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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. Sameh S. Ahmed

Contents

Solving Satisfiability Logic Programming Using Radial Basis Function Neural Networks

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Abstract

We proposed a new technique to solve QBF based on Radial basis function neural networks (RBFNNs) and Prey-Predator algorithm (PPA). Prey-Predator algorithm (PPA) is a neural learning algorithm used to determine the parameters of the networks. We built the neural networks to represent the logic programming in Conjunctive Normal Form (CNF), which has at most three variables in each clause (3-CNF). Then, these neural networks are developed to be recurrent neural networks to deal with universal variables in QBF problems. The neural networks models can be applied to solve a wide range of practical applications of Satisfiability logic programming, such as NP-complete decision problem, and computer network design.

Keywords: logic programming; Satisfiability; Radial basis function neural network, Prey-Predator algorithm

1. Introduction

Logic programming is used to describe relations, and have both a declarative and an operational meaning [1,2]. The general objective of artificial neural network is stored experiential knowledge and makes it available for use, similar to the brain. It acquires knowledge through the learning process, and use the power of communication between artificial neurons to store knowledge. The advantages and the importance of the RBFNNs come from that they have a simple topological structure , faster learning algorithms, high approximation capability, and have been widely applied in many science and engineering fields [3-5].

Prey-Predator algorithm (PPA) is a new metaheuristic algorithm, introduced by Tilahun and Ong (2012) [6]. PPA is developed for optimization problems such as particle swarm optimization algorithm [5,7,8]. The algorithm is a more general algorithm where some of well-known algorithms, including simulated annealing, particle swarm optimization, firefly algorithm and evolutionary strategy, become a special case [7,9] . It is inspired by how the predators run after their prey and how the preys try to survive in the ecosystem.

A proportional logic programming is a set of axioms, clauses, or rules which in turn consist of Boolean variables (literals), i.e. atoms and negated atoms only (negation is denoted by $\neg$) [2,10,11]. Quantified Boolean formula or QBF) is an extension of propositional logic programming in Conjunctive Normal Form (CNF) [1,11,12]. QBF is a proportional logic programming with existential quantification and universal quantification. The algorithms which are used to check the stability of the logic programming are called Satisfiability or SAT solvers [13]. In practice, SAT is fundamental in solving many problems, such as, circuit design, and computer network design. The simplest SAT solver is called the truth-table method. It constructs the full table, which will have 2^n rows when P has n variables, and report whether the final column, representing P has value 1 in any row. Davis Putnam Logemann Loveland (DPLL) algorithm [14] works on the principle of assigning variables, simplifying the formula to account for that assignment and then recursively solving the simplified formula. Zhang and Malik have developed a new method for evaluating QBF [1]. This method is based on the DPLL algorithm. Their experiments show that conflict driven learning strategies, when adapted in a QBF solver, can speed up the search process vastly. But still the most used strategy for SAT solvers.

In this paper, we presented a novel preprocessing technique for QBF based on RBFNNs Prey-Predator algorithm (PPA-RBFNNs), with commercial software MATLAB®. It is the extension of that conference paper with additional of discussion [15]. PPA is selected on the basis that it is a new generalized algorithm and gives promising results when tested on benchmark problems as well as modeled transportation and engineering problems [6]. The outline of the paper

is as follows. In section 2 a brief introduction on radial basis function neural network will be discussed followed by pray predator algorithm in section 3. In section 4, Logic programming, QBF solvers and first order logic programming are discussed. In section 5, 3-QBF solvers based on RBFNNs and PPA is proposed with details. At the end there will be a conclusion in section 6.

1. Radial basis function neural networks

A RBFNN in its form consists of three layers, namely, input layer, hidden layer, and the output layer. Each hidden neuron implements a nonlinear activation function and each output neuron implements a weighted sum of hidden neuron outputs. The activation functions in the hidden layer, such as Gaussian function, are also called radial basis function. RBFNN has typically three layers [16,17]: namely, an input layer, a hidden layer [18] and a linear output layer, as shown in Fig. 1. The hidden layer neurons receive the input information, followed by certain decomposition, extraction, and transformation steps to generate the output information. RBFNNs with good specification should have less hidden units and high prediction accuracy. So, the effective number of the hidden neurons is a relatively small number.

Pursuant to that, each hidden neuron is allocated to respond to each of sub-spaces of the input regions, formed by the clusters of training samples [19-21]. The advantages and the importance of the RBFNNs comes from that they have a simple topological structure and their ability to reveal how learning proceeds in an explicit manner.

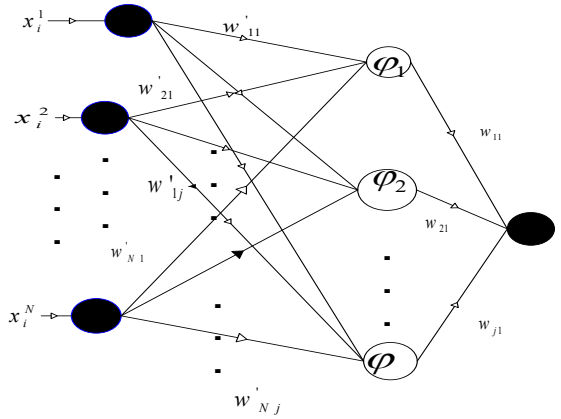

Fig. 1: Structure of a radial basis function network

The output neuron L represents a map F that satisfies the interpolation condition

$$F_L(x_i) = d_{iL},\ \mathrm{i} = 1,...,R \quad (1)$$

Where:

- $\{x_i \in \Re^N, i = 1,...,R\}$ is the input data set,
- $\{d_{iL} \in \Re,\ i = 1,...,R\}$ is a corresponding output target set in the output neuron L.
- $\{F_L(x_i) : \Re^N \to \Re,\ i = 1,...,R\}$ is a corresponding output actual set in the output neuron L.
- The interpolating function F_L has to pass through all the training data points. Accordingly, the radial basis function neural network technique has the following form
- $$F_L(x) = \sum_{m=1}^{J} w_{mL}\,\varphi_m(x) \quad (2)$$

Where:

- $F_L(x)$ is the actual output value of the output neuron L which corresponds to the input value $x \in \Re^N$.
- w_{mL} is the output weight between the hidden neuron m and the output neuron L.
- φ_m is the activation function in hidden neuron m.
- J is the number of hidden neurons.

The following equation gives the activation function (Gaussian function) which is used in RBFNN [18].

$$\varphi_m(x) = e^{-\frac{(\sum_{h=1}^{N} w'_{hm} * x^h - c_m)^2}{2\sigma_m^2}} \quad (3)$$

Where:

- φ_m is the radial basis function in hidden neuron m .
- c_m and σ_m^2 are the center and the width of the hidden neuron m respectively.
- $x = (x^1, x^2, ..., x^N)$ is a value entered in the input layer.
- w'_{hm} is the constant input weight between the input neuron h and the hidden neuron m .

The training sets in RBFNN is labeled pairs $\{(x_i, d_i),\ i = 1, ..., R\}$, where R is the number of data sets [16,18,22]. In other words, it represents associations for a given finite set of input–output data. As mention above, d_i is the target output value which corresponds to the input data x_i . The actual output value is represented by the map F_L that is encoded with the binary values $\{0, 1\}$. 0 and 1 are used to emphasize "false" and "true" respectively. The difference between the actual values and the output target values can be obtained by using a differentiable function, such as the sum of squared error function [23].

2. Prey-Predator Algorithm

Two important areas in neural networks are optimization and validation. On the optimization aspect, the efforts are directed towards building networks that are efficient and fast. On the validation aspect, the networks need to be functionally correct.

Prey-Predator algorithm (PPA) is a new metaheuristic algorithm introduced by Tilahun and Ong [5,6,24] for optimization problems. It is inspired by the interaction between a predator and preys of animals in the ecosystem. Randomly generated solutions will be assigned as a predator and preys depending on their performance on the objective function. A solution with least performance will be assigned as a predator and the others preys. A prey with better performance of the objective function will be called best prey. After the assignment of predator and preys, the preys will run away from the predator and follow preys with better performance. The predator does the exploration by running randomly and chasing the prey with least performance. The best prey in the other hand does only a local search for exploitation purpose.

PPA is a more general algorithm which will coverage to other algorithms under different values for the algorithm parameters. It has also been tested on different problems including public bus timetabling and gives promising results [6]. PPA is effective and suitable for use in many areas of science and engineering [5,25]

3. Logic programming and the Satisfiability

4.1 Logic programming

Logic programming seems to use like the relational database, and certainly has several properties because the knowledge about it is easy to change [1,2,12]. Propositional logic programming is built up from propositional variables (Boolean variables) through the use of the Boolean connectives ($\wedge, \vee, \leftarrow, \neg$), where the Propositional variables can be assigned by values: True or False. A proportional logic program consists of a set of logic clauses each one of the forms:

$$\bigvee_{i=1}^{k} \mathrm{A}_i \leftarrow \bigwedge_{j=1}^{r} \neg B_j \bigwedge_{j=r+1}^{n} \mathrm{B}_j \qquad (4)$$

where

$k, r, n \in \mathbf{Z}^+$. $\forall A_i$ and $\forall B_j$ are atoms. The arrow may be read "if", the symbols $\vee$ and $\wedge$ read "or "and" and" respectively.

Clauses can be either represented in Disjunctive (logic **or**) Normal Form (DNF) or Conjunctive (logic **and**) Normal Form (CNF), which is widely being used to represent clauses. A clause is in CNF if it is in form $\bigvee_{i=1}^{n} A_i, n \in \mathbf{Z}^+$, where A_i a literal. So, a logic programming is in DNF if and only if has the form $P = \bigwedge_{i=1}^{n} F_i, n \in \mathbf{Z}^+$, where F_i is a clause in CNF.

A logic programming is in the 3-CNF if each clause consists of three literals as maximum. 3-satisfiability problem or 3-SAT problem is a mapping problem from a logic programming in 3-conjunctive normal form (3-CNF) to "truth values" (1 and 0), which refer to true

and false respectively. A logic programming P is satisfiable, if and only if there is a substitution of "truth values" for its literals that makes it true.

Quantified Boolean formula (QBF) is a proportional logic programming with existential quantification and universal quantification. However, propositional logic programming is equivalent to QBF with only existentially quantified variables. QBF can be used to solve many practical problems ranging from artificial intelligent (AI) planning. QBF [26,27] has the form: $\overleftarrow{q}F$, where F is a propositional logic programming expressed in CNF, and $\overleftarrow{q}$ is a sequence of universal quantifier ($\forall$) and existential Quantifier ($\exists$). For example, $\forall x \exists y \ Like(x, y)$ means '' for all x, there exist at least one y like x''. We can replace the positions of the same type of the quantifiers without affecting the truth value, while the positions of different types of quantifiers cannot be switched. For example $\forall x \exists y \ greater(x, y)$ is not equivalent to $\exists y \ \forall x \ greater(x, y)$. Then $\forall x \exists y \ greater(x, y)$ reads "for every number x, there is a number y that is greater than x", which is true, while $\exists y \ \forall x \ greater(x, y)$ reads "there is a number **y** that is greater than any number", which is not true.

