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On the application of text clustering in Engineering Change process

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Abstract

In modern industry, the development of complex products involves engineering changes that frequently require redesigning or altering the products or their components. In an Engineering Change process, Engineering Change Requests (ECRs) are natural language written texts exchanged among process operators. ECRs describe the required change on a product or a component and the solution. After the change implementation, ECRs are stored but never consulted, missing opportunities to learn from previous projects. This paper explores the application of text clustering to natural language texts written during the Engineering Change process in industry. In detail, the use of Self Organizing Map (SOM) to the problem of unsupervised clustering of ECR texts is explored. A case study is presented in which ECRs collected during the Engineering Change process of a railways industry are analysed. The results show that SOM text clustering has a good potential to improve overall knowledge reuse and exploitation.

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Keywords: Text mining; Engineering change requests; Engineering change management.

1. Introduction

The development of complex products, such as trains or automobiles, involves Engineering Changes that frequently require redesigning or altering the products and their components. As defined by [1] "Engineering Change is an alteration made to parts, drawings or software that have already been released during the design process. The change can be of any size or type, can involve any number of people and can take any length of time". A change may encompass any modification to the form, fit and/or function of the product as a whole or in part, materials, and may alter the interactions and dependencies of the constituent elements of the product. A change can be needed to solve quality problems or to meet new customer requirements. Although Engineering Change management was historically seen as a typical design and manufacturing research field, several contributions highlighted the effect of Engineering Change on other business processes such as material requirement planning [2] and enterprise resource planning [3]. An overview of the Engineering Change process and a big picture of literature on Engineering Change management are provided respectively by [4,5].

The Engineering Change Request (ECR) is the document, which initiates the Engineering Change process. ECR is used to describe a required change or a problem, which may exist in a given product. After the ECR, the impact of a change is discussed among involved stakeholders and the best possible solution is identified.

Once the implementation of a change is completed, too often ECRs are no longer consulted by who could benefit from them. However, reviewing the ECR documents could offer a chance to improve both the design of a product and the Engineering Change process. A change may be a chance to both improve the product and do things "better next time" [6]. ECRs are documents containing structured and unstructured data, which, if analysed, may be useful to discover information relating to recurring problems and solutions adopted in the past.

This paper explores the use of text clustering to the problem of unsupervised clustering of ECR documents. Text clustering is an unsupervised learning method where similar documents are grouped into clusters. The goal is to create clusters that are coherent internally, but clearly different from each other. In particular, the application of text clustering based on Self-Organizing-Map (SOM) is shown.

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SOM is a neural-network model and algorithm that implements a characteristic nonlinear projection from the high-dimensional space of input signals onto a low-dimensional regular grid, which can be effectively utilized to visualize and explore properties of the data [7,8]. A case study is presented and ECRs collected during the Engineering Change process of a railway industry are analysed. The results show that text clustering has great potential to improve overall knowledge reuse and exploitation in an Engineering Change process.

The reminder of the paper is organized as follows. In Section 2, the Engineering Change process in industry is described. In Section 3, the basic concepts of the text mining theory and SOM based text clustering are described. In Section 4, the case study and the experimental results are both discussed. In Section 5, conclusions are given.

2. The Engineering Change process in complex products industry

For complex products, such as trains, automobiles or aircraft, engineering changes are unavoidable and products or components have to be redesigned, retrofitted to accommodate the new changes to new installations and products. Engineering Change processes in complex environments such as automobile, train and aviation industry were also studied by [3,9]. The main phases of a real Engineering Change process in complex products industry can be summarized as follows:

- *Phase 1*: a request of an Engineering Change is made and sent to an engineering manager. In this phase, standard ECR forms are used outlining the reason of the change, the type of the change, which components or systems are likely to be affected, the person and the department making the request, etc.
- *Phase 2*: potential solutions to the request for change are identified.
- *Phase 3:* technical evaluation of the change is carried out. In this phase, the technical impact of implementing each solution is assessed. Various factors are considered, e.g. the impact upon design and product requirements, production schedule, resources to be devoted etc.
- *Phase 4:* economic evaluation of the change is performed. The economic risk of implementing each solution is assessed. Costs related to extra production times, replacements of materials, penalty for missed due date, etc. are estimated.
- *Phase 5:* Once a particular solution is selected, it is approved or not approved. The change is reviewed and a cost benefit analysis is carried out. When a solution is approved, the Engineering Change order is prepared and issued.
- *Phase 6:* Implementation of the Engineering Change and identification of the documents, such as drawings, to be updated.
- *Phase 7:* Update of the as-built documents. As built documents are usually the original design documents revised to reflect any changes made during the process, i.e. design changes, material changes, etc.

Iterations of the process occur for example when a particular solution has negative impact on product requirements or is too risky to be implemented so the process returns to *Phase 2* and another solution is identified. Another iteration is possible when the costs of a solution are too high or more risk analysis is required or when the proposed solution is completely refused. No review process of similar changes faced in the past is carried out during the process or at the end. This aspect is emphasized by [4] by highlighting that after a period of time, the change should be reviewed to verify if it achieved what was initially intended and what lessons can be learned for future change process. Various factors can discourage to examine the solutions adopted in the past to a particular change. First of all, the lack of opportune methods to analyse the documents collected during the process, i.e. ECR. ECR are often forms containing parts written in natural language. Analysing these kinds of document in the design phase of a product or a component or when a new change request occurs could be very time consuming without an appropriate solution.

In this context, text clustering application can improve the process. When a new ECR occurs, in fact, ECRