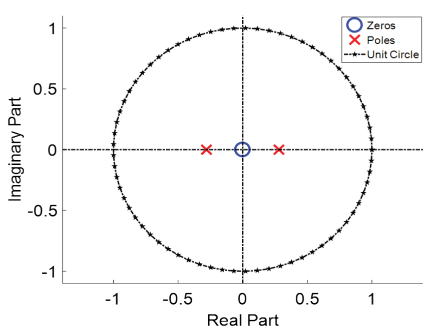

Fig. 6. Zeros and Poles for the system model.

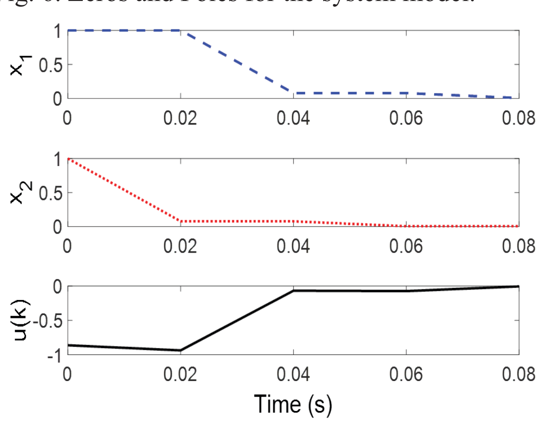

Fig.7. System states response.

3. Results and Discussion

The algorithm assessed the effectiveness under a set of identical simulated conditions representing the wide range of HF conditions that may be encountered, comparing performance with the existing simple fixed speed controller as given in Table 2. In order to achieve good simulation results, the values of α , δ , and state feedback gain (k) are given with 0.9902, 2.372, and K=[0.1154 0.2249] respectively. Moreover, simulations for controlling pump flow as a function of left atrial or left ventricular end diastolic pressure is also considered. The immediate responses of the control algorithm are evaluated in both rest and exercise scenarios. In both scenarios, the system parameters are set to work over a period of the 60s. Within this period the parameters are linearly changed to induce the system at the 30s based on the conditions in Table 2.

3.1 The transition from normal to rest

This scenario has conducted theevaluate the performance of the controller and estimator to immediately respond to change into hemodynamical characteristics of the system. Fig. 8 shows a plot of stroke volume (SV). The reduction in total blood volume associated with decreases of heart rate (HR) by 10 bpm, produced a reduction in stroke volume of the left and right ventricular. These changes correlated with a shift to the left of the left ventricular pressure-volume loop and the right ventricular pressure-volume loop was slightly shifted to the right which resulting in a reduction in left ventricular end-diastolic and left ventricular end- systolic volumes and pressure. Therefore, the controller was able to decrease the aortic pressure (P_{ao}) within safe mode as presented in Fig. 9. In addition, the controller was able to decrease the average pump rotational speed from 2850 rpm to 1800 rpm (see Fig. 10) and keep the system safe from suction by recording the variables of estimated average pulsatile flow within a minimal rate of 3.35 L/min as depicted in Fig. 11.

3.2 The transition from rest to exercise

This scenario is conducted to study the merits of the controller whether able to keep the pressure-volume loops within accepted values to prevent flow form over perfusion or not. At the 30s "with conditions stated in Table 2", the controller responds to shift left ventricular pressure-volume loop to the rightward and highly increased the left ventricular stroke volume as presented in Fig. 12. The aortic pressure (P_{ao}) is increased within safe mode as depicted in Fig. 13. In addition, the controller was able to increase the average pump rotational speed from 2850 rpm to 3400 rpm (see Fig. 14) and keep the system safe from over perfusion by recording the variables of estimated average pulsatile flow with a maximum reading of 5.2 L/min as demonstrated in Fig. 15.

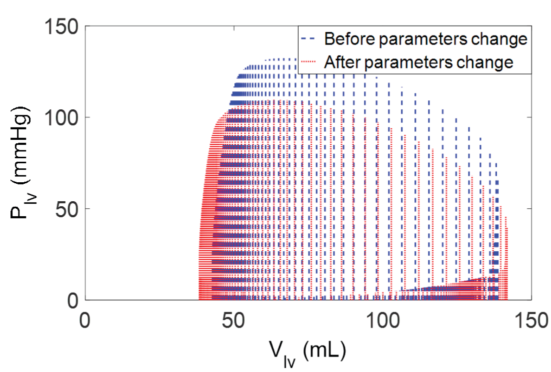

Fig. 8. LV pressure-volume loops before and after the reduction of total circulatory volume (Vtotal) @ the transition from normal to rest.

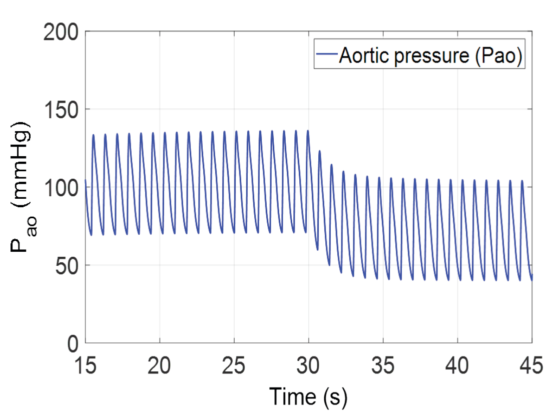

Fig. 9. Time waveform of aortic pressure @ the transition from normal to rest

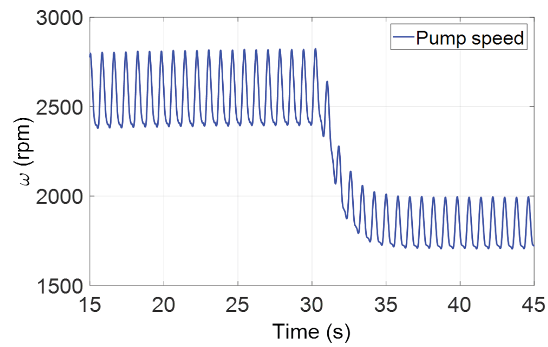

Fig. 10. Time waveform of pump speed @ the transition from normal to rest

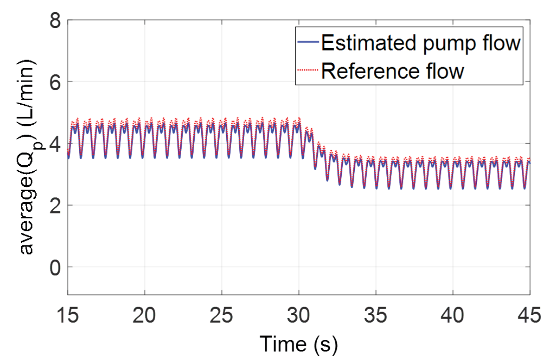

Fig. 11. Estimated pump flow vs Reference flow @ the transition from normal to rest

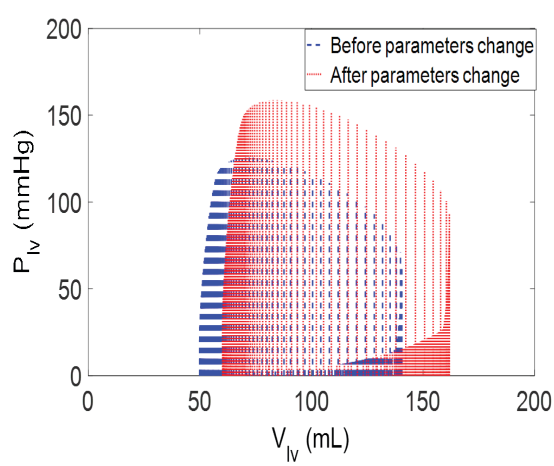

Fig. 12. LV pressure-volume loops before and after the reduction of LV contractility (Emax) @ the transition from rest to exercise

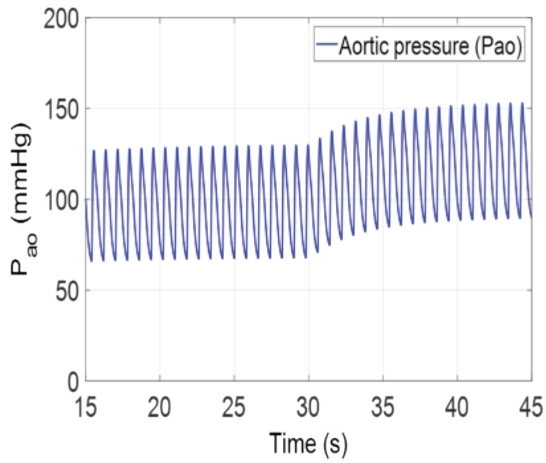

Fig. 13. Time waveform of aortic pressure at the transition from rest to exercise

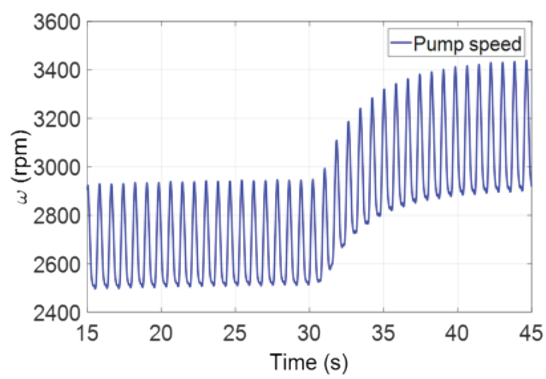

Fig. 14. Time waveform of pump speed at the transition from rest to exercise

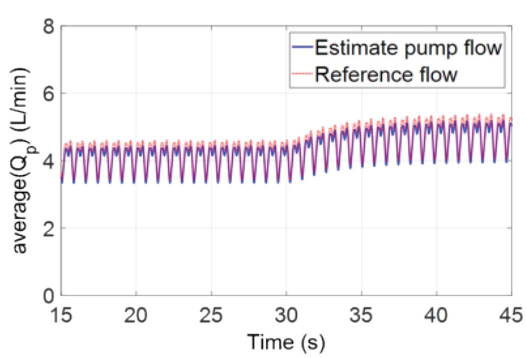

Fig. 15. Estimated pump flow vs Reference flow at the transition from rest to exercise

The ability to control the speed of continuous flow or VADs may enable the generation of simulated pulses, however till date, circulatory support is conventionally provided at a constant mean rotational speed in-spite of the sensitivity to left ventricular and aortic pressure, invariably reduces the pulse pressure [22,23]. In this work, a methodology is proposed to evaluate the merits of an FSF control method involving sensor-less and non-invasive thereof in a range of identical simulation scenarios. The results of this method stated that the controller has advantages to track the generated reference signal with the safe mode at varied speed as illustrated in Figs. 10, 14.

The software simulation model currently simulates rest and exercise with changes in HR, cardiac contractility, and systemic vascular resistance. Clinically, it is observed that large changes in pump pulsatility during postural changes, patients sometimes feeling faint. Patients have sometimes felt faint during Valsalva manoeuvres e.g. coughing or straining [24]. So we believe it is important that we enhance our software model to represent these events. In addition, the aortic valve is observed to be closed in most LVAD patients. However, with the postural change, cardiac recovery and in exercise it may open. We have found that the aortic valve offers a lower resistance path than the LVAD bypass route, the native heart sometimes pumping significant flow relative to that via the LVAD. So, we believe this different pumping state could impact greatly to our overall control strategy and so requires online detection.

Future works are subjected to examine ventricular suction, pump regurgitation, and other states in a mock loop, and in animal studies. However, the state of pump regurgitation has not been able to be detected. This may occur in exercise at a fixed speed when the pump is effectively underpumping. It is important that we identify regurgitant pump flow. It is proposed that we first seek to identify this state in pulsatile mock loop studies using the motor current signal. We plan to then validate this algorithm in animal studies.

4. Conclusions

This In this work, a full state feedback control law is implemented to derive VADs based state space pump model. Refinement of non-invasive pump estimation and state identification for detecting regurgitation pump flow is achieved. Intensive computer simulation studies are conducted to evaluate the merits of control algorithms by changes the cardiovascular system parameters to induce heart failure cases. The results figure out that the controller can track the generated reference flow within minimum error. In the future, the work can be extended to evaluate the controller performance combined with the estimator on the mock-loop system.

