Automated Analysis of Patient Experience Text Mining using a Design Science Research (DSR) Approach

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***Abstract*— Online forums of hospitals are a common method of collecting patient feedback on the healthcare received. The feedback data obtained are often free text and large which may make a manual analysis of the data difficult and time-consuming. An approach to automatically analyse patient experience data would be beneficial for the hospital staff in several ways. In this paper, a Design Science Research (DSR) paradigm based framework is proposed that is used for our ongoing research in developing solutions with an aim for an automated approach to analyse patient experience data using natural languages processing techniques such as Sentiment Analysis, Topic Modelling, and Dependency Parsing. The framework design proposed provides a three-stage iterative process wherein at each iteration the patient feedback is deeply analysed based on the outcomes obtained from the preceding ones. This iterative approach facilitates the development of a strong, effective patient feedback analysis system.**

Keywords-patient experience; sentiment analysis; text mining; topic modelling; DSR

I. INTRODUCTION

Understanding patient experience enables hospitals to identify their weaknesses in providing healthcare. It provides opportunities for them to reflect on their functioning and thus, make efforts towards addressing the limitations in relation to the service provided. Further, understanding the patient experience can also contribute towards making the hospital processes more efficient, which in turn will lead towards better utilisation of resources and the addressing of patient concerns.

The National Health Service (NHS) provides health care within England, Scotland and Wales and is a public health service established shortly after the Second World War and caters for all residents of the UK. The NHS describes patient experience as a core dimension of good quality care [1]. It is an imperative task for the NHS to measure patient experience in order to monitor and improve health care performance, enhance strategic decision making and record progress for health care organisations [2].

An effective method of collecting a patients' feedback is to provide an online forum, where they can anonymously provide their views on the health care service they have received on a website feedback form at their own convenience. In 2008, the NHS created a website called *NHS Choices* that invites patients to leave their feedback about their experience with the healthcare providers of the hospital, which they can do using two approaches. One method is to provide ratings to a given hospital on different metrics on a scale of 1 to 5 stars. Moreover, in addition to rating their visit on different metrics, they can also leave feedback in the form of comments in the comments section of the website. Thus, the NHS has a large database of patient feedback covering most hospitals across the United Kingdom (UK). The number of comments and feedback across the database runs into the hundreds of thousands.

The process of collecting patient feedback via website source provides the healthcare professionals easy and convenient access to patient feedback data that can be used for analysis purposes. The hospital administration and researchers can use the feedback database to identify the strengths and weaknesses of their healthcare service and further employ them to address the identified issues.

Online reviews are generally written as free text and do not adhere to any structure or format. This makes analysing and understanding the patient experience more challenging than when dealing with closed questions, as the possibilities regarding the feedback content are endless. Techniques, such as keyword searching can help in searching for topics in patient feedback; however, this does not recognise positive and negative feedback. To address the challenge of analysing a large patient feedback database, automated methods would enable the analysis process to be more sustainable and time effective. The recent advancements in information analysis technologies, such as text mining and natural language processing, has resulted in them being widely applied to analyse the user experience of products by various companies.

In the last few years, studies have applied sentiment analysis approaches for analysis of patient experience data. Studies such as [6] and [7] applied SVM, decision trees, and Naive Bayes approaches of Sentiment Analysis and were able to classify patient comments into complaints/praise attributed to specific staff as well as feedback about other aspects, such as access, wait time, privacy, facilities, etc. In [8], the authors analysed the patient experience data provided by US hospitals on Twitter. They assessed tweeted reviews for over 2,000 US hospitals and identified those related to patient experience. Their preliminary results showed that the patient experience present on the tweets did not match that

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regarding the Hospital Consumer Assessment of Healthcare Providers and Systems (HCAHPS) ratings. However, there are limited studies that have explored how such language processing methods could be utilised to analyse patient experience.

In this paper, the ongoing research on applying natural language processing to provide a framework with an aim for automated analysis of a patient experience is introduced. The methodology that is being used in the ongoing research is explained in detail in Section II. Section III describes our developed framework for the research followed by conclusion in Section IV.

