

Optimization of Missing Value Imputation using Reinforcement Programming

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Abstract— Missing value imputation is a crucial and challenging research topic in data mining because the data in real life are often contains missing value. The incorrect way to handle missing value will lead major problem in data mining processing to produce a new knowledge. One technique to solve Missing value imputation is by using machine learning algorithm. In this paper, we will present a new approach for missing data imputation using Reinforcement Programming to deal with incomplete data by filling the incompleteness data with considering exploration and exploitation of its environment to learn the data pattern. The experimental result demonstrates that Reinforcement Programming runs well and has a great result of SSE of new data with assigned value and shows effectiveness computational time than the other five imputation methods used as benchmark.

Keywords—Missing value; imputation; Data Preprocessing; Reinforcement Programming; Machine Learning;

I. INTRODUCTION

Data in real life are often corrupted by missing values, it could be found in data collected from surveys or industrial databases. Missing values in surveys data may cause by the costumer who leave a blank answer through several questions or simply have no opinions about the questions. In other hand industrial databases could contains a lot of missing values because of human error or system error, this situation could lead a complicate process of data mining because most algorithms of data mining could not be directly applied to incomplete data [12]. Trustable data is a major issues for knowledge discovery, machine learning and data mining in a system [2]. The quality of data could be produced by a good data preprocessing. Missing values in database is one of the biggest data cleaning problem in data preprocessing. Therefore, missing value imputation has received considerable attention and many imputation methods have been proposed in recent years.

Data preprocessing goal is to produce a high quality dataset; thus, missing values are a part of knowledge that would show some important information [3]. The easiest way to process data with missing value is to remove all field which contains missing value. But this technique will lead a massive important information loss since in many cases the databases contain a large amount of missing value [5]. For solving missing imputation problem, a lot of techniques have been developed. Currently, these algorithms are categorized as

follows [8,9]: Firstly, Ignoring method to handle missing values inside of datasets is to deletes the field which contains missing values. But this method could causing the massive important knowledge loss because in many condition the database may contain a big number of missing value and make datasets noisy and low quality [4]. Secondly, Toleration. The strategy requires the process of data mining algorithm on the set with dataset. But it is not widely applicable, as most analytic methods work on real life database. Thirdly, Imputation, a term of a process to handle dataset with missing value by replacing missing data with substitute values. To assign close probable values could be estimated by analyzing a complete dataset. These solution could be done by using techniques in specific artificial intelligent algorithms such as classification [6], clustering [7] and feature selection [4] or using specific machine learning algorithms to perform a self-study process for learning the dataset. Machine learning is an option to complete missing value by learning toward the pattern of data. One of machine learning algorithm that has robust characteristic to handling optimization problem is Reinforcement Programming [10], a new algorithm that could perform well for solving cases by considering exploitation and exploration of its environment.

In this paper, a new solution for solving missing imputation has been proposed. The new solution done by using Reinforcement Programming to assign missing values by analyzing all dataset, RP should assign accurately value into missing value data by examining exploitation and exploration process. Intensive experiments and comparisons are done and shows that effectiveness of imputation techniques by using Reinforcement Programming where more robust than the other imputation methods as comparison benchmark. Furthermore, the result of imputation could lead some noise dataset because the inserted value was not representing actual value that should written in those missing value in data. Therefore, it is necessary to observe the performance of current imputation methods for filling the missing values. The Reinforcement Programming will be compared to another four imputation algorithm.

The rest of the paper is organized as follows. In section 2, related works about missing imputation will be discussed. In section 3, some used definitions in this paper will be introduced and the brief description will be given in this section. As for section 4, details system design of missing value imputation using Reinforcement Programming will be presented. In section 5 the experiment and comparison result will be shown

to give the brief explanation of Reinforcement Programming performances. And finally section 6 will be summarize the whole paper.