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Heuristics for a Scheduling Problem in a Wireless Network

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Abstract
This study considers a network problem, for which we propose a new component in a network architecture called a scheduler. For each set of packets requested by a user, the scheduler solves a scheduling problem inassigning packets to routers. The related problem is NP-hard. We search to find some approximate solutions to solve the problem. This is because the optimal solution is based on the branch and bound method, which is generally characterized by a very high run time. In this study, we propose several heuristics, based essentially on multi-fit, a subset-sum problem, and dispatching rules. The efficiency of the heuristics is measured by using several indicators,includinga comparison with a lower bound. The performance of the algorithms is represented in experimental results. As shown herein, in 100% of cases, the best heuristic value represents the optimal solution.

Keywords: wireless network, routers; dispatching; scheduling; big data.
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1. Introduction

Nowadays, network technologies have a primary role in our daily lives [1]. In particular, wireless networks,which are continuously broadcast by all using means of transferring data, are improving more and more. A wireless network is also becoming a way to make life easier, and encourages people to use new information technology. Generally, on a wireless network, there is a huge amount of data to transmit and control. The security requirements of wireless networks are essential for protecting wireless transmissions [2] [3]. In addition to security, the correct manipulation of data and the use of appropriate routing in networks can facilitate the utilization of additional data, and a user can receive an amount of data in a fixed time period. A better method of dispatching data in the network can also permit users to transmit more data through the network. In the case of "big data," maximization of transmission of the big data is guaranteed by choosing the best method to assign packets on routers. Several scientific researchers havestudied scheduling in networks.

The authors in [4] propose a dynamic batch co-scheduling *(DBCS)* scheme to schedule packets in a heterogeneous network processor, and assume that the workload is perfectly divisible. Other authors discuss the scope of packet scheduling as a mean to control traffic and improve performance [5]. A study of scheduling in wireless high-speed networks, considering quality of service *(QoS)* requirements, is performed in [6]. In addition, modern radio-links canalso transport data.

Scheduling and planning problems have been traditionally solved and modeled on directed graphs using a classical critical path method, to obtain a schedule that minimizes the completion time of several jobs with precedence [7]. Some heuristics have been developed to solve a parallel machines problem with a make span, and to show their performance [8]. An exact method using a branch and bound algorithm was presented in [9]. The authors in the latter work show the performance of their heuristics in several classes of instances using experimental results. In [10], a branch and bound algorithm based on several sophisticated lower and upper bounds was developed. Recently,the authors in [11] have shown a new method for an optimal solution of the hard instances mentioned in the literature. The authors in latter work utilize an innovative arc-flow model, derived from the duality between the bin packing problem and the parallel-machine scheduling problem.

In addition, a performed arc-flow description is developed in [12], to minimize a weighted makespan on identical parallel machines.Other authors use the parallel machines problem in other domains, like the smart city in [13].

Recently, authors apply scheduling methods in the wireless network in [14], [15], [16], [17],

In this study, we use algorithms to solve the problem of dispatching packets in the wireless network. A proposed architecture containinga scheduler component is also presented.

This paper is structured as follows. Section 2 is dedicated to the specification of the general network problem. Section 3 proposes several heuristics. In Section 4, the experimental results are presented, together with interpretation and analysis. Section 5 concludes the paper.

2. Problem description

In this section, we present the proposed network architecture and a description of the problem.

2.1 Network architecture

This architecture focuses on the addition of the component scheduler.This component will be responsible for dispatching sent packets to routers. This manipulation gives the user the ability to send more data. This is important and worthwhile, particularly in a situation that requires sending a huge amount of data from a number of users at the same moment. The architecture is based on dividing the received data with two essential components. This first one is the data center, responsible for receivingmultiple data and protecting them against attack, by encrypting them and subdividing them into packets. The following figure shows the architecture and the placement of each component in the network.

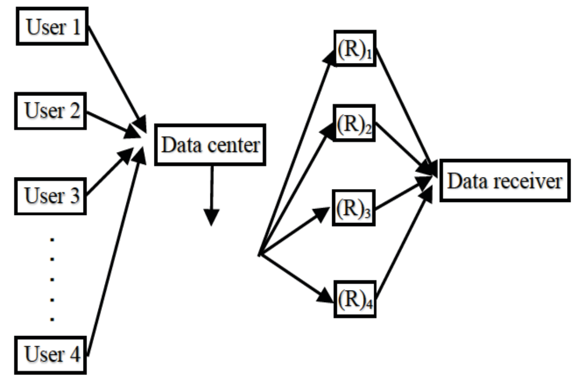

Fig. 1. Proposed router-scheduler architecture

In Figure 1, it can be observed that the only way to have access to routers for the final sending of data is through the scheduler. The scheduler is responsible for assignment of packets created by the data center. An efficient algorithm must be adopted to choose which router is available to receive data, and how packets must be dispatched. This type of problem is NP-hard.