First-Order Logic extends Propositional Logic with predicates, functions, and quantifiers [11]. Predicates have a value of true or false, where it can take arguments, which are terms. On the other hand, the functions are given values in the logic programming. The terms evaluate to values other than truth values such as integers, real numbers, and functions applied to variables and constants. For example, the sentence (Anyone succeed in computer science exams and winning the lottery is happy) is represented in First-Order Logic (FOL), as

$$\forall x \ Succeed(Computers, x) \wedge Win(Lottery, x) \rightarrow Happy(x) \quad (5)$$

4.2 Satisfiability

A propositional logic programming is said to be satisfiable if there is an assignment of truth values to its literals in a way that makes the programming true. Satisfiability or SAT problem is an example of NP-complete problems. NP-complete problems are decision problems that have only two outputs values, which are 1 and 0, which refer to true and false respectively. SAT can be used to solve many practical problems. The logic programming below represents the general form of 3-SAT Boolean formula that consists of (N) clause; each one consists of three literals. Note that, each literal is either an atom or negated atom.

$$\begin{aligned} P = & (A_{11} \vee A_{12} \vee A_{13}) \wedge \\ & (A_{21} \vee A_{22} \vee A_{23}) \wedge \\ & \vdots \\ & (A_{N1} \vee A_{N2} \vee A_{N3}) \end{aligned} \quad (6)$$

For example, the following below is an unsatisfiable *3-SAT* logic programming with 12 literals, 5 clauses, and 3 variables. This logic programming can be seen to be unsatisfiable by inspection: the first and second clause requires (respectively) that at least one variable is true and at least one variable is false, whereas the last three clauses (together) require that all variables have the same truth value.

$$P = (\neg A \vee \neg B \vee \neg C) \wedge (A \vee B \vee C) \wedge (A \vee \neg B) \wedge (C \vee \neg A) \quad (7)$$

QBF solvers are used to answer the question of whether or not $\overleftarrow{q}F$ is true or false. The satisfiability problem (*SAT*) is *QBF* solvers under the restriction all variables are existential. *QBF* solver is slower than SAT because; the search must solve both settings of every universal variable. A formula $F[T/A]$ is obtained by setting variable A to the value 1 (True) in F. A formula $\exists A F$ is true if and only if at least one of $F[T/A]$ and $F[\perp/A]$ is true. Similarly, $F[\perp/A]$ is obtained by setting variable A to the value 0 (False) in F. And also, a formula $\forall A P$ is true if and only if $F[T/A]$ and $F[\perp/A]$ are true. To determine $F[T/A]$ in CNF, we have two steps

- Removing all the clauses in logic programming F that contain *A*.
- Deleting $\neg A$ from all the clauses that contain $\neg A$.

The simplest QBF solver is called semantic tree method [28]. This method is a very well-known method in logic. The method is an automatic method of semantic analysis, which consists of determining the logical values of sub formulas of a given formula. The evaluation of the following QBF,

within the semantic tree method, is illustrated in Fig. 2. $P = \exists A_1 \exists A_2 \forall A_3((A_2 \leftarrow A_1) \wedge (A_2 \leftarrow A_3))$ is satisfiable if and only if both of $F[T/A]$ and $F[\perp/A]$ are true.

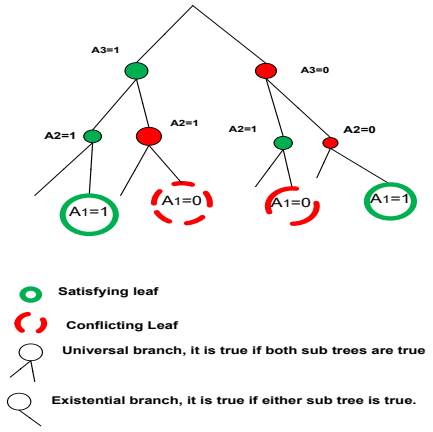

Fig. 2: A semantic tree proof of the stability of

$P = \exists A_1 \exists A_2 \forall A_3((A_2 \leftarrow A_1) \wedge (A_2 \leftarrow A_3))$.

In AI, a proof must always be built from a fixed set of inference rules. DPLL algorithm has been used widely as a complete (it finds a solution if one exists; otherwise correctly says that no solution exists) and efficient procedure to solve SAT [14]. The basic idea of the SAT-DPLL algorithm is:

i. Given a logic programming P in CNF.

ii. Assign a truth value for a variable.

iii. Find the set of all unit clauses created from step ii. A unite clause is a clause which has exactly one literal, which is still unassigned. Note that the literals assign the needed value.

iv. Iteratively retry step ii until there is no change (found transitive closure) If the current assignment cannot yield true for all clauses - fold back from recursion and retry a different assignment else - "guess" another variable (recursively invoke and return to 1.

4. 3-QBF solvers based on RBFNNs and PPA

Deciding the stability of QBF problem is an extension of the Boolean Satisfiability problem. So, Boolean Satisfiability problem (SAT) is QBF under the restriction all variables are existential. QBF problem is in practice much harder to solve than SAT. In this paper, we present a new algorithm used to check the stability of logic programming. Firstly, we used it as a SAT solver, and then we used it as a QBF solver. The new algorithm is based on radial basis function neural networks. The following is the outline of the new SAT algorithm, which is based on RBFNNs (SAT-RBFNNs). After that, we developed it to be 3SAT-RBFNNs. This is done by reduction the logic programming, for example, the reduction of a formula F by a literal A is denoted by $F[T/A]$ or $F[\perp/A]$. To determine $F[T/A]$ in CNF, we have two steps; removing all the clauses in logic programming F that contain A, and also, deleting $\neg A$ from all the clauses in F. After that, we extended the algorithm to use as a QBF solver. In this case, we used recurrent radial basis function neural networks (RRBFNNs) to deal with universal variables. The steps below are the outline of SAT-RBFNNs algorithm.

i) Given a logic programming in CNF.

ii) Calculate the training data for each clause in the logic programming [29]. We used the following equation to determine the training data for each clause.

$$F_Z(A_1, A_2, ..., A_n, B_1, B_2, ..., B_m) = \sum_{i=1}^{n} A_i - \sum_{i=1}^{m} B_i \quad (8)$$

where $\{A_1, A_2, ..., A_n, B_1, B_2, ..., B_m\}$ are all literals in clause Z and $\{A_1, A_2, ..., A_n\}$ is the set of atoms, while $\{B_1, B_2, ..., B_m\}$ is the set of negated atoms. F_Z is the actual output data which corresponding to $\{A_1, A_2, ..., A_n, B_1, B_2, ..., B_m\}$. We have replaced $\perp$ and T by 0 and 1 respectively, to emphasize "false" and "true".

iii) Building a RBFNN initial structure represents the logic programming. We identify an input neuron for each variable, and output neuron for each clause.

iv) Obtain parameters of the RBFNN by using a neural learning algorithm, such as PPA.

The 3SAT-RBFNNs can be optimized as follows

i) Given a logic programming in CNF.

ii) Convert the logic programming into 3-CNF. The reduction of a formula F by a literal A is denoted by $F[T/A]$ or $F[\perp/A]$.

iii) Building a RBFNN initial structure represents the logic programming. We identify an input neuron for each variable, and output neuron for each clause.

iv) Since the logic programming is in 3-CNF, the values of the parameters in the RBFNN can be obtained from Table 1.

The semantics of a QBF can be defined recursively in the following way:

- If F is the empty set of clauses then $\overleftarrow{q}F$ is true.
- If F contains an empty clause then $\overleftarrow{q}F$ is false.
- A formula $\forall AF$ is true if and only if $F[T/A] \wedge F[\perp/A]$ are true.
- A formula $\exists AF$ is true if and only if $F[T/A] \vee F[\perp/A]$ is true.

The main difference between SAT-solver and QBF-solver is with the solutions of QBF in order to verify both settings of each universally quantified variable. So, to use SAT-solver to solve the QBF problem, we reduce a formula by universal variables. In this case, the algorithm is called QBF-RBFNNs.

The following is the outline of the new 3QBF-RBFNNs algorithm:

i) Given a logic programming in CNF.

ii) Reduction of a formula F by universal literals.

iii) Convert the logic programming into 3-CNF.

iv) Building a RBFNN initial structure represents the logic programming. We identify an input neuron for each variable, and output neuron for each clause.

v) Since the logic programming is in 3-CNF, the values of the parameters in the RBFNN can be obtained from the Table 1.

Table 1: the parameters of the RBFNNs which represent 3-CNF, by using PPA

3CNF clause	centers: C_1, C_2, C_3	widths $\sigma_1^2, \sigma_2^2, \sigma_3^2$	weight W_1, W_2, W_3	SSE
$A_1 \vee A_2 \vee A_3$	1.0000, 1.9647, 2.9493	0.0276, 0.8861, 0.6650	0.5487, 0.6612, 0.6267	0.0017
$A_1 \vee A_2 \vee \neg A_3$	0.0599, 0.9597, 1.9554	0.0757, 0.9173, 0.6634	0.5644, 0.6508, 0.6301	0.0020
$A_1 \vee \neg A_2 \vee \neg A_3$	0.0607, 0.9600, 1.9557	0.0770, 0.9181, 0.6631	0.5640, 0.6505, 0.6296	0.0020
$\neg A_1 \vee \neg A_2 \vee \neg A_3$	-2.0014, -1.1313, 0.0399	0.0332, 0.9592, 0.6678	0.5051, 0.6669, 0.6654	0.0035

To see the evaluation of

$$F = \exists A_1 \exists A_2 \exists A_3 \forall A_4((\neg A_1 \vee A_4 \vee \neg A_2) \wedge (A_2 \vee \neg A_3) \wedge (A_2 \vee A_3) \wedge (A_1 \vee \neg A_4 \vee \neg A_2) \quad (9)$$

We have using the 3QBF-RBFNNs, we follow the following steps.

i) As mentioned, the logic programming should be in CNF. So, the first step is already done, because the formula is in 3-CNF, where each clause have at most 3 literals.

ii) Reduction of a formula F by universal literals, where we have only one universal variable, which is A_4. Accordingly, we determine $F[T/A_4] \wedge F[\perp/A_4]$, because the formula F is true iff $F[T/A_4] \wedge F[\perp/A_4]$ is true. As mentioned, $F[T/A_4]$ is equivalent to F with deleting the clauses which contain A_4, and also deleting $\neg A_4$ from all clauses in F.

5. Conclusions

We presented a new QBF-solver based on RRNFNNs. The new technique is also used as a new SAT-solver. The main importance of this technique is open a new field in computing the stability within the artificial neural networks. This technique is also suitable to use in the first order logic programming. In this study, the key components are RBFNNs, PPA,

and 3-CNF. We determine the RBFNNs parameters which represent the 3-SAT, by using PPA. A large number of applications can be represented by the new methods such applications of SAT, planning problems, NP-complete problems and electronic circuits.

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Prioritization of the Public Works Contract Provisions Causing Dissatisfaction to Contractors

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Abstract

The Saudi Arabia's Public Works Contract (PWC) is an old Standard Form of Contract that requires amendments. Provisions related to risk allocation, valuation of variations and other associated factors continue to cause dissatisfaction to contractors' administration of public construction contracts. This paper embarked on identifying and prioritizing the contractual provisions of the PWC that cause dissatisfaction to contractors in the administration of infrastructure projects in the Kingdom. Severity analyses of the contractual provisions reveal *site risks allocation, valuation of variations*, *subcontracting*, *security for advance payments*, and *final payment delays* as the most critical challenges. This paper provides original contribution to knowledge by establishing a methodical investigation of the shortfalls of the PWC as they affect contractors in the procurement of public infrastructure in the Kingdom. Consequently, the current shortfalls of the PWC as they affect contractors were identified and viable recommendations were pointed out. In essence, the paper presents a pioneering attempt and methodology that highlighted the weaknesses of the Public Works Contract, which is the legal framework governing the contract for engaging construction companies to perform public infrastructure works in Saudi Arabia. The paper makes pioneering attempt to draw the attention of authorities and key stakeholders concerned to urgently consider some amendments to the Public Works Contract in order to improve the shortfalls identified in this paper. This could boost the confidence of foreign contractors and attract them to invest their capital and technical expertise in the Kingdom's construction industry.

Keywords: Public Works Contract, public infrastructure, contractors, severity index analysis

1. Introduction

The Kingdom of Saudi Arabia is unarguably the leading economy in the Arabian Gulf and has the largest construction market with public and private sector projects running into billions of dollar. The main forces stimulating investments in the provision of basic social infrastructures are rapid growth in population in addition to the tremendous increase in oil revenues in the past decade (Bannan, and Elmualim, 2014). However, the award of construction contracts for public infrastructure dropped by 51% in the first quarter of 2016, signaling that the Kingdom's construction market is experiencing a difficult period as lower oil prices continue to place constraints on capital expenditure (NCB, 2016). Notwithstanding the plunge in Saudi Arabia's oil revenues, the Kingdom still has plans to implement an unprecedented scale of public infrastructure program over the coming decade to support the country's National Transformation Program i.e. Vision 2030. The plunging price of crude oil and the need to realize the visions of the National Transformation Program brought about renewed interest in Public Private Partnerships in the country. The government's acknowledging the significance of investment in public infrastructure to help its economy grow is now turning its attention to the private sector especially large construction companies to diversify its funding sources to meet the funding gap in the provision of public infrastructure. The government looks to the construction companies for mobilizing additional funding for public infrastructure projects, providing superior value for money, and enhancing quality facilities and service delivery. To this regard, there have been well-publicized massive business prospects for prospective construction companies, yet little has been discussed of the mandated Standard Form of Contract that governs all public construction works in the Kingdom.