II. RELATED WORKS

Many research has been developed by researchers to put concern in missing value imputation. A lot of techniques has been proposed for generating imputation algorithm. One of these technique is solving missing imputation by using regression as state by Qin Y et.al. [17] Using many forms of regression models such as linear or semi parametric and logistic regression. EM imputation also has been done by where the algorithm using the function based on Expectation-Maximization (EM) algorithm [22]. Another simple missing value imputation is by assigning a new value by using Mean or substitution: Where It replacing missing values by using mean or mode value for all subgroup.

Alongside with regression technique, Artificial Intelligence algorithm could also implemented as an approach to solve missing value imputation. The first one is by using Rubin [14] in 1976 developing a techniques to deal with incomplete data that is still used until today. Another approach offered by Mohamed et al. Offered for missing imputation using both agent-based and neural network-based, to estimate the missing values replacement in databases [11]. A combination algorithm of dynamic programming, neural networks and genetic algorithms (GA) proposed by Nelwamondo et al. performing an approach value of missing value imputation by using a dynamic programming using neural networks [10]. Another artificial intelligence approach was suggested by Quilan[15] for solving missing imputation using decision tree approach. Bayesian also became one of solution proposed by Hruschka Jr., Hruschka and Ebecken [16] to substitute missing values. Fuzzy-rule0based model for imputing value in missing value imputation also proposed by Abebe et al. [18] where empirical comparative analysis of result using fuzzy and ANN has been proposed. M. Subasi et al. [19] also proposed a new imputation methods for missing value in binary data. Another empirical comparative analysis on list wise deletion also proposed by Musil et al. [20] its mean substitution, simple regression, regression with an error term are used as missing imputation. univariate linear, spline and nearest-neighbor also proposed by Junninen et al. [21] by combining the best features of univariate and multivariate methods by using multivariate regularized expectation-maximization algorithm, nearest-neighbor, self-organizing map, as hybrid methods.

III. PREMILIES

A. Missing Imputation

Missing data exists in almost every statistic data. When data are missing from survey nor system, an analyst should put right decision to impute values for those missing value in data, it could be single or multiple imputation.

Single imputation methods can be done by using mean imputation, in which a mean of a category in those data that will be imputed to missing values in overall data. Another way to do single imputation is by using regression imputation

methods in which missing values are predicted from a regression function to the observed data and imputed the result to missing values in the overall data. The primary difference between single and multiple imputation is the number of value of imputation that are made for missing values. In single imputation, one value for replacement is produced and imputed for every missing values. In multiple imputation, the missing values are imputed independently, estimates and create multiple value as imputation, one by one in every single missing value.

B. Reinforcement Programming

Reinforcement Programming (RP) is an adapted algorithm of machine learning [10], Reinforcement Learning which inspired by human behavior in solving a problem by considering experiment or appetency to try something new. RP has same general flow to solving problem as Reinforcement Learning except RP did not set a certain condition as the goal. Reinforcement Programming works for solving optimization cases, the function evaluation done by Reinforcement Programming is a function measurement for defined problem. As for implementation, Reinforcement programming has the same behavior of Reinforcement Learning, RP considering exploration of uncharted territory and exploitation of current knowledge to find solution. The solution determined by as much reward as possible in process learning. Reward and punishment are a value given by environment from the agent step. In RP, this policy is learned through the agent interactions its environment. In every interaction the agent will remember the current states of the environment, and chooses an action to perform, whether to do an exploitation step or exploration step. After executes this action, the agent will count the states of the environment, and receives a scalar reinforcement signal reward or penalty.

The benefits of Reinforcement Programming are to bring a benefit in optimization case using an intelligent learning approach based on Reinforcement Learning. With involving the characteristics of Reinforcement Learning, Reinforcement Programming provides an experience-based learning to achieve the global optimum.