To propose some methods to solve the above problem, we must further describe it.

2.2 Scheduling problem description

Let P be a set of n packets. Each packet j is characterized by its size S_j . We denote s_j^T as the necessary time, related to the size of packet, for the packet to be sent by the router (sending time). Hereafter, we suppose all routers have the same technical characteristics. The problem is known as minimizing the makespan on a parallel processor. t_j is the starting date of sending the packet j from the router. Thus, $t_j + s_j^T$ will be the end of the sending time,and is denoted by f_j . Once all packets have been sent, each router has its completion time, denoted by c_i. $C_{max} = \max_{1 \le j \le n} (f_j)$ is the max completion time of all routers, and the number of routers. Minimizing the makespan is related to finding a schedule which that minimizes C_{max} The proposed three-field notation in [18] for the problem is $P|\square|C_{max}$.

In this study, we utilize heuristics to solve the problem. As mentioned above, the problem is considered as NP-hard in the strong sense [19]. This is one of the most intensivelystudied problems in optimization, because it has remarkable theoretical interest, and because it has many real-world impacts and applications.

3. Heuristics

In this section, we present four heuristics used to schedule packets on the different routers. The results given by each heuristic will be compared by referring to the best value (minimum), and comparing it with the lower bound for the problem. In this study, we use the lower bound from the literature $P|\square|C_{max}$ of the described in [9], and denote it by $\tilde{L}_{TV}$.

3.1 Non-Increasing size of packets heuristic (NSIP)

The packets are sorted in decreasing order of their size, and are scheduled on routers according to this order.

Example 1

We consider the following instance,with two routers ($r = 2$) with five packets ($n = 5$). The time spent in each packet to be sent is presented as follows:

j	1	2	3	4	5
s_j^T	3	2	4	7	3

The schedule obtained after applying the non-increasing size of packets heuristic *(NISP)* is given in Figure 2.

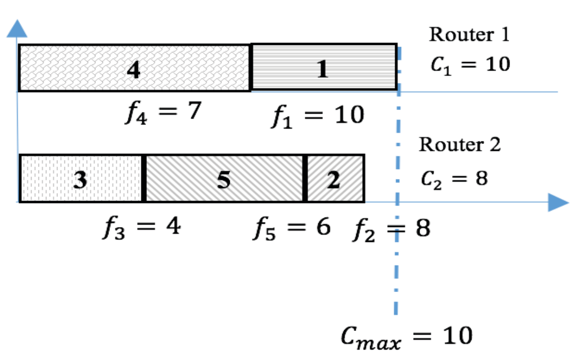

Fig. 2. Schedule applying non-increasing size of packet heuristic(NISP)

In this example, the time spent to send all packets is 10, by applying the heuristic.

3.2 Non-decreasing size of packets heuristic (NDSP)

Here, the packets are sorted in an increasing order of their size, and are scheduled on routers according to this order.

3.3 Greedy subset-sum heuristic (GSS)

This heuristic, based on a greedy algorithm for iteratively solving several subset-sum problems (SSPs) denoted by $(R)_k$ $(k = 1,.... r - 1)$, is as follows:

$$(R)_k: \left\{ \begin{array}{c} minimize \sum_{J_j \in Q_k} s_j^T y_j \\ subjectto \sum_{J_j \in Q_k} s_j^T y_j \geq L(Q_k, r-k+1 \\ y_j \in \{0,1\} \ \forall P_j \in Q_k \end{array} \right\}$$

In the above:

- $Q_1 = P$ and $Q_{k+1} = Q_k \setminus P_K$, where P_K is an optimal subset-sum for $(R)_k$ ($k = 1$, ..., r - 1).
- L $(Q$, $K)$ denotes a valid lower bound on the makespan of a reduced instance defined on $k \leq r$ routers and a subset of packets $Q \subseteq P$.