1.1 Overview of the Saudi Arabian Public Works Contract (PWC)

In the construction market, procurement approaches are regarded as context in which construction services and facilities are acquired (Tawiah and Russell, 2008; Peter *et al.*, 2012). Selecting a suitable procurement approach to provide proficiency in the supply chain could lower public infrastructure project costs by about five percent (Gordon 1994). As the main public sector client, the Government can adopt some procurement approaches to assign contractual obligations and transfer the risks to contractors when procuring infrastructures for the general populace (Love *et al*., 2011).

The *Government Tenders and Procurement Law* (2009), which governs all public infrastructure construction projects in Saudi Arabia provides that all government bodies and agencies must use the *Public Works Contract* (PWC) to engage construction companies to perform public works. As part of control measures, the Law further provides that where the contract value of a public infrastructure project is more than SAR50 million and contract duration is more than one year, the government entity involved must first submit draft copies of the contract to the Ministry of Finance for approval before signing the contracts. The PWC comprises of two parts; 'the principal document of the contract' and 'general conditions'. The eight articles contained in the first part deal with matters that are usually specified in standard agreement of construction contracts while the sixty one articles in the second part highlights terms and conditions that are similar to those commonly found in standard general conditions of contracts. The PWC was drafted based on the 1977 FIDIC Construction Contract and has been decreed as the mandatory standard form of contract in the Kingdom since 1988.

1.2 Problem Identification

Standard forms of construction contract have been in use for long in the construction industry to stipulate and administer the rights as well as obligations of parties to a construction contract (Cheung *et al*., 2006). Over the years, the PWC has been receiving serious criticisms from construction companies due to the one-sided contractual conditions that mostly favour and protect the Employer in contracts for public infrastructure construction. The contractors contend that the PWC is an old Standard Form of Contract that requires amendments. Provisions related to risk allocation, valuation of variations and other associated factors continue to cause dissatisfaction to contractors' administration of public construction contracts. Despite the problems identified above, no published scientific research has been reported about identification and prioritization of the aspects of risk allocation and other associated factors in the PWC that cause dissatisfaction to contractors' in the administration of public construction contracts. This is considered paramount in order to enhance contract administration, satisfaction of contracting parties and improve efficiency of construction projects delivery.

As response to the highlighted problems above, this paper embarks on identifying and prioritizing the contractual provisions of the PWC that cause dissatisfaction to contractors in the administration of infrastructure projects in the Kingdom.The paper will further seek to determine the severity (through ranking) of the contractual provisions based on the extent at which they cause dissatisfaction to contractors in the administration of public infrastructure contracts.

2. The PWC provisions causing dissatisfaction to contractors

The multi-billion dollars spent by the Kingdom on public infrastructure projects over the years as well as the rapid growth in the private sector market led to a major influx of foreign construction contractors and consultants into the Saudi Arabian construction market. However, despite the huge prevailing business opportunities for the international construction companies, there have been concerns and issues about the PWC, which is the legal framework governing the contract for engaging construction companies to perform public infrastructure works in the Kingdom. To corroborate this, not long ago, the Kingdom's National Anti-Corruption Commission (Nazaha) reported that over 44% of the total government projects were hit by time overruns (Tago, 2015). The Commission attributed the project delays to poor contract documents, poor design quality and specifications, incessant issuance of change orders variations among others.

Although the Government Tenders and Procurement Law (2009) mandated the use of PWC to engage construction companies to perform public works, yet it remains an old Standard Form of Contract that requires serious amendments.

As part of the findings of this paper, the contractual provisions which are perceived to be posing problems to contractors and often lead to their poor contractual satisfaction and affect contractors' performance in administering the contracts will be analysed. The

sections that follow will seek to explore some of the aspects of these provisions.

2.1 Claims

During project execution, monetary and extension of time claims could crop up from various aspects (Abdul-Malak *et al.,* 2002; Hegab and Nassar 2005; Yates and Epstein 2006). Kulalanga *et al.,* (2001) pointed out that a claim arises in procurement contract where one of the contracting parties feels that the contractual obligations and responsibilities of the other party have not been fully discharged accordingly. The PWC requires the Employer to perform the contract in good faith and in case the Employer breaches the contract, the Contractor has the right to claim for damages. However, the bone of contention for the construction companies is that the PWC stipulates that where the Contractor fails to submit his claims for damages within thirty days of the claim having arisen, the Contractor's right to compensation is inevitably relinquished!

2.2 Allocation of Site Risks

Risk allocation and sharing is a fundamental contractual control issue for construction projects that has been widely discussed in recent years in the construction industry (Hanna *et al.*, 2013). Fair and balanced allocation of risks and liabilities helps to decrease the rate of contractual disputes as well as enhances a good working relationship between contracting parties. Project owners usually take advantage of their pre-contract influence to transfer more risks and liabilities to contractors when designing construction contracts (Loosemore and McCarthy, 2008; Xu *et al*., 2010; Shumway *et al*., 2004a,b, Zhang *et al.*, 2016). Such lopsided risk allocation and sharing of liabilities as pointed out by Kangari (1995) and Jin (2010) may possibly result to sharp practices on the part of the contractor by over pricing claims and lower project performance.

The allocation of site risks is indisputably one of the key contractual mechanisms that remains inconsistent with international standard forms of construction contract and affect both local and foreign contractors in the provision of social infrastructures in Saudi Arabia. The PWC provides that the Contractor is required to inspect the construction site and inform the Employer of any latent adverse physical conditions within ten days after they are discovered. To complicate issues more for the Contractor, the contract warns that the Contractor stands to lose his right to compensation that would otherwise arise if he fails to comply with this one-sided provision. Not that alone, the Contractor is also required to examine the structural and architectural designs and details, along with the soil investigations, and without any delay report to the Employer of errors in the designs or specifications and other technical errors that might affect safety.

2.3 Liability for Defects

The construction of infrastructure facilities for the public is often associated with cost and time overruns, which usually does not meet up with clients as well as end users expectations especially where defective works are observed before handover (Love *et al.*, 2011). One of the foremost shortfalls with this contractual provision is that the PWC does not specify a standard duration for the defect liability period, which is referred to as 'maintenance period' in the Contract. Usually during the maintenance period, the Contractor is obliged to remedy the listed defects as instructed by the project Engineer. However, the Engineer may well require the Contractor to find for defects at his own cost. What is more baffling is that failure to do so gives right to the Employer to bring in other contractors to do the tasks and to claim the costs of the repair works from the main Contractor. Another shortfall with this provision is that the PWC obliges the Contractor to provide guarantee for the constructed facilities against total or partial collapse or damage for ten years resulting from defects, except the contracting parties decide on a shorter duration. A quick check reveals that this practice is in line with obligations of decennial liability commonly enforced on contractors in the Middle East.

2.4 Suspension of Works

Another subjective provision of the PWC is the issue of suspension of works. The PWC provides that the Employer has right to suspend the works for an unspecified period though he will bear the resultant costs incurred except where it was stipulated in the contract or was required for carrying out the works properly due to climatic conditions, Contractor's breach of contract, or for the general safety of the works. Unfortunately, the Contractor whether local or foreign has no such express right in the PWC to suspend the works. To make matters more difficult for contractors, there is no civil code in the country. Thus, where the Employer fails to carry out his contractual obligations, there is no right to suspend the works in the Kingdom's general law.

2.5 Termination of Works

Also prominent among the grey areas of the Saudi Arabian Public Works Contract (PWC) is contract termination. It is common in most standard forms of contracts that a project owner has the right to terminate a contract prior to completion without rendering the action a breach of contract (Terrell and Surace, 2016). The PWC stipulates that the Employer may take away the contract works from the Contractor, as well as engage third party contractors to finish up the works at the expense of the main Contractor, if the Contractor bribes or tries to bribe Employer's personnel; delays the start or progress of the works; defaults in his contractual obligations and fails to remedy this upon fifteen days' notice; improperly assigns the contract or subcontracts its execution; if he is insolvent; or passes away (death). Unfortunately, just like in the case of 'Suspension of Works', the Contractor has no express contractual right to terminate the contract. Yet again, this is an aspect in which the lack of a civil code in the Kingdom bites. In the UAE for instance, the general law further complement the Standard Form of Contract by stipulating specific termination rights.

2.6 Dispute Resolution:

Disputes in construction contracts are generally unavoidable (Musonda and Muya, 2011). These disputes are costly, time consuming and often hamper the business relationship between disputing parties. The high rate of disputes especially amongst owners and contractors remains an enormous challenge bedeviling key stakeholders in the administration of construction contracts in the industry (Bayraktar *et al.*, 2012). The causes of contractual disputes in construction projects could be traced to inadequately prepared contracts, poor planning, complexity of the project site works, poor cash flow management, and ineffective communication lines amongst others (Chan *et al.*, 2006; Tanielian, 2013; Cheung and Pang 2013). Moreover, Haugen and Singh (2014) noted that even well prepared contracts do not provide guarantee that construction projects would be dispute free.

The PWC stipulates that all disputes are to be resolved by the Board of Grievances, which is part of the Kingdom's local court system. The problems associated with dispute resolution in the Board of Grievances are that their proceedings could be unequal, slow, expensive, uncertain and complicated. The PWC does not make provision for multi-tiered dispute resolution method where the Engineer's decision is followed by amicable settlement. Not that alone, the local standard form is silent about referring disputes to arbitration, adjudication, mediation and other efficient methods used for resolving construction disputes in developed countries.

2.7 Valuation of Variations

Variations remain one of the most unavoidable circumstances and common to all kinds of construction projects, which plays a key role in ascertaining the final project costs and time (Günhan *et al.*, 2007).To corroborate this, Serag, *et al.*, (2010) emphasizes that nowadays, variations in construction contracts are prevalent in nearly every construction project, usually resulting to about 5–10% rise in the original price of the contract. The fragmented nature of the industry due to involvement of various parties and stakeholders gives the industry its distinct uniqueness. The fragmented nature of the industry and poor quality control among others make it more complex and results to variations, which affect project's time and cost performance and often lead to disputes (Mohamed, unpublished data, 2001). Today, variations are fast becoming normal occurrence in construction projects. The Public Works Contract provides that the Engineer may instruct the contractor to make changes to the works. Nonetheless, the project Engineer should seek the consent of the project Employer prior to giving instructions for any change.

3. Methodology

The data for this study was obtained using survey questionnaire. The questionnaire approach is suitable for this research because questionnaires are cost effective method of data collection in a survey research as travelling to so many respondents across the Eastern Province of Saudi Arabia to obtain the respondents views would be expensive (Burton and Bartlett, 2005). Besides, it is faster to conduct survey using questionnaire approach (Mujis, 2004). In order to ensure that the respondents completed the questionnaires, the questions were made simple and short so that it was easy for the respondents to understand. The research questionnaire passed through three levels of surveys. In the first survey, the authors targeted selected respondents to identify the aspects of risk allocation and other associated factors (contractual provisions) in the PWC that continue to cause dissatisfaction to contractors' in the administration of public construction contracts. These respondents include Cost/Planning Engineers, Contract/Procurement Engineers, Project Engineers, and a selected sample of academics and researchers in the field of construction contract

management. They have considerable experience that permit an understanding of construction contract management, procurement management, project management and risk management in the Saudi Arabian construction industry, which was very valuable for this research. In the second survey, the factors provided by the respondents in the first survey were collated and presented to the respondents to assess and rank the extent to which the factors cause dissatisfaction to contractors' in the administration of public construction contracts. The data obtained from the second survey were analysed and sent back to the respondents (third survey) to seek their opinion on results obtained, to which most of the respondents agree to the entire rankings obtained by them and other respondents.