II. THE DESIGN SCIENCE RESEARCH (DSR) PARADIGM

The Design Science Research (DSR) methodology is currently being used for our research. The DSR paradigm is a widely popular research approach in Information Systems (IS) research. It is referred to as a problem-solving paradigm because it aims at building "artefacts" that are aimed at addressing a problem. The artefacts address the problems or enhance existing solutions and are important tools for arriving at research outcomes and reviewing them to decide how the artefact adopted can be further utilised [3]. The DSR process follows a systematic procedure in which the artefacts are developed with systematic creation, capturing, and communication of knowledge from the design process. DSR uses an iterative process, whereby the artefacts are reconstructed at each iteration and thus, can be described as a continuous learning process that enhances the artefacts quality incrementally [4].

Vaishnavi & Kuechler developed a methodology for DSR as shown in Figure 1 [5]. The model puts more emphasis on the process of contributing to knowledge. The DSR process here is based on the knowledge built and comprises five main stages: *Awareness of Problem*, *Suggestion*, *Development*, *Evaluation*, and *Conclusion*.

The *awareness of problem* aims at understanding the problem in the context of the application using various resources available. The outcome of this process leads to the development of the *suggestion* of the research project. In the *suggestion* phase, various insights into the application domain are obtained during this phase and the specifications for the solutions are acquired which leads to the development of a tentative design. In the *development* stage, the first artefact is developed. The *evaluation* phase focuses on evaluating the performance of the developed artefact, the outcomes of which may be used to further improve the artefact design and performance.

In our research, the aim is to develop an automated analysis of patient feedback to identify their sentiment and opinions about the healthcare service. The DSR methodology is well suited for us to achieve this, as DSR is an iterative process and our artefact developed will be a three stage iterative process wherein at each iteration the patient feedback is deeply analysed based on the outcomes obtained from the preceding ones. This iterative approach facilitates the development of a strong, effective automated patient feedback analysis system. In the following section, the DSR methodology based framework of our research is presented.

III. A DSR BASED FRAMEWORK FOR AUTOMATED PATIENT EXPERIENCE ANALYSIS

To develop a patient feedback analysis system that can potentially automate the process, the five-phase design process steps mentioned in Figure 1 is adapted and used as the DSR approach for the study. The study will be carried out in three iterations and the adapted DSR approach enables the identification of the problem in each iteration, finds a solution, develops and evaluates the performance of the solution methodically and hence, is suitable for the research goals. The DSR methodology of our study is illustrated in Figure 2.

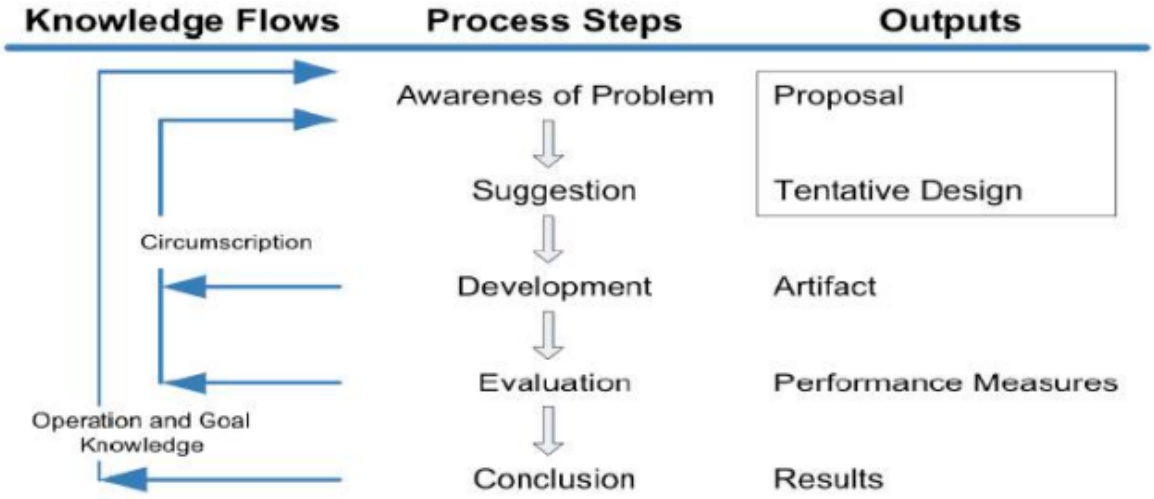

Figure 1. Design Science Research Phases (Kuechler, Park and Vaishnavi, 2007)