System architecture given in Fig. 1, explain the flow of Reinforcement Programming while find the best solution from optimization problem. The basic Reinforcement Programming algorithm starts with an initialization phase, where

- i. Assign data item and set into variable dataset
- ii. Set modeling state value calculation(depend on optimization cases)
- iii. Set probability for exploration rate. Use 0.5 to get a balanced action for exploration and exploitation.
- iv. Assign the value of new state in state.
- v. The agents process state evaluation to whether receive reward or punishment for current action.

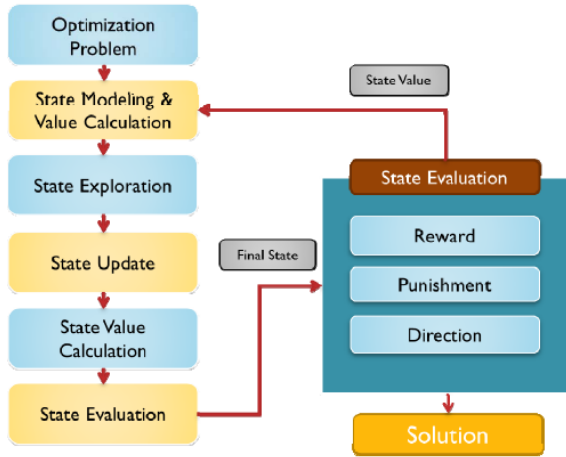


Fig. 1. Step of Reinforcement Programming

First step, RP processing case based function by modeling state and state value calculation. Then agent will begin state exploration in finite environment of problem, the actions that can be taken by agent is determined by exploration rate. If a random number is bigger than exploration rate than the agent will choose solution randomly in finite area. But if the random numbers are smaller than exploration rate than agent will consider taking an action based on reward. After take an action agent updates the current state and calculates current state value. A value from current state will label as reward or punishment, and determining the next direction of exploration. If agent receives punishment, then the agent will change its direction for the next exploration step. This process will be iterates in some value that already assign as number of learning time for agent of RP.

An extension of this algorithm is algorithm is presented where the parameter is an adaptively updated during the execution of the algorithm. This algorithm is given in Fig. 2. Reinforcement Programming needs to initialize dataset to identify problem environment. Agent will place randomly or assigned value depends on handled cases. After calculate state value, agent will determine action between exploration and exploitation. Then execute action and calculating new state value to determine reward based on state current value. Reward of new state in the environment is computed through the following Equation (1) and (2)

$$r_p \leftarrow r_p + \beta \cdot (1-r_p) \quad (1)$$

The equation 2 show the formula for increasing reward value. And in case to give punishment, Reinforcement Programming used formula above to decrease reward value. Where β is a constant to set a value of reward with scalar 0.1 until 1.

$$r_p \leftarrow r_p - \beta \cdot (1-r_p) \quad (2)$$

The more scalar that will be used it will impact the increase or decrease value of reward. The output of Reinforcement Programming algorithm is a solution of given problem.

IV. MISSING VALUE IMPUTATION SYSTEM DESIGN USING REINFORCEMENT PROGRAMMING

The system of missing value imputation using Reinforcement Programming using the basic idea for analyzing the dataset with multiple missing value to assign the most suitably imputed. Where, each complete dataset is analyzed independently. General system design flow for imputation using Reinforcement programming algorithms impute missing value shown in Fig. 2.



Fig. 2. General system design for Missing imputation using Reinforcement Programming

The first flow of general system design in Fig. 2 is data sources imputation. In this process, the structure and pattern of the data should be known. The data itself could be in number or text and exist in finite range. The understanding of data pattern are important issues before any imputation algorithm implemented, it is because every data has their own characteristic and could not receive the same treatment. Knowing data distribution and data limitation that every field is should be done in very first step in this general system, it will affect the state initiation for Reinforcement Programming.

After knowing and understanding the pattern and structure of data that will be proceed, Reinforcement programming is ready to solving missing value in data input. Firstly, Reinforcement Programming declare a new State consist of missing value index. Each state point is filled by certain range number bounded by different maximum and minimum value. Illustration of designed state are shown in Fig. 3.