3.1 Sample of the Study

Judgmental sampling was used to carefully select the contractors for the survey. Final list of 120 respondents was prepared after meticulous selection of contractors (both local and foreign) in the cities of Dammam, Khobar, Dhahran and Jubail located in the Kingdom's Eastern Province. The Province being among the top construction hubs in the Kingdom has so many on-going infrastructure projects being undertaking by many local and foreign construction companies. It was strongly assumed and believed that the participants have wider experience and are competent to provide meaningful and unbiased information. The rating scale used for the assessment of the factors in the second survey is as follows; 5 stand for very high extent; 3 for moderate extent and 1 for very low extent. In the third survey however, the respondents were requested to rate their level of agreement on the obtained prioritization of the factors on a five-point Likert scale where 1 = strongly disagree; 2 = disagree; 3 = undecided; 4 = agree and 5 = strongly agree. In many previous studies, similar scales have been adopted by various authors like Kometa *et al.*, 1994; Chan and Kumaraswamy, 1997; Tam *et al*., 2000; Odusami, 2002; Frimpong *et al.*, 2003; Zeng *et al*., 2005; Enshassi *et al*., 2010 and Sodangi *et al.*, 2014.

3.2 Method of Analysing the Factors

Severity index was used to rank the extent to which the contractual provisions of the PWC (factors) cause dissatisfaction to contractors' in the administration of public construction contracts.The analysis of severity indices is a nonparametric statistical technique commonly used by researchers in the field of engineering and technology management to examine data obtained from questionnaire respondents concerning ordinal assessment of attitudes (Bubshait and Al-Musaid, 1992; Proverbs *et al.*, 1997; Elhag and Boussabaine, 1999; Sodangi *et al.*, 2014). The analysis of severity indices uses weighted percentage scores to compare the severity of the shortfalls in the contractual provisions (factors) of the PWC under study. In this method, analysis of frequency was first done to determine the response frequency for different factors being evaluated. Subsequently, the response frequencies were used to determine severity index for every factor using the below equation:

$$S.I = \sum_{i=1}^{5} w_i * \frac{f_i}{n} * 100 \Big/ (a * 100) \quad \cdots\cdots (1)$$

Where: i is the point given to each criterion by the respondent, ranging from 1 to 5; is the weight for each point (=rating in scale of points, which "1" is the very low extent and "5" is very high extent);

is the frequency of the point i by all respondents; n is the total number of responses; and a is the highest weight, in this study a=5. The five levels of extent to which factors cause dissatisfaction to contractors' are transformed to severity index values: very high (80-100%); high (70-79%); Moderate (60-69%); Low (40-59%) and very low (0-39%). This interpretation would later be used in prioritizing the severity level of the factors under the study (Chen *et al.*, 2010; Sodangi *et al*., 2016).

3.2.1. Reliability Test

Reliability Test was run to ascertain how reliable the research method was. This was done after using the severity index torank the extent to which the contractual provisions of the PWC (factors) cause dissatisfaction to contractors' in the administration of public construction contracts.Though questionnaires are widely considered as some of the approaches used for collecting data in survey research method, they are subject to measurement errors which could be systematic or random (Cohen and Manion1994). There are several methods for calculating the reliability of measures (De Vaus, 2002). These methods comprise of the test-retest, internal consistency, parallel-forms, and panel of judges' methods among others. Yet,

there is no particular method that is applicable to all situations (Sodangi *et al.*, 2014). When dealing with multi-item measures, De Vaus (2002) pointed out that the internal consistency measure is the best method to adopt as it does not encounter the problems of the test-retest method. Also, the internal consistency method enables the use of Cronbach's coefficient alpha because the strength of the coefficient gives the most thorough analysis of patterns of internal consistency by examining how groups of variables are related to groups of other variables and the coefficient does not rely on just one split-half coefficient but on all the possible combinations of splits (De Vaus, 2002). The use of Cronbach's coefficient alpha as a measure of internal consistency suggests how well the items that make up the questionnaire fit together. For instance, if a given set of items are comparatively similar, it is possible that the correlations among the items that make up the set will be high. Thus, the questionnaire that contains these items will be considered as having a high internal consistency (Pett *et al.*, 2003). The internal consistency measures indicate reliability using a coefficient ranging from 0 to 1; a higher value (0.7) of the coefficient indicates that the set of questions are highly reliable (De Vaus, 2002).

In general, this technique indicates reliability using a coefficient ranging from 0.0 to 1.0; a higher value (0.7) of the coefficient is mostly considered as being the minimum level acceptable and indicates that the set of questions are highly reliable (Dewberry, 2004). If the coefficient is less than 0.7, it signifies that the items are unlikely to be reliably measuring the same thing. George and Mallery (2003) established a generally known rule for explaining the results of this test as follows: 1.00 - 0.90 is considered outstanding; 0.79–0.70 is acceptable while 0.59–0.50 is considered poor. However, where the coefficient is obtained to be less than 0.50, it then means unacceptable reliability.

4. Analyses of Survey Results

One hundred and twenty questionnaires were distributed to experts as mentioned in Section 3.1. Forty eight questionnaires were completed, received and analyzed for this paper. A reasonable explanation on why the whole completed questionnaires were useable was because the respondents are experienced. The Forty eight questionnaires returned represent a response rate of 40%, which is considered acceptable for questionnaire survey. Like other questionnaire surveys in the field of construction engineering and management of projects undertaken by Chan and Kumaraswamy (1997) suggests that a response rate of 21% is considered adequate, Aibunu and Jagaboro (2002) suggest 30-40% while Ensahaassi *et al.*, (2010) and Sodangi *et al.*, (2014) assert that 20% response rate could be accepted when using judgmental sample for a survey questionnaire. By and large, the response rate of 40% obtained from this survey is considered to be satisfactory. Reliability test was used by the authors to rely on the responses the questionnaire items gave; erase any doubt associated with analysis based on such data, and to indicate how reliable the questionnaire for this study is.

4.1 Profile of the Respondents

In this part of the questionnaire, the questions were addressed to the respondents to obtain information on their respective profiles. Purposely, this part identifies the respondents' organizations; nature and value of projects being executed and level of experience. Most of these companies belong to the 'Grade I' category produced by the Contractors Classification Agency in the Kingdom. These companies have in the last five years, executed projects worth between SAR200 and SAR500 million as obtained from the respondents. Although focusing mainly on the contractors' responses could be argued here due to their perceived bias towards project owners and the Standard Form itself (PWC), the authors would like to infer that this paper is part of a larger study on the subject. In this paper, only results from the contractors' viewpoints were presented in order to obtain an accurate and clear picture of their perception towards some of the highlighted shortfalls in some of the contractual provisions of the PWC. It is expected that in the next article, which shall be extracted from the main study, perceptions of all the relevant key stakeholders will be duly presented. Thus, this could be accepted as parts of the limitations of this paper for now.

The sample of respondents comprise of Cost/Planning Engineers, Contract/Procurement Engineers, and Project Engineers. These set of professionals are key players in executing and managing construction contracts for construction companies. The equal proportion of these professionals (respondents) indicates that the key players in managing construction contracts are adequately represented in the survey. From the results, it is clear that the respondents have the requisite competencies to give valid and authentic response to the survey and their responses are considered vital for this survey.

From Fig. 1, it is clear that the respondents and their

parent companies have been involved in building, industrial, roads and water/sewage construction projects. A closer look at the Figure would reveal that most of the respondents and their companies are involved in building construction projects followed by roads construction projects. This information captures the main image on the nature of infrastructure contracts being awarded by the government in order to boost socio-economic development in the province. Thus, the required information provided by these respondents is considered reasonably reliable and vital for this survey.

On the respondents' experience in their respective organizations, it was obtained that over 40% of them have been in their respective positions for over ten years now and 58% have spent between five and ten years in their current positions in the companies.This seems to suggest that the respondents have adequate years of experience to give necessary information in highlighting the problems associated with the contractual provisions of the PWC that influence dissatisfaction among construction contractors in the Kingdom's construction industry.

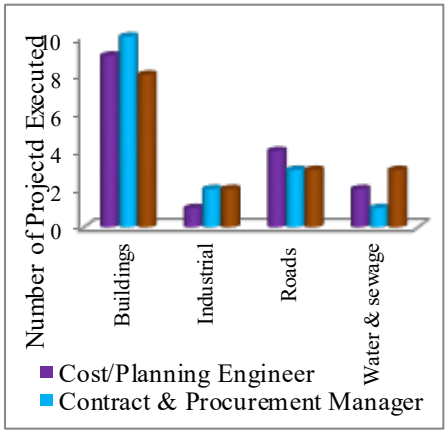

Fig. 1: Respondents' Involvement in Projects Executed by the Company

4.2 Determining Severity Index

Table 1 presents the snapshot of the severity indices and rankings for the contractual provisions of the PWC (factors) that cause dissatisfaction to contractors' in the administration of public construction contracts.

Table 1: Severity indices and rankings of factors

Factors	S.I. (%)	Rank
Site Risks Allocation	96	1
Valuation of variations	95	2
Subcontracting	93	3
Security for Advance Payments	91	4
Final Payment delays	90	5
Extension of Time & Penalties	89	6
Defects Liability	87	7
Claims Procedures	86	8
Suspension of Works	84	9
Termination of contract	83	10
Dispute Resolution	81	11

From interpretation of the severity index scale provided by Idrus *et al*., (2010), which was mentioned above, it could be easily deduced that 'high severity' index starts from 70% upwards i.e. 70-100%. From the Table 1, it is obvious that the entire contractual mechanisms evaluated by the respondents have 'very high' severity indices. The severity indices obtained, indicate the extent to which the contractual mechanisms contained in the Saudi Arabian Public Works Contract affect contractors in the procurement of public infrastructure in the Kingdom.

As expected, among the top-five most severe factors are *'site risks allocation'*(96%),*'valuation of variations'*(95%), *'subcontracting'* (93%), '*security for advance payments*' (91%), *'final payment delays'* (90%). The allocation of site risks is indisputably one of the top most rated factors that affect contractors in procuring public infrastructure in Saudi Arabia. This is not surprising since the PWC provides that the Contractor is required to inspect the construction site and inform the Employer of any latent adverse physical conditions within ten days after they are discovered. To complicate issues more for the Contractor, the contract warns that the Contractor stands to lose his right to compensation that would otherwise arise if he fails to comply with this one-sided provision. Not that alone, the Contractor is also required to examine the structural and architectural designs and details, along with the soil investigations, and without any delay report to the Employer of errors in the designs or specifications and other technical errors that might affect safety.

Variations (Change Orders) remain one of the most unavoidable circumstances and common to all kinds of construction projects, which plays a key role in ascertaining the final project costs and time (Günhan *et al.*, 2007).To corroborate this, Serag, *et al.*, (2010) emphasizes that nowadays, variations in construction contracts are prevalent in nearly every construction project, usually resulting to about 5–10% rise in the

original price of the contract. The fragmented nature of the industry due to involvement of various parties and stakeholders gives the industry its distinct uniqueness. The fragmented nature of the industry and poor quality control among others make it more complex and results to variations, which affect project's time and cost performance and often lead to disputes. (Mohamed, unpublished data, 2001). Today, variations are fast becoming normal occurrence in construction projects.

Surprisingly, despite the high volume of on-going construction projects in Saudi Arabia and the criticality of variations in construction projects, the PWC has inadequate details for valuing variations. This is quite alarming as this could be a recipe for disputes among contracting parties and disputes have considerable impact on project completion costs and time. Thus, it is not surprising to see that the respondents rated this contractual to have the highest severity. As a matter of urgency, the relevant ministry in the Kingdom needs to do something fast about this issue so as to improve the resident foreign contractors' satisfaction level and to attract top prospective foreign contractors to the Kingdom's construction market.