Therefore, for the first router, we assign packets until reaching L on $(R)_1$. The remaining packets and remaining router will constitute the second problem $(R)_2$ to solve, i.e., the new SSP, where packets are assigned until reaching , and so on [9].

A pseudo-polynomial is used to solve the subset-sum problem, using a dynamic programming algorithm developed by [14].

3.4 Multi-Fit router dispatching heuristic (MFD)

This heuristic is developed based on the dispatching work presented in [20]. This heuristic uses bin-packing techniques trying to search fora minimum capacity, such that all number of packets will fit into the routers.

For each fixed bin capacity, the first fit decreasing *(FFD)* method is used to fit the number of packets to the bin. We assume that the number of packets have been sorted, such that $s_1^T \geq \cdots \geq s_n^T$.

The *FFD* method assigns a number of packets in succession to the lowest-indexed routers that can contain them within the fixed capacity.

Here, $L_{max} = max\left(s_1^T, s_r^T + s_{r+1}^T, \left\lceil \frac{\sum_{j=1}^{n} s_j^T}{r} \right\rceil\right)$ and comprises the lower bound, and U_{max} is a calculated upper bound obtained by applying the largest processing time first *(LPT)* heuristic for $P||C_{max}$.

bin denotes the number of bins used after applying *FFD*, and *ite_n* is a fixed iterative number.

ite_n is predetermined, and is the number of iterations of *FFD*. We set $ite_n = 30$.

The algorithm of the multi-fit dispatching heuristic (MFD) is given here.

***MFD* algorithm**	
***Step* 0**	Set $i = 0, C_1 = U_{max}$ and $C_2 = L_{max}$
***Step* 1**	Set $C_3 = \left\lfloor \frac{C_1+C_2}{2} \right\rfloor$, Set $i = i + 1$.
***Step* 2**	Apply FFD with capacity C_3.
***Step* 3**	If we can assign all number of created new jobs n into m regions, then set $C_1 = C_3$ and go to Step, otherwise set$C_2 = C_3$. Go to **Step 4.**
***Step* 4**	If $i = ite_n$ then **STOP**, otherwise go to **Step 1**.
End	If $bin > r$ or $bin < r$ then result given by LPT is taken, otherwise result given by FFD is taken.

4. Experimental results

In this section, we present the experimental results found after execution of our implementation. To assess the performance of the proposed lower and upper bounds, we coded them in Microsoft Visual C++ (Version 2013). All of our experiments were performed on a personal computer with an Intel® Core™ i7 1.8 GHz processorand 8GB RAM. The operating system used is Windows 7, with 64 bits.

To obtain a better analysis of the actual performance of the heuristics, we tested them on a set of instances,inspired from [11] and also used in [9]. The sending times were generated according to the following distributions:

Class 1: discrete uniform distribution on [1-10] ;

Class 2: discrete uniform distribution on [5-15];

Class 3: discrete uniform distribution on [5-20];

We fixed the number of routers as the following:

$r = \{2,4,6,8,10,15\}$. The number of packets is greater than the number of routers with a remarkable difference, i.e., n = {100,500,1000 ,5000,10000}.

For each class and for each pair of *r* and *n*, 10 instances were generated. In total, we have 900 instances.

We use the following notations:

- *UB*: the minimum upper bound obtained after execution of all heuristics.
- *U:* the value obtained by the studied heuristic.
- Min_u: the number of instances when the upper bound of the studied heuristic is equal to *UB*.
- $\text{GAP}_u = \frac{U-UB}{UB}$: the gap between the studied heuristic and the minimum heuristic value.
- $\text{GAP}_L = \frac{U-\tilde{L}_{TV}}{\tilde{L}_{TV}}$:the gap between the studied heuristicandthelowerbound.
- Min_L *:* the number of instances when the lower bound of the studied heuristic is equal to $\tilde{L}_{TV}$.
- *Time*: the time spent to execute the heuristic, or the lower bound in a corresponding instance. This time will be in seconds (s), and we denote a time by "–" if the time is less than 0.001 s.