2	3	2	1	2	2	2	2	1	2	2	2	8	0	1	1
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Fig. 3. State design for Missing imputation using Reinforcement Programming)

Where S_i is the element in the missing dataset.

Fig. 3 showing the state that used to representing solution of imputation value that will be inserted into the actual missing value in dataset. State representing a missing variable in datasets. Every part in state will be limited by different minimum and maximum value. To evaluate the state value, SSE will be implement as measurement. Each solution that is defined by state (S) will be updated though the next iteration.

After calculating the state modelling, state action will be taken, whether it is exploration or exploitation. To choose between this two action RP will randoming a certain number and if random number is greater than exploration rate-decided in first program running, then exploration action will be taken. If the random number is less than exploration-rate, then, RP will do action step by considering reward value that has been received since the first time program run. Exploration done by randoming certain value in finite area that has been declared, while exploitation choose the best reward value that has been collected from process before. The action that will be added to current state as for produced new state is shows in equitation (3), Where dp is current direction that agent has and step is how much number of step,

$$\text{action} \leftarrow \text{dp} \cdot \text{stepp} \quad (3)$$

The next cycle after deciding action to execute by RP is that RP will update its current state to a new state. As for measurement the new state update, the SSE of new state will be evaluate, it is call as state evaluation cycle. In this cycle. There will be three kind of state evaluation given to current step. The first one is reward if the current action shows the smaller SSE than the current SSE. New action will be assigned by the multiply result of direction and current step. Its to make agent not too big step nor too small step on exploring a solution. The direction itself can be positive or negative depends on the current action as shown in equitation (4).

$$\text{newS} \leftarrow S \quad (4)$$

The current state assign in new state to get the comparison value between current state and last state.

$$\text{newSp} \leftarrow \text{newSp} + \text{action} \quad (5)$$

Then, agent will assign the new value to new state by adding last state to current action. The new value saved in variable newsv. Next step, agent evaluates the value of current state, if the newsv are shorter than sv value than the agent will keep the newsv as current solution. If new state value has greater distance result than sv than the agent direction will be change to the opposite value and the punishment will be given in reward matrices. Reinforcement Programming will be repeated until the requirement are fulfilled. The Requirement it self are the defined number of iteration in first time the program will be run. After the number of iteration for processing data with Reinforcement Programming finish. The current state (S) will be assigned to missing value in original dataset. This, will make a new data without any missing value

V. EXPERIMENT

The experiment for solving missing data imputation using Reinforcement Programming shown in this chapter. Missing data imputation is a challenging research topic in data preprocessing. Data, both from surveys or system, is likely to had a lot of missing data. One way to input missing value is using machine learning, and this experiment will show how Reinforcement Programming fill the missing value and how good the performance is. To evaluate the final data after imputation process, this experiment will use SSE or Sum of Square Error. The simple flow of missing value imputation is given as follow:

1. First, analyze data input and which element contains missing value.
2. Next, determine value range of field which contains missing value.
3. Finally, keep the solution field for input missing value with minimum SSE.

The initial problem was a data samples for testing missing imputation algorithm. The result using Reinforcement Programming will be captured and compared to another 3 simplest way of data mining to input value and Genetics Algorithm will be also compared to shows the performance of Reinforcement Programming. Where SSE will be used as measurement.

A. Data Plot Example

The dataset will be used in this experiment is hepatitis data that usually used for data mining assessment The data consist of 21 field with categorical types. Twenty field is shown the characteristic of patient whether has hepatitis or not. And the last field represent the condition of patient.