The problem associated with valuation of variations (change orders) is indisputably among the top most rated contractual provisions that affect contractors in the contract administration of public infrastructure in Saudi Arabia. This is not surprising considering the fact that a Contractor who is entitled to payment for variation works can easily lose his right to payment for variation works if he simply fails to include details of his variation claims in the monthly report submitted to the Employer. The Public Works Contract provides that the Engineer may instruct the contractor to make changes to the works. Nonetheless, the project Engineer should seek the consent of the project Employer prior to giving instructions for any change. There is no single provision in the PWC which states that the Contractor may well assume that all change order instructions given by the Engineer are actually approved by the Employer. Consequently, the Contractor bears all the risks of the Engineer acting outside his powers. The PWC further provides that all change order instructions must be in writing. However, the change order must not either change the object of the contract, the contract value must not be exceeded by more than ten percent or reduced by more than twenty percent. The PWC requires the Engineer to value variations to the works by reference to any appropriate rates in the contract. If there are no relevant rates and a fair price cannot be decided, the valuation of variations should then be made by the original tender evaluation committee.

Subcontracting is another key aspect of the contractual provisions of the PWC that affect mostly foreign contractors in procuring social infrastructures for the public. As obtained in most standard forms of construction contracts, the project Contractor is usually liable for the performance of his entire Subcontractors. In spite of that, the Public Works Contract further insists that a foreign Contractor is obliged to engage local contractors for not less than thirty percent of the works unless the Ministry of Finance provides some specific exemption to the Contractor. This usually affects the performance of the foreign contractor since the choice of local subcontractors will definitely have a greater influence on the project's overall performance. Contractual issues related to subcontractors' errors in design, quality of materials or workmanship, and delays caused by subcontractors are among many other problems that could be associated with many local contractors. Besides, the safety and quality culture and the technical abilities of these subcontracting companies are not at par with their foreign counterparts and having about 30% of these local subcontractors aboard a contractor's project team could spell doom for the foreign contractor. Although there are some reputable local subcontractors around, their hands are usually full considering the high number of on-going infrastructure projects in the Kingdom. Additionally, a foreign Contractor is also required to patronize specific services of local establishments like insurance and transportation, and to generally give higher priority to local products and services.

Security for advance payments is another grey area causing serious concerns to contractors in the contract administration of infrastructure projects in the Kingdom. The PWC provides that advance payment for up to five percent of the contract value may be made to the Contractor by the Employer as long as it does not exceed SAR50 million. Surprisingly, this advance payment is made against a guarantee of the same amount of the advance payment, which is subsequently recouped from deductions from certified progress payments at the same rate! This is done in such a way that within ten days of accepting the Contractor's tender, he is required to furnish the Employer with an irrevocable bank guarantee of five percent of the contract value. This guarantee serves as a security to the Employer and must remain in place until handover stage of the project. What causes sleepless nights to contractors is that the PWC is silent on the conditions in which the guarantee can be called by the Employer. More worrisome is the fact the PWC does not specify any pre requisites to such a call being made!

Final payment delays is another factor rated by the respondents as having very high severity, which requires close attention since it affects contractors in the contract administration of public infrastructures in the Kingdom. The PWC was prepared based on estimated quantities that are subject to re-measurement by the project Engineer. As is usually the case, applications and certifications for progress payments are to be made and issued respectively every month while the Contractor is entitled to receive his payments no more than thirty days later. The main bottleneck for the Contractors with this mechanism is that the payment of the final amount due to the Contractor is delayed pending the completion of provisional acceptance of project and the issuance of certificate from Zakat & Income Tax Department. This must be done before the contract's final account settled and the performance bond returned to the Contractor upon completion of the project.

4.3. Reliability Test

The overall Cronbach's alpha for the eleven factors was obtained from the reliability analysis. The overall Cronbach's alpha of 0.92 is considered 'excellent' by George and Mallery (2003) as it indicates very strong internal consistency among the eleven items. In essence, these test results indicate that professionals (respondents) who tended to assign high points for one factor also tended to assign high points for the other factors. Likewise, respondents who assigned low points for one factor also tended to assign low points for the other factors. Therefore, knowing the points for one factor would enable accurate prediction of the points for the other factors. However, this ability to predict scores from one item (factor) would not be possible when the Cronbach's alpha is low. Given that analysing statistical data depends on measurements being both reliable and valid then the ability to obtain consistent responses makes a measurement reliable and a questionnaire item is reliable if it gives dependable and consistent responses from the respondents (De Vaus, 2002). De Vaus (2002) further emphasized that there is a need to rely on the responses that a questionnaire item gives in order to erase any doubt associated with analysis based on such data. Thus, it could be inferred that the responses obtained from the respondents are dependable and consistent and the items (factors) are reliable and valid.

It is duly acknowledged here that this research was likely to be affected by some certain constraints and biases, which is common for survey based research works of this nature. The adoption of judgemental sampling method in selecting the sample also helps to reduce bias by offering the researcher some degree of control. As it was a structured questionnaire survey, evaluation of the factors' level of severity was limited to only the selected professional (respondents). Even though the size of the study sample may perhaps be relatively small, findings of this paper produce useful guidance that could be used to highlight critical shortfalls of the contractual provisions of the PWC that require urgent attention. Notwithstanding the limitations highlighted before now, it is the opinion of the authors that the severities of the factors in the order of prioritization presented in this paper satisfactorily represent the opinions of the stakeholders in the Saudi construction industry.

5. Conclusion

This part presents the main conclusions from the preceding sections. It draws together the major themes of the paper. Questionnaire surveys were carried out across the construction industry to identify and prioritize the contraction provisions of the PWC (factors) that cause dissatisfaction to contractors in the contract administration of public infrastructure projects in Saudi Arabia. Severity index analysis was used to analyze the respondents' feedbacks. Thereafter, a ranking of the factors was produced. Findings of the study suggest that *valuation of variations*, *site risks allocation, subcontracting*, *security for advance payments*, and *final payment delays* were the most critical factors (contractual mechanisms of the PWC) that affect contractors in the contract administration of public infrastructure projects in Saudi Arabia.

This paper provides original contribution to knowledge through a methodical investigation of determining the shortfalls of the PWC as they affect Contractors in the contract administration of public infrastructure projects in the Kingdom. Consequently, the current shortfalls of the PWC were identified and valuable strategies were suggested to overcome the highlighted limitations. In essence, the paper presents a pioneering attempt and methodology that highlighted the weaknesses of the Public Works Contract, which is the legal framework governing the contract for engaging construction companies to perform public infrastructure works in Saudi Arabia. The paper makes pioneering attempt to draw the attention of authorities and key stakeholders concerned to urgently consider some amendments to the Public Works Contract in order to improve the shortfalls identified in this paper. This could boost

the confidence of both local and prosperous foreign contractors and attract them to invest their capital and technical expertise in the Kingdom's construction industry.

6. Recommendations

The adoption of a project alliancing contracting approach can help to reduce some of the problems faced by public project owners and contractors due to the shortfalls of some contractual provisions of the PWC for certain high risk acquisition projects, including inappropriate risk allocation, valuation of variations, cost overruns, time overruns, and adversarial relationships within contracting parties. As a new approach for undertaking constructing projects that's a dramatic departure from traditional contracting practices, project alliancing demands collaboration, cooperation, no-blame culture, equitable sharing of risk and reward, and open and sincere communication between the parties. In project alliancing, all uninsurable project risks are shared between participants of alliance project, as against the specific allocation of risk, which is common practice in traditional standard forms of contract like the PWC. Project Alliancing manages project risks entirely differently from traditional contracts like the PWC that attempt to allocate (or shed) risk between project participants. Project alliancing comes with the 'pain-share-gain-share' compensation model structure, which ensures that all uninsurable project risks are shared between the contracting parties with the belief that collective responsibility leads to enhanced overall project outcomes. The effect of sharing project risks as opposed to allocating risk is that the project team will either win or lose as a team. Thus, this creates an environment where teamwork and collaboration are essential for project success. In this new contracting approach, there is no incentive for one party to emphasize on maximizing individually, since the individual will only succeed if the overall team and project becomes successful. This helps to ensure that all key project decisions are being made to be "best for project" as opposed to "best for self" decisions.

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Three-dimensional Interaction of Granular Media Simulated by Discrete Element Method

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Abstract

Despite of being a vigorous constituent of natural and built environment, three dimensional interaction and behavior of the granular media is not yet convincingly understood. As a part of the progressive effort to achieve this goal, a three dimensional numerical model , based in Discrete Element Method (DEM), is developed and validated for fundamental principal of energy conservation and elasto-plasticity of the material. The model successfully simulates the conservation of total energy, pure elastic and elasto-plastic behavior of granular material. A plain strain compression test is also performed on the three dimensional specimen of the material, with- and with-out the pre-consolidation pressure to reproduce field conditions. A typical behavior of stress ratio with a peak value followed by strain softening has been successfully replicated. The void ratio has shown a trend of first decreasing and then dilating before becoming constant, which is in close agreement to the actual behavior.

Keywords: Numerical modelling,discrete element method, granular media, validation, visco-elasticity, plain strain compression

1. Introduction

Abundance of granular media makes it more attractive for many professions (civil engineering, chemical engineering, production engineering, powder technologies etc.), however its complex interacting behavior is not yet fully understood, e.g.; it deforms like solids (Peters and Dziugys 2002), flows like liquids and compresses like gases. Physical modeling and subsequent micromechanical studies of such a media was practically less fruitful, though some efforts have been made to understand/compute the stress-strain response of soil using photo-elastic experiments (Oda, Nemat-Nasser, and Konichi 1985). Many researchers are concentrating their efforts on numerical modeling in their recent endeavors to understand well the failure mood and micromechanics of granular media. Phenomenal advancements in computing technology in recent years have enabled the researchers to simulate the granular media to study its interactive behavior and subsequent failure mechanisms under different boundary conditions (Cleary 2004).

Discrete nature of granular media primarily requires a discontinuous simulation method; therefore, Discrete Element Method (DEM) is unanimously considered the best approach to deal with the granular media studies (Kozicki and Dons 2008). This method allows covering a wide spectrum of phenomena like laboratory and field tests, landslides and slope stability issues, shallow and deep foundations, macro and micro level failure responses, seepage and permeability problems (Catherine 2011). DEM uses a fundamental and basic philosophy of considering each particle as an element, which explicitly withstands stresses and strains. These elements interact solely at contacts and observe Newton's laws of motion, under the actions of external forces like force of gravity, axial stresses etc. The material response (macro and micro level) is then determined using individual movement and mutual interaction of huge population of elements.

In this work, a three dimensional numerical model is developed to simulate granular interaction and several tests are carried out to ensure its practical validity.

2. An overview of Discrete Element Model

With an enormous development in the field of computing power and numerical algorithms, there could be multiple options for the solution to problems of increasing complexity. However, discrete element method (DEM), owing to its distinctive features, has been regarded as most efficient and effective method to deal with granular media. DEM was first introduced by Cundall (1971) to address the problems of rock mechanics. Since then, significant progress has been

made in the development of DEM methodologies and applications. In DEM, the basic particles are considered to be rigid (i.e.; they possess a finite mass and rotational inertia) and each particle is independent to have translation and/or rotational movement. The contact between particles occurs over an infinitesimal area and each contact involves only two particles. The equilibrium contact forces and displacements are determined through a series of calculations by tracing the movement of the individual particles. The time step for these iterations should be small enough that the disturbance of any particle cannot propagate farther than its immediate neighbour (Starck and Cundall 1979; Lunding 2008; Cundall 1988a; Thornton 2000; and Rowe 1962).

In this study, a numerical model, rooted in discrete element method, is developed to simulate three dimensional interactions of spherical shaped granular particles. This model is actually the extension of a two dimensional model, developed by Iwashita and Oda (1998) and used in many of his works like; the study of rolling resistance at contacts in simulation of shear bank development (Iwashita and Oda 1998), the study of micro-deformation mechanism of shear banding (Iwashita and Oda, 2000), the study on influence of inherent anisotropy on micromechanical behaviour of granular materials (Mahmood and Iwashita 2009), the study of microstructure evolution inside the shear band in biaxial compression test (Mahmood and Iwashita 2011). The contact mechanism is modelled by a hard sphere-soft contact model, in which an overlapping is allowed at all contact points (as shown in Fig. 1).