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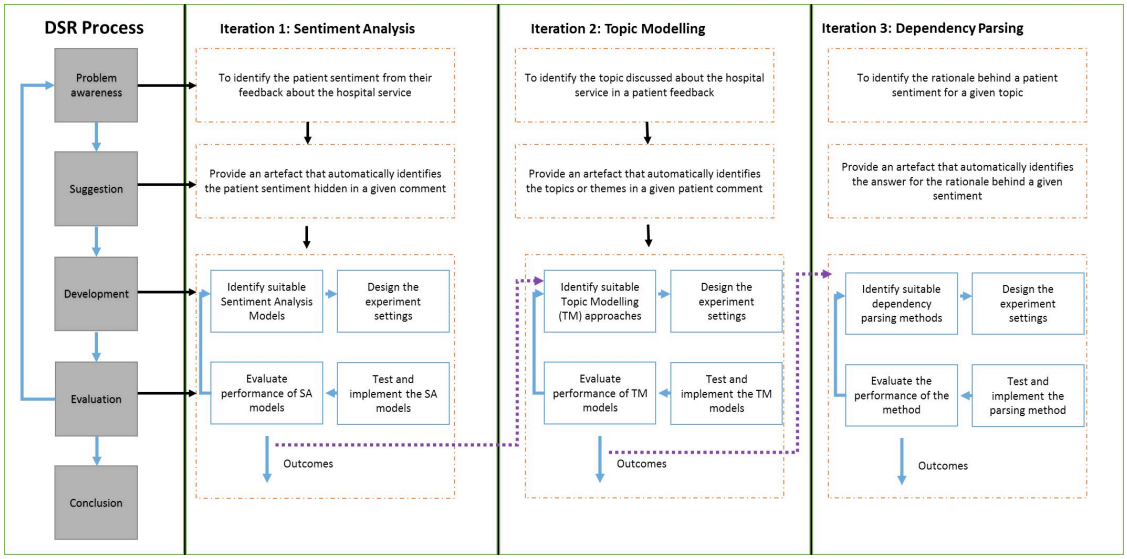

Figure 2: The proposed DSR based framework for automated analysis of patient experience data

A. *Iteration One: Sentiment Analysis of Patient Feedback Data*

The first iteration of our ongoing research is to apply Sentiment Analysis (SA) approaches to the *NHS Choices* patient feedback database. The aim of this iteration is to find the sentiment of the patient feedback in their comments provided on NHS hospitals on the NHS website. The sentiment identification is performed by the application of Sentiment Analysis approaches that analyse and classify a comment into positive or negative sentiment based on its contents.

It can be seen that the problem is the need to identify the patient sentiment from the comments obtained for each NHS hospital from the NHS Choices website. The suggestion is to develop an artefact that can automatically or semi-automatically identify the patient feedback or sentiment in the comment as positive or negative. To develop this artefact, there are several sub-steps. The first is to identify suitable Sentiment Analysis (SA) models from the literature research that can identify the sentiment in the comment. The next sub-step is to design the experiment settings where the SA models are implemented on the feedback database. This involves identifying the processes for cleaning and preparing the database for the analysis, tools and technology required to implement the SA models.

The next step is to evaluate the outcomes of the SA model implementation. The evaluation is an analytical approach in this iteration, whereby it is focused on the accuracy of the SA model in identifying the correct sentiment in the patient feedback. If the sentiment identified by the SA model matches the ground truth sentiment, then the SA model is said to be accurate. The outcomes of this iteration will be used for the second iteration of the study.

B. *Iteration Two: Topic Identification from Patient Feedback*

The next iteration of the study is to identify topics in the given patient feedback. The aim is to understand what specific area of the healthcare service the patient has discussed in their feedback, such as the maternity department, parking facilities or the waiting period in the hospital. In Figure 2, it can be observed that the DSR framework for iteration two is more or less similar to the iteration one approach. The problem in this iteration is to identify the topic being discussed by the patient in their feedback about the hospital on the NHS website. Therefore, in line with the problem, the artefact aimed at providing a model that can potentially automatically identify the topics or themes being discussed by the patient in a given comment.