TABLE I. HEPATITIS DATA THAT IS USED FOR MISSING IMPUTATION

no	Value
1	2,30,2,1,2,2,2,1,2,2,2,2,1,00,85,18,4,0,?,1
2	2,50,1,1,2,1,2,2,1,2,2,2,2,0,90,135,42,3,5,?,1
..	...
155	1,43,1,2,2,1,2,2,2,2,1,1,1,2,1,20,100,19,3,1,42,2

This data consist of a lot missing data that will be filled with value from reinforcement programming. As a result we will have 5 algorithm that will be run and compared in one table and diagram, this is used for indicating which algorithm runs good to solving imputation.

B. Experimental Comparison

As for the experiment comparison, we ran total 100 times experiment for Reinforcement Programming and Genetic Algorithm where every algorithm runs 50 times. With 5 different iteration number and every iteration runs 10 times each. At very first experiment has been done by ran 10 times

procedure for tenth iteration experiment, but it shows weak stability because the minimum of iteration number. Therefore, this paper runs different iteration numbers and increases the number after 20 times project running. As for the increase number, we add 50 as adding of new iteration number. So, we have 10, 50, 100 and 150 iterations of each algorithm which are run in twenty experiment times.

It shows that the bigger iteration number it will produce a high value and stability of result and stability for solving problem. But, it is also slowing down the computational process.

TABLE II. COMPARISON SUMMARY BETWEEN FIVE ALGORITHM

Replacement Methods	1500	2000	2500	3000	3500
zero	0.219355	0.219355	0.219355	0.219355	0.219355
mean	0.2	0.2	0.2	0.2	0.2
mean per category	0.167741	0.1677	0.1677	0.1677	0.1677
RP	0.1870	0.179	0.1770	0.1606	0.1506
GA	0.2516	0.2193	0.2258	0.2193	0.2193

Table 2 shows information about comparison summary between five algorithms. This experiment shows that reinforcement programming shows better than another four algorithms. It is shown that Reinforcement Programming could produce the highest value in imputing missing value in data. And we could see the visualization by looking at Figure 4.

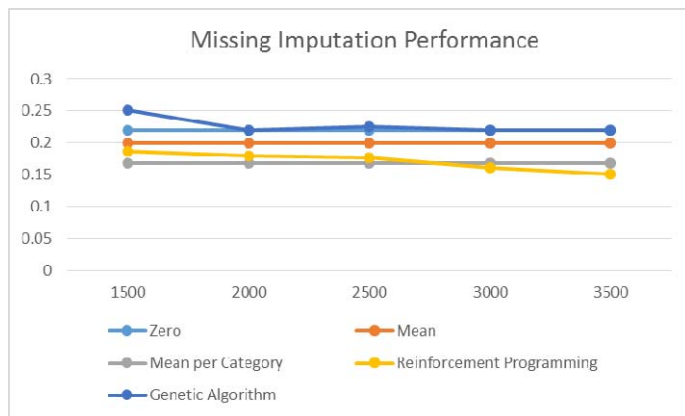


Fig. 4. Accuracy comparison between RP and other algorithm for missing value imputation performance.

Fig. 4 represents the information about algorithm optimum result. From three algorithms compared above, Reinforcement Programming is stable in solving solution and takes short time of computational time. After we increase the number of iterations, we can clearly see that Reinforcement Programming can produce a more precise solution than the other four algorithms.

VI. SUMMARY AND DISCUSSION

Missing value is a challenging issue in data mining, the incorrect handling method will cause a major problem in data mining or knowledge discovery process, such as inconsistency data mining result. This paper focuses on an algorithm of a machine learning approach for missing value called Reinforcement Programming. Reinforcement Programming has the capability of convergence and behavior to solving imputation problem by using exploration and exploitation. This two major parameters will let Reinforcement Programming learn toward different data patterns. Finally, when comparing the experimental result for Reinforcement Programming with zero imputation, Mean per Category imputation, and Genetic Algorithm, Reinforcement Programming performs better than the other algorithms. Both in SSE and computational time consuming, this leads to a conclusion that Reinforcement Programming could run better in solving missing imputation.

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