This overlapping distance $u_n u_n$ (normal to contacting particles) for two spheres A and B with their radii as r_a r_a and $r_b r_b$, respectively, can be calculated by Eq. (1)

$$u_n = \sqrt{\{(x_b - x_a)^2 + (y_b - y_a)^2\}} - (r_a + r_b)$$

$$u_n = \sqrt{\{(x_b - x_a)^2 + (y_b - y_a)^2\}} - (r_a + r_b) \quad (1)$$

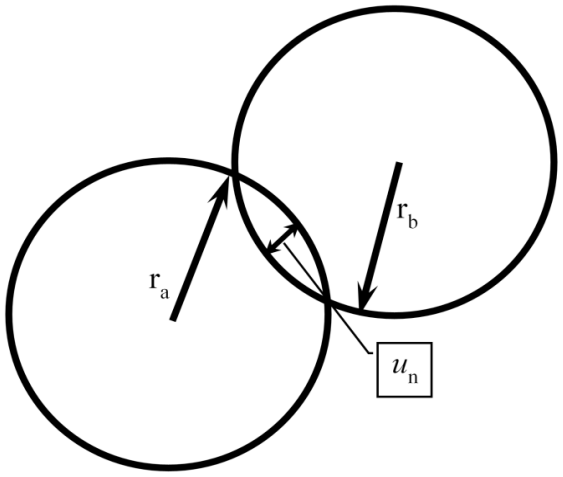

Fig. 1: Contact mechanism and overlapping between two spherical particles

Normal force at contact point is then determined by Eq. (2) using the overlapping distance:

$$f_n = \begin{cases} k_n u_n + C_n \frac{du_n}{dt} & u_n < 0 \\ 0 & u_n \geq 0 \end{cases}$$

$$f_n = \begin{cases} k_n u_n + C_n \frac{du_n}{dt} & u_n < 0 \\ 0 & u_n \geq 0 \end{cases} \quad (2)$$

where k_n k_n and $C_n C_n$ are spring coefficient and damping coefficient in normal direction, respectively. And u_n is the deformation or overlapping along the centre lines of the two contacting spheres.

Similarly, tangential force can also be calculated by Eq. (3);

$$fs = \begin{cases} k_s u_s + C_s \frac{du_s}{dt} & abs(k_s u_s) < k_{lim}\, u_n \\ sin(k_s u_s) \times k_{lim}\, u_n & abs(k_s u_s) \geq k_{lim}\, u_n \end{cases} \quad (3)$$

where k_s, C_s, k_{lim} and u_s k_s, C_s, k_{lim} and u_s are tangential spring coefficient, tangential damping coefficient, limiting value of spring coefficient and tangential overlapping distance, respectively, whereas 'abs' represents the absolute value.

Linear Kalvin model is employed to simulate normal displacement, whereas a shear slider with shear stiffness (k_c) is used to capture the sliding resistance (as shown in Fig. 2a). This shear slider becomes functional when normal forces (f_n or N) and tangential forces (f_s or μN) at any contact point hold the following inequality:

$$| f_s | \geq \mu f_n | f_s | \geq \mu f_n \quad (4)$$

where, μμ is the coefficient of friction between two particles.

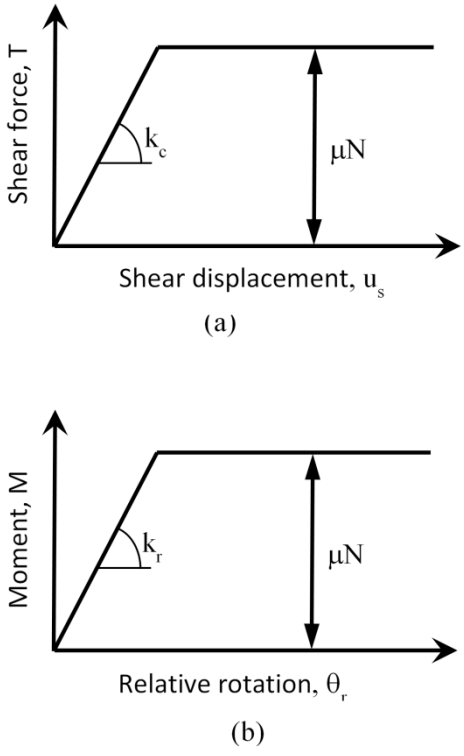

Fig. 2: Sliding and rolling at a contact: (a) Sliding; (b) Rolling (after Iwashita and Oda 1998)

In order to simulate the shear band (micromechanical behaviour) of granular media (Abdalsalam and Gutierrez 2010; Pengcheng and Yannis 2012), rolling resistance is measured through a set of spring, dash pot, no-tension joint and a slider as shown in Fig. 3. Rolling resistance moment is calculated using Eq. (5).

$$M = -k_r \theta_r - C_r \frac{d\theta_r}{dt} M = -k_r \theta_r - C_r \frac{d\theta_r}{dt} \quad (5)$$

where, k_r and C_r are rolling stiffness and viscosity coefficient, respectively. Slider for rolling become functional provided moment M crosses a limiting value of ηf_s (Fig. 2b)

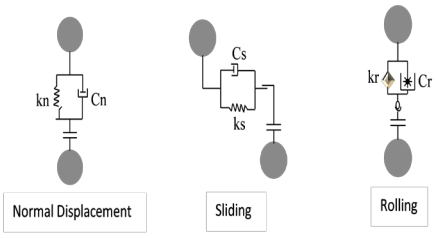

Fig. 3: Contact model using springs, dashpots, sliders and no-tension joints (after Iwashita and Oda 1998)

$$|M | \geq \alpha f_n |M | \geq \alpha f_n \quad (6)$$

where, α is the coefficient of rolling friction.

3. Validation and Calibration of Discrete Element Model

Any numerical model needs to be validated analytically and experimentally before using it for complex geotechnical problems, as proposed by (O'Sullivan, Bray, and Cui 2006) and many others. Most convenient and practical approach is to first simulate some small scale and simplified phenomenon before leading to complex and real problems. Calibration of results against experimental data and/or field measurements is required in any case. For the subject study, validation of numerical model is first checked by using some small scale and simplified tests for energy conservation and dynamic relaxation. Furthermore, two biaxial compression tests are performed on relatively complex models to study the qualitative response of spherical shaped particles.

3.1 Energy conservation test

To verify the dynamic stability of the numerical model, a stack of nine (09) spherical balls, discrete in nature, is used to check conservation of total energy in the system. The first ball is placed on a rigid wall (fixed in space) and the remaining balls are stacked on the top of each other such that there is no initial contact force at any of the contact, as shown in Fig. 4.

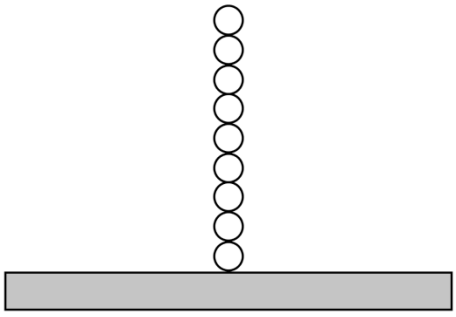

Fig. 4: Stack of nine balls and their initial position to study energy conservation of the system

The diameter of each ball is 1.0 m and density of the material is 2600 kg/m^3, which makes mass of each ball equal to 1,361 kg and the gravitational acceleration as 9.81 m/s^2. The top surface of the rigid wall is considered as datum for this test and its coordinates are set as (0,0,0). The total energy of the stack at the beginning of the test is only gravitational energy, which equals 540.73 kN-m. Moreover, it was ensured that there is neither any gain nor any loss of energy in terms of mechanical energy, damping or friction etc.

3.2 Elasticity and visco-elasticity test

For simplicity, soil is modelled as elastic material in some cases. However, its actual behaviour is more close to that of visco-elastic material. To make sure that proposed numerical model successfully envisages actual soil behaviour, the same balls stack set up is used in a different way. Only one ball is taken from the stack and released from an elevation of 0.75 m with a clear height of 0.25 m (radius, R = 0.5 m) as shown in Fig. 5. The damping ratio for the ball is taken as 0.05 (5.0 %).

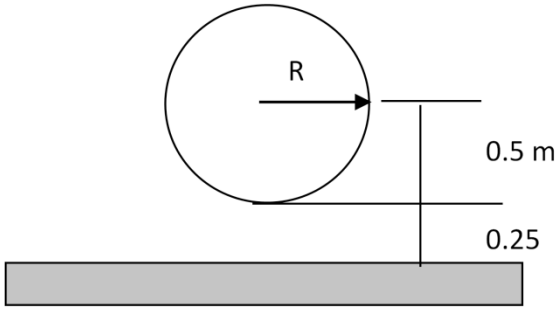

Fig. 5: Single ball setup at its initial position to investigate elasticity and normal dynamic relaxation of the model

3.3 Biaxial compressional test

A three dimensional specimen of spherical soil particles (as shown in Fig. 6), having dimensions of 1.5 x 1.5 x 3.0 and aspect ratio of 2.0, is used to perform a plain strain compression test with a prior uniform compression. The specimen is composed of 6,750 spherical particles with their diameters varying from 0.3 to 0.5 m with a constant value of 0.75 as friction coefficientcorresponding to 36.9 degrees of friction angle, representing a course grained granular material. Each particle is assigned a predefined position in a uniform and regular grid; however, its diameter is randomly selected by the program. The X-Z and Y-Z boundaries are considered flexible, to transmit confining pressure to the inner particles, while the top and bottom boundaries (in X-Y plane) are considered as rigid walls. Plain strain compression test is performed in two stages. First, a prior uniform compression is applied in which the specimen is allowed to compress under a specified confining pressure. In second stage, loading is applied to the specimen in the form of strain through top and bottom rigid walls, while maintaining the same confining pressure which is used for its prior compression.

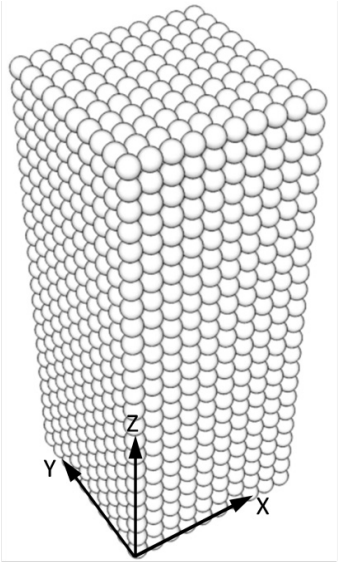

Fig. 6: Three dimensional arrangement of spherical particles to perform plain strain compression test

4. Results and Discussion

Detailed discussion about the results, for all the validation test setups described in section 3, is made in the following sub-sections

4.1 Energy conservation test

The total energy of each ball in the stack of nine (09) balls, shown in Fig. 4, consists of three components: kinetic energy, potential energy and gravitational energy. In this test, only gravitational force is applied to the stack of balls and the balls are released from their initial position. The balls are pushed into each other and continue to oscillate up and down forever, conserving the total energy as expected and shown in Fig. 7.

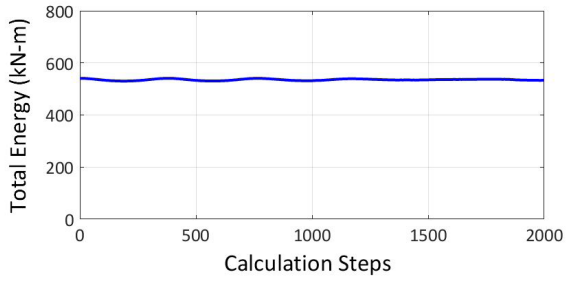

Fig. 7: Total energy of a stack of nine balls, shown in figure 4

4.2 Elasticity and visco-elasticity test

Elasticity and visco-elasticity are major parameters in the proposed numerical model for two reasons. First, the material in granular media which behaves visco-elastically; secondly, since DEM is originally designed to solve dynamic problems with explicit integration for static problems, dynamic relaxation (damping) must be performed in order to achieve convergence. Besides the afore mentioned two reasons, the magnitude of damping coefficient is very critical as excessively small value can lead to spurious vibrations, to which granular media are very sensitive. On the other hand, sufficiently large magnitude can result in simulation of the material as immersed body system, which is not the case in reality.Fig. 8 convincingly shows that elastic and visco-elastic behaviors of the system are precisely modelled.