Our experimental study is based on several analyses of several indicators.After execution of all heuristics, we calculate the average time for the whole 900 instances. This average time is equal to 0.016s, which is a good and reasonable execution time. The average gap between the lower bound and the best heuristic is equal to 0. This means that the lower bound is equal to the upper bound in of instances. Therefore, the optimal solution is obtained for of instances. Reaching the optimal solution within a polynomial time is a very important result, and shows that heuristics were efficiently used to solve the studied problem. The following table presents the variation in GAP_L and *Time* according to the number of packets.

Table 1 shows that the average gap is equal to 0 for all heuristics, excluding *NDSP*. In addition, from the heuristic *MFD*, we deduce that the time increases when increases. The same observation holds for all other heuristics.

For *NDSP* , the gap for n =100 is equal to 0.04 and for n = 500 is equal to 0.01 However, for all remaining n values, the gap is zero. The greatest time is 0.183 s , reached for the heuristic *MFD* when the number of packets is 10000 .

Table 1. The behavior of and for each heuristic according to

n	*NISP*		*NDSP*		*MFD*		*GSS*	
	GAP_L	*Time*	GAP_L	*Time*	GAP_L	*Time*	GAP_L	*Time*
100	0.00	-	0.04	-	0.00	0.001	0.00	-
500	0.00	-	0.01	-	0.00	0.004	0.00	0.001
1000	0.00	-	0.00	-	0.00	0.015	0.00	0.002
5000	0.00	-	0.00	0.001	0.00	0.067	0.00	0.008
10000	0.00	0.001	0.00	0.001	0.00	0.183	0.00	0.030

In Table 2, we present the behaviors of gap and time according to the number of routers.

The faster heuristics are *NISP* and *NDSP*. The *MFD* and *GSS* are more time consuming, reaching 0.081 s for the heuristic *MFD* when r = 2.

Surprisingly, the minimum time given for is 0.027s, as compared with r = 15 , for which the time is 0.038s. This means that the time is not a fixed order according to r.

Table 2. The behavior of and for each heuristic according to

n	*NISP*		*NDSP*		*MFD*		*GSS*	
	GAP_L	*Time*	GAP_L	*Time*	GAP_L	*Time*	GAP_L	*Time*
2	0.00	-	0.00	-	0.00	0.081	0.00	0.002
4	0.00	-	0.00	-	0.00	0.056	0.00	0.005
6	0.00	-	0.01	0.001	0.00	0.027	0.00	0.006
8	0.00	-	0.01	0.001	0.00	0.051	0.00	0.009
10	0.00	-	0.01	-	0.00	0.070	0.00	0.010
15	0.00	-	0.03	-	0.00	0.038	0.00	0.015

In Table 3, we present the differences between class hardness. Values of the gap do not change according to class. However, the time shown for Class 2 suggests that it is slightly harder than other heuristics. Indeed, the maximum spent time for the MFD heuristic reaches 0.095s.

Now, we show the overall statistics given by all heuristics as compared with the lower bound, which is equal to the best heuristic value. The results are given in Table 4. *perc* denotes the percentage calculated based on all of the 900 instances.

Table 3. The behavior of and for each heuristic according to

Class	*NISP*		*NDSP*		*MFD*		*GSS*	
	GAP_L	*Time*	GAP_L	*Time*	GAP_L	*Time*	GAP_L	*Time*
1	0.00	0.000	0.01	0.000	0.00	0.012	0.00	0.008
2	0.00	0.000	0.01	0.000	0.00	0.095	0.00	0.008
3	0.00	0.000	0.01	0.000	0.00	0.054	0.00	0.008

Table 4.Comparing heuristics according to lower bound

	MFD	*NDSP*	*MFD*	*GSS*
Min_L	656	1	693	900
perc	72.9%	0.1%	77.0%	100.0%
GAP_L	0.14	1.18	0.07	0.00
Time	0.000	0.000	0.054	0.008

From the above table, it is clear that the best heuristic is *GSS* , where the *perc* is equal to 100%. However, unsatisfactory results are given by the heuristic *NDSP,* where there is only one instance among the 900 whose value is equal to the lower bound. This means that only one instance gives an optimal solution. However, the 899 remaining instances give an approximate solution, with an average gap equal to 1.18%.

The heuristic with the maximum execution time is *MFD*. Indeed, the average time overall 900 instances is 0.054s. The comparison between *MFD* and *NISP* shows that the application of *MFD* improves the result by 4.1%. This is obtained based on Table 4, where *perc* = 72.9% for *NISP* and *perc* = 77% for *MFD*.