To develop the artefact, the Latent Dirichlet Allocation (LDA) Topic Modelling (TM) approach will be used. After the TM approach is implemented, and then the topics and themes for each patient comment are automatically identified. This reveals which topics are being discussed in the patient feedback. The next step is to identify the sentiment for each topic identified in the patient comment. To achieve this, the sentiment identified for each comment from the SA models from iteration one is used i.e. for each comment, the identified sentiment is mapped to the relevant topics to obtain a sentiment score for that topic across the patient feedback database. A difference in iteration two when compared to iteration one during the development stage is that the iteration two study requires the outcomes of the SA model obtained from the first iteration, i.e. second iteration of the study is dependent on the previous iteration.

The evaluation of the topics identified in iteration two involves both analytical and observational evaluation. The former refers to when the sentiment score for each topic is computed based on the sentiment scores found from the

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iteration one. The observational part of the evaluation pertains to when the topics are identified by the TM method. The topics are bags of words that are likely to belong to a particular theme and they need to be manually analysed in order to assign a label to each of them. This is achieved by involving NHS experts to observe each topic's elements and provide a label for each category.

The outcomes of iteration two will be disseminated by representing the topics identified using data visualisation approaches in the R programming environment to make them accessible to hospital staff. Finally, the topics identified by the TM approach in iteration two will be used for further study and analysis in iteration three for the Dependency Parsing investigation aimed at identifying the rationale behind the patient sentiment.

C. Iteration Three: Rationale Identification of Patient Sentiment

In the third iteration, the aim is to identify the rationale behind a particular sentiment of the patient in a given comment or review. In other words, the purpose is to find out why the patient is happy or unhappy about a particular topic in a given comment. The problem being addressed in this iteration of the study is to find the possible reason behind a patients' sentiment for a particular topic in a given comment. To achieve this, the artefact developed will implement a Natural Language Processing method called Dependency Parsing. This identifies the keywords in a given comment that could potentially summarise the patient feedback for a given topic in the comment. Specifically, this is achieved by extracting a "noun-adjective" pair for each topic in a given comment and this pair are expected to provide the keywords in the comment that indicate the reason behind the patients' happiness or unhappiness about the healthcare service provided.

Similar to the previous two iterations, once the suitable Dependency Parsing methods are identified and the implementation environments are finalised, the experiment settings are created and implemented. For this iteration, the R programming environment will be utilised and the openNLP and coreNLP methods available in the literature will be adopted. Further, similar to how iteration two was dependent on the outcomes of the iteration one, iteration three is also dependent on those from the two preceding iterations. This is because the "noun-adjective" pair that is extracted to summarise the patient comment is performed on a per topic basis. In other words, for each topic, the reason behind the patient sentiment is identified. In particular, the unigram topics identified from the TM method are used for Dependency Parsing in this study.

The evaluation of the topics identified in iteration three is both analytical and descriptive. The analytical evaluation refers to when the Dependency Parsing methods implemented automatically analyse the feedback data and identify a noun-adjective pair from the comments. The descriptive part of the evaluation pertains to the noun-adjective pair identified providing a summary of the patient comment on a given topic. Thus, it potentially describes the patient comment by a pair of words.

Similar to iteration two, the outcomes of iteration three will be disseminated via visualisation techniques. In this visualisation, the users will be able to list all the comments for a chosen topic and then for each comment, they will be able to visualise the most salient noun-adjective pair that potentially summarises the comment for the given topic, either negatively or positively.

Thus, it can be noted that the DSR approach is deemed suitable to design a framework for our study as it provides a systematic approach to formulating the problem, identifying potential solutions, implementing and testing the solutions and finally, evaluating and disseminating the outcomes. The iterative approach is a strong aspect of the DSR method and is particularly suitable for the current study as each part of the study is dependent on the outcomes of its predecessor study.

IV. CONCLUSION

The DSR method is an iterative process that enables the development of an artefact for solving a problem. It is suitable for our research, as the main goal is developing an artefact for analysing patient experience automatically. Our artefact will be developed in three iterations and each successive iteration study is dependent on the outcomes of the previous iteration. This approach would enable us to develop an effective framework to analyse the patient experience data and can be beneficial to hospitals to assess their performance in achieving high patient satisfaction.

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