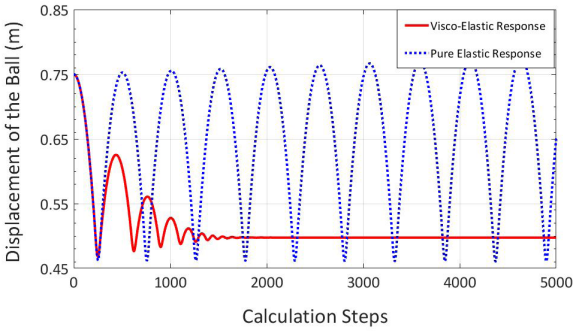

Fig. 8: Displacement versus time plot of the ball, shown in figure 5, both with- and with-out dynamic relaxation

The ball keeps on oscillating around its initial position when modelled without damping and released from an initial clear height of 0.25 m above a rigid wall surface. When the normal dynamic relaxation (damping ratio = 0.05 or 5.0 %) is applied, the vibration attenuates considerably over time and the ball takes practically a static position after fifteen hundred (1500) iterations, while touching the rigid wall surface.

4.3 Biaxial compressional test

4.3.1 Pre-consolidation and stress release

Soil samples extracted from the field to perform laboratory experiments are often disturbed; the degree of disturbance depends on the method of extraction and type of sampler though. One typical disturbance for samples taken for compression or consolidation tests is the loss of confining pressure from adjoining soil. Therefore, a pre-consolidation pressure is applied to reproduce field conditions before performing laboratory compression or consolidation tests. To simulate this phenomenon in the proposed numerical model, a pre-consolidation pressure is applied to the specimen shown in Fig. 6 by using a confining pressure of $1x10^5$ N/m^2. At this stage of the analysis, only top, bottom, right and left rigid boundary walls are used to transmit the confining pressure to the inner particles, while front and back walls remained inactive in the stress transfer.

Average velocity of all particles is plotted against calculation cycles in Fig. 9. The plot shows a drastic decrease in average velocity of particles as time passes. The particles are first displaced at a very high speed of 12 m/s because of their initial configuration at a regular grid. However, under the effect of hydrostatic confining pressure, they soon came in contact with

the neighboring particles, which forced those to slow down to almost zero velocity in just 100,000 iterations.

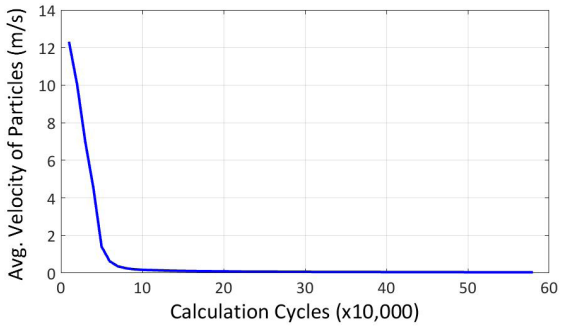

Fig. 9: Velocity profile of all particles of three dimensional sample (shown in Fig. 6) over time

4.3.2 Plain-strain compression test

Plain-strain compression test is performed on the three dimensional specimen of spherical particles, shown in Fig. 6, for both the conditions of with- and with-out pre-consolidation.

For the case of without pre-consolidation, the axial stress $(\sigma_{11})(\sigma_{11})$ is applied by moving top and bottom rigid wall boundaries while the lateral stress (σ_{33}) (σ_{33}) is kept constant through flexible boundary. The axial strain is then calculated by Eq. (7);

$$\varepsilon_{11} = {}^{\Delta H}/_{H_o} \varepsilon_{11} = {}^{\Delta H}/_{H_o} \quad (7)$$

where, $H_0 H_0$ is the initial height of the specimen and $\Delta H \Delta H$ is change in the height of specimen.

For pre-consolidated case, the sample is first consolidated under a hydrostatic confining pressure of $1x10^5$ N/m^2 using top, bottom, right and left rigid wall boundaries. In second stage, the right and left rigid wall boundaries are replaced with flexible boundaries and axial strain $(\varepsilon_{11})(\varepsilon_{11})$ is applied through top and bottom rigid wall boundaries.

Fig. 10 shows a plot of stress ratio $({}^{\sigma_1}/_{\sigma_3})({}^{\sigma_1}/_{\sigma_3})$ against axial strain which is well consistent with the stress strain pattern of granular media. The stress ratio first increases with axial strain until it reaches its peak value of 2.45, after which the sample entered into strain softening zone. Similarly, the void ratio of the sample is plotted against axial strain (shown in Fig. 11). The void ratio also followed a typical trend of first decreasing and then dilating (e.g. Poulos 1971;De Josselin de Jong 1976; and Joseph 2012). After crossing 7% axial strain, the void ratio became almost constant at 0.775.

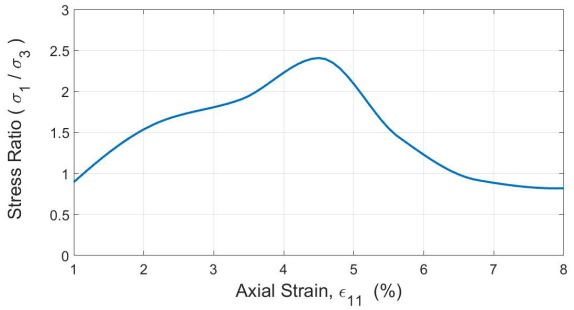

Fig. 10: Stress Ratio versus Axial Strain

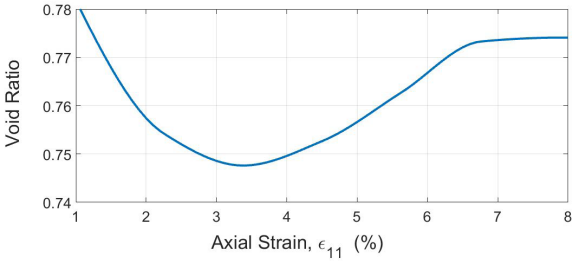

Fig. 11: Void Ratio versus Axial Strain

5. Conclusions

Knowing the importance of the granular media and an ongoing struggle to understand its interacting mechanism, an attempt has been made in terms of a numerical model to simulate three dimensional interactions of spherical soil particles. As convention, the model is attested for basic law of energy conservation and confirmation to envisage elastic and visco-elastic behavior of complex granular media before leading to perform a plain strain compression test on a three dimensional specimen.

The proposed numerical model successfully models the contacts between particles as pure elastic and visco-

elastic. A particle with an initializing force follows a typical trend and keeps on oscillating in case of pure elastic contact model, whereas it attenuates when damping is applied. The system also shows a strong affirmation to law of conservation of total energy.

Finally, a plain strain compression test is performed to a three dimensional specimen of spherical balls with and without pre-consolidation pressure by using different combinations of flexible and rigid boundaries. During pre-consolidation, the velocity of particles sharply decreases to zero value after a number of iterative calculations which suggest a rigid pack by making solid contact between neighboring particles.

In plain strain compression on a pre-consolidated sample, the stress ratio first increases with axial strain until it reaches its peak value of 2.45, after which the sample entered in the strain softening zone and is well consistent behavior of granular media. The void ratio of the sample also follows a typical trend of first decreasing and then dilating. After crossing 7% axial strain, the void ratio became almost constant at 0.775.

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Proposed PHR Architecture for Saudi Arabia Health Services

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Abstract

This study addresses the necessity to develop a new personal health record (PHR) system, which represents a benefit, compared to the existing electronic health record (EHR). To bring this necessity on stage, we proposed the development of a globally accessed PHR system in the kingdom of Saudi Arabia. Therefore, the proposed PHR system is targeting the development of PHR theme that involves a patient centric tool that is mostly controlled by the individual (patient). Due to several issues including but not limited to travelling and far distances between cities in the kingdom of Saudi Arabia, the PHR system should be immediately available electronically. By the achievement of this stage, all other working EHR systems (in all health care providers) should be linked into one integrated PHR system. This vision once implemented could deeply help individuals maintaining their health and be an active party in their health management.

Keywords: PHR, EHR, patient-centric, global access.

1. Introduction

The Center for Information Technology Leadership (CITL) defines a PHR as having both an infrastructure component, which allows for data viewing and sharing, and an application component, allowing for self-management and information exchange (Vincent et al., 2008). PHR can also be defined as a new technological approach aimed at standardizing electronic management of medical information between the patient and its physicians (Artur et al., 2015). The definition of PHR in the context of this research is the single-logical patient health record along with the data elements comprising that record. While electronic health record (EHR) means the clinical generated health-data record.

Due to vast available technology surrounded us; it can help patients, particularly those with chronic diseases, manage and monitor their health care. The available and inexpensive smart phones along with their PC-like capabilities, can collect, store, update patient's information, and transmit it via internet to a centric-PHR system (Win *et al.*, 2006, Vance et al., 2015). Therefore, patient who access such PHR system from a portable communication device can make informed health decisions using fewer health system resources. Using mobile-PHR facilitates the establishment of patient-centric health care services. Thereby, the delivery of healthcare can be integrated across the continuum of services, from prevention to follow up, and care can be coordinated across all settings (Wendy *et al.*, 2009).

Abroad access to PHR is a key point for the provision of support to assist healthcare providers in their treatment plan, individuals manage their health, which in turn, enabling them to enhance health services and risk minimization (Rolim *et al.*, 2010). Off-hospital PHR services may be requested by the patient himself since PHR system can be remotely accessed, patient managed and centralized updated. The most interesting potential PHR system applications are categorized into five main domains: decision support, social networking, provider-patient interaction, disease/ health management, and financial services (Wendy *et al.*, 2009, Vassiliki *et al.*, 2013). However, this work focuses on provider-patient interaction to allow Saudi People able to access and interact with their PHR systems. Concerning patient's health care, PHR system should provide full- guidance through their treatment to facilitate the required notifications.

2. Literature Reviews

Oberdan *et al.*, 2010 conducted a research on current medical processes, which are responsible for gathering patient's data. They concluded that the current processes are slow and more error prone, which in turn requires more labor work to collect data and to analyze the data. Koufi *et al.*, 2013 introduced a prototype PHR-based system, which aims at supporting chronic disease management at any point of care such as Google's Android. In fact, the proposed prototype assists healthcare professionals in assessing an

individual's condition and in forming the appropriate treatment plan for patient while it provides individuals with step-to-step guidance to their treatment plans.

Aaron *et al.*, 2011found that while barriers to PHR adoption exist (such as concerns about privacy, security and the lack of visible use of PHRs by others within immediate social groups) intention to use PHRs are high. Their findings suggest that active consumer involvement in healthcare may be on the rise and, more importantly, that information may become a key mediator in the physician-patient relationship.

Leslie *et al.*, 2011used a multi-method approach to evaluate PHR systems. They interviewed potential end users (clinicians and patients) and conducted evaluations with patients and caregivers as well as a heuristic evaluation with HCI experts. They investigated three PHR systems: Google Health, Microsoft Health Vault, and World MedCard. Their results demonstrate that both usability concerns and socio-cultural influences are barriers to PHR adoption and use.

Hosam *et al*., 2012 studied the development of conceptual framework for the exchanging of patient records located in different hospitals all over KSA. Their system design is based on Cloud Computing Service Oriented Architecture. Generally, this work utilizes a web service technology to share EHRs among different health care providers. Due to the lack of a comprehensive taxonomy that fully describes the PHR system, a PHR taxonomy has been created by CIST (Vincent *et al.*, 2008) for data viewing and sharing. The developed taxonomy might help in the definition of the field of PHRs and provide a framework for assessing PHR value.

The PHR system has the potential to facilitate access to health-related information, improve care, promote more active patient participation in their health and further the cause of patient-centered care in the country (Paraskevas *et al.*, 2015). Marie et al., 2016studied the adoption of PHR in Canada and concluded that still an uncommon sight in the Canadian healthcare IT landscape. However, their results showed that both specialists and patients need to be provided with a much greater awareness about PHR system.

3. Methods

3.1 Problem statement and motivation

Due to the vast distances between cities in the kingdom of Saudi Arabia, people usually met some difficulties in accessing their health data outside their living-nearby health services. However, as their health information is kept secured in the local databases of those healthcare centers. Therefore, patients sometimes may need to get services from different healthcare centers for different reasons such as traveling to another city, emergency accident while traveling, and the need for specialized care from distance health center. The stored health information in a healthcare center (EHR) is usually accessible only to healthcare personnel of that center. For every healthcare center, there are separate systems to record patients' health information. Therefore, bringing all those EHRs into one integrated, updated and improved PHR is the utmost necessity. We are motivated to having a full-integrated medical data for each patient accessible anywhere and at any time in the Kingdom of Saudi Arabia. Without a doubt, this vision could deeply improve the possibilities of risk prevention and correctly medical intervention.

3.2 Architecture Design

Being needed, globally reached, and inexpensive, Mobile-PHR is proposed to meet the needs for saving human's health in Saudi Arabia. Along with the various available health care providers scattered all around the country, in addition to the wide distance that separates cities inside KSA, mobile-PHR could play an important role in risk reduction, perfect diagnosis, and self-care. The architecture that we are investigating relies on the connection of several EHRs from different hospitals and health care providers to be integrated into one globally reached system, the mobile-PHR system.

In this section, we will discuss three main categories in relation to PHR adaptation in Saudi Arabia:

- Personal health

Patient's profile is the core element of personal health component. The awareness of patient to adopt such technology and their willingness to use it are also pillars in personal health component. Thereby. The ability of patient to manage his/ her health education and their ability to interact with their health-care providers can improve disease prevention and risk reduction.

- Supportive

Does this project will be fully supported by ministry of health so this service will be introduced by free? or patients will be charged for it? And how health-care providers will be

engaged to manage PHR's resources.

- Information infrastructure

The PHR should be able to manage health record information that applied interoperability-based standards. As PHR contains a significant amount of sensitive information, security constitutes a major concern when building PHR-based applications (Win, Susilo & Mu, 2006). Surely, PHR must guarantee security and privacy issues.

We propose Patient health record architecture for Saudi Arabia in which it elaborates the process of combining different EHRs into single-customized PHR. An overview of the system is presented in Fig. 1.

Fig. 1: An overview of the proposed health-data integration This process describes how different EHRs can be updated and integrated into one component (integrated component). Regardless the issuer of EHR (public or private hospital) and regardless the used infrastructure to implement that EHR, data coming from different EHRs can be stored, updated and managed from one place, the integrated component. However, we are trying to eliminate health-care provider's dependence, by neglecting the thinking of the nature of their platforms and just bring their data into our proposed web service to be utilized for PHR system development. Fig. 2 below demonstrates how people, institutes and any other third parties can benefit from this proposed model to gain global access to the authorized medical data using their authorized access to the PHR system.

3.3 Components description:

This part concerns the elaboration of each component in the proposed model and how it is functioning to its connected components.

- EHR:

Electronic health record represents the electronic management of medical information between the patient and its physicians, in the context of this work; EHR is managed locally by health-care provider.

- PHR:

Personal health record represents an integrated single-logical patient health record along with the data elements comprising that record in which its database may be changed, modified, or updated globally.

- Government hospital:

It represents any hospital owned by government that introduces a medical-care free of charge to its citizens, which in turn maintains its own EHRs that can be part of the integrated PHR system.

- Private hospital:

It represents any private hospital that introduces a paid medical-care to people, which in turn maintains its own EHRs that can be part of the integrated PHR system.

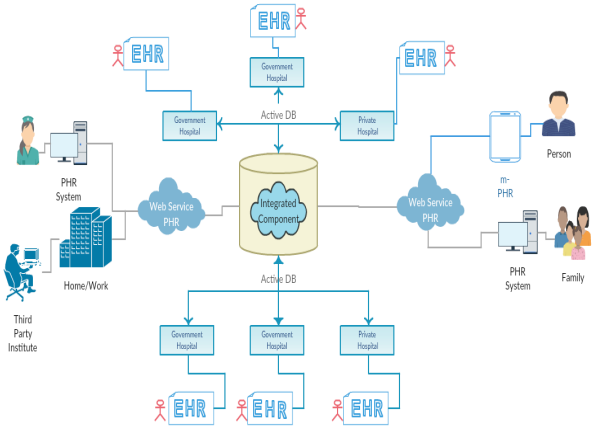

Fig. 2: Global access to PHR system by different parties

- Integrated component:

It is an integrated architecture that accommodates data from different health-care providers, update the data, protect the data and disseminate it to authorized users.

- Web service:

A web service is any piece of software that uses a standardized XML messaging system, which is available over the internet. XML is used to encode all communications to a web service regardless the operating system or programming languages running in user's side.

- PHR user:

Any authorized user of PHR system (Patient, physician, Doctor, etc...) that have some privileged functions into his/ her PHR system.

4. Discussion

As EHR, system plays an important role in containing patient's health data, still, patient himself/ herself away from that record which in turn prevents him/ her from participating in managing and updating

his/ her health care. However, the development of electronic PHR by independent vendors and national health systems is understood to empower patients and create a new kind of consumerism in healthcare (Vezyridis &Timmons, 2015). Thereby, bringing the vision of adopting a PHR system that has the capabilities of letting patients being involved in the management of their health care, being willing to share their health data, being able to participate in any health activity, and being able to access their health data globally, without doubt, will improve health services and improve health style to those patients. However, there is not even a single PHR system being deployed in Saudi Arabia considering the special needs of Saudi Arabian society. Therefore, 164 respondents were participating in a survey to measure the ability of Saudi people to move towards the adaptation of PHR system in the kingdom of Saudi Arabia. Among these 164 respondents, there was only one female while the rest of 163 respondents were males.

There were eleven questions asked in the awareness section of the questionnaire. The intent of this division was to gauge the knowledge of the respondents on the PHR. For the analytical purpose, these eleven questions were split into two parts; the first character is comprised of those selected five questions whose responses may be 'Yes' or 'No' or even 'No Answer at All'. Nevertheless, the second part was comprised of the remaining six questions where there were some given options on 'Strongly Agree', 'Agree', 'Neutral', 'Disagree', 'Strongly Disagree' or 'Missing Values'.

In the given Fig. 3, we can notice a significant boost in the favor of sharing the medical information of the individuals on a PHR system/site. Even so, we may likewise discover that a great number of respondents were not aware of the term PHR that may be a cause of their reluctant behavior towards adoption of PHR. Another worth noticing ratio in the given Fig. 1 is the stage of understanding the treatment prescript by the doctor through PHR, as most of the answerer showed their willingness to adopt the PHR approach for the quality improvement of their health care.

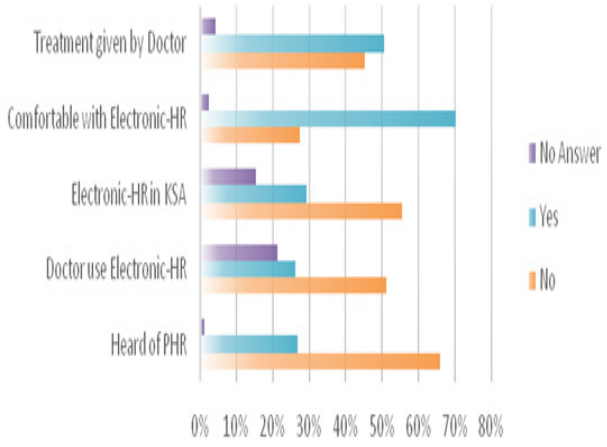

Fig. 3: The favor of sharing the medical information of the individuals on a PHR system

Fig. 4 below illustrates their response. As noticed in the Fig. 4, most Saudi's people are willing to share their health data and be part of their health management. Aiming to have a PHR system that is globally accessible which in turn allows them to access and participate in their health management.

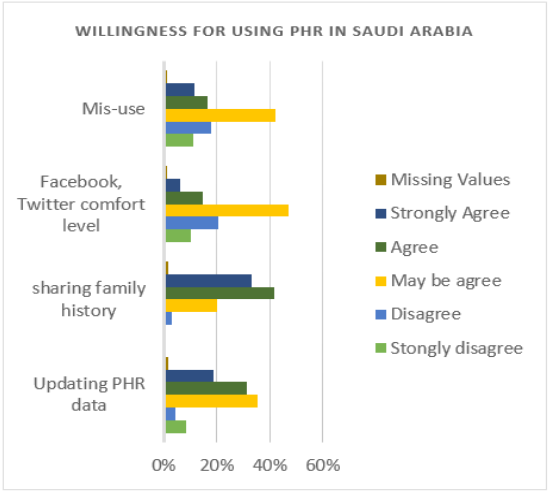

Fig. 4: The willingness of using PHR system between Saudi's people

The bulk of the respondents (57.3 percent) indicated their business title was public and the next largest group (29.9 percent) was unemployed, 6.7 percent people were regarded in their businesses, 5.5 percent were doing private jobs and only 0.6 percent respondents were employed in some other professions. The interviewees made it certain to involve those respondents who are educated and who can properly

interpret the queries asked in the questionnaire.

As illustrated in Fig. 4, Saudi's people showed high degree of sharing their family's health-data history. This indicates a good sign since it measures the culture of sharing family health-data history. In addition, it reflects them believe about the family health history as an important factor in developing diseases especially the chronic ones. The results also demonstrate low agreement in sharing their health data through social networks. This raises the concerns about security and privacy issues.

One more important indication highlighted by the above results, is that there is a big concern about the reasons behind sharing and using the data available in PHR systems by different parties. People seem to be worried about the misuse of their health data. Finally, there was a big agreement upon updating the PHR data by patients themselves. This in fact contributes towards lowering labor work and saving costs. The survey also shows that there were some ambiguities in the conduct of the respondents towards the misuse of their personal information that they are sharing on PHR. Yet, there was likewise a huge ratio of the neutral respondents in the survey who were most probably being the flexible individuals ready to take this technology change.

The proposed architecture provides a global access to the PHR system, direct access to any training or education materials that may be given by health-care providers; it should support free-platforms to run the PHR system, facilitates the connection between patients and doctors, and importantly, this architecture allows doctors to directly proceed to treatment in case of emergency.

The proposed architecture hypothesizes that PHR system could potentially change healthcare services over the coming years. As it enables patients to become more involved and engaged in their health care by letting them accessing their health information, which was not available previously, with low cost and easy access electronically. However, PHR could facilitate health management by following clinician's guidelines. The patient can access and manage his/ her PHR to check for upcoming events such as tests, appointments, cancelation of appointments, manage medications, receive advices and/ or have some consultations.

A PHR system has given control to the consumer and has provided patients with autonomy and empowerment. However, "full intent of functionality and use of PHRs will occur when patients and providers believe the information is safe, accurate, reliable and applicable for improving health" (Vance. B et al, 2015).

5. Conclusion

In this work, we proposed a PHR architecture that can be globally accessed, managed by both health-care providers and by patient, and platform-free application. Saudi people concern about their health care. However, bringing their health information to be distance-accessed, without doubt, plays a more active role in their healthcare using a patient-centric information tool - the PHR. In addition, perceptive and motivated patients in Saudi Arabia can be taught and trained about their health status and they can be engaged in health-care culture dissemination that might improve the ability of patients in managing their health. This system once approved for adoption in Saudi Arabia, without doubt will improve the introduced health services and it will assist towards disease prevention and emergency treatment intervention. Finally, we hypothesized that increased patient engagement in their healthcare can improve the quality of the provided services and surely improving their health life style.

Acknowledgements

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