The maximum GAP_L gap is given for *NDSP* and the minimum value is given for *GSS*.

Additional details on the GAP_L values for each heuristic are given in Table 5.

Table 5 shows that the maximum value of GAP_L is obtained as 0.09 for the heuristic *NDSP* when $n = 100$ and $r = 15$.

The maximum value of GAP_u is obtained as 9.49 for the heuristic *NDSP* when $n = 100$ and $r = 15$. The maximum time of 0.240s is obtained for *MFD* when $n = 10000$ and $r = 2$.

Table 5. Comparing heuristic based on GAP_L

n	r	MFD	$NDSP$	MFD	GSS
100	2	0.00	0.01	0.00	0.00
	4	0.00	0.02	0.00	0.00
	6	0.00	0.04	0.00	0.00
	8	0.01	0.06	0.00	0.00
	10	0.00	0.05	0.00	0.00
	15	0.01	0.09	0.01	0.00
500	2	0.00	0.00	0.00	0.00
	4	0.00	0.00	0.00	0.00
	6	0.00	0.01	0.00	0.00
	8	0.00	0.01	0.00	0.00
	10	0.00	0.01	0.00	0.00
	15	0.01	0.02	0.00	0.00
1000	2	0.00	0.00	0.00	0.00
	4	0.00	0.00	0.00	0.00
	6	0.00	0.00	0.00	0.00
	8	0.00	0.00	0.00	0.00
	10	0.00	0.01	0.00	0.00
	15	0.00	0.01	0.00	0.00
5000	2	0.00	0.00	0.00	0.00
	4	0.00	0.00	0.00	0.00
	6	0.00	0.00	0.00	0.00
5000	8	0.00	0.00	0.00	0.00
	10	0.00	0.00	0.00	0.00
	15	0.00	0.00	0.00	0.00
10000	2	0.00	0.00	0.00	0.00
	4	0.00	0.00	0.00	0.00
	6	0.00	0.00	0.00	0.00
	8	0.00	0.00	0.00	0.00
	10	0.00	0.00	0.00	0.00
	15	0.00	0.00	0.00	0.00

Another metric to measure the performance of heuristics is based on the variation in the GAP_u according to the ratio $\frac{n}{r}$.

Figure 3 below givesan overview of the variation for the heuristic.

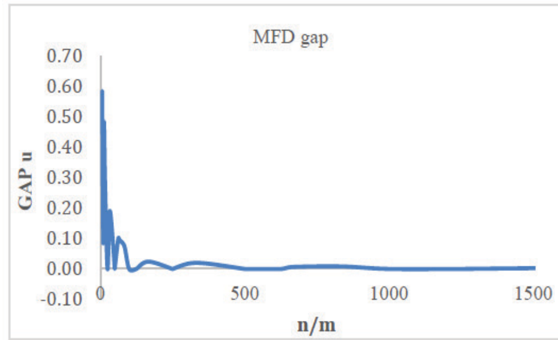

Fig. 3. Variation in the gap according to $\frac{n}{r}$ for multi-fit dispatching heuristic *(MFD)*

We observe from Figure 3 above, the GAP_u values descendas the ratio $\frac{n}{r}$ increases, until reaching 0.

5. Conclusions

The application of a network uses an amount of data. The assignment of data is a very critical issue. In this work, we proposed a new architecture of a network, based on the best dispatching of packets on routers. The goal is to have a near-optimal solution. This subject is even more important whenthe time is a critical factor. The problem becomes very hard, and a solution is needed when we are faced with very large data and/or sending a large amount of data.

In this study, we use four heuristics to solve the network problem, based on dispatching of packets on routers. The first and second heuristics are based on dispatching rules. The third heuristic is based on the resolution of a sub-set problem. Finally, the last heuristic is based on a multi-fit problem. To show the efficiency of the heuristics, we use a lower bound from literature to compare with each heuristic. The experimental results show that in 100% of cases, the best heuristic is equal to the lower bound. This means that we reach the optimal solution without needing rescue, to exactly solve the problem. The time for all heuristics is very reasonable and polynomial. This study can therefore be applied to a scheduling problem in a network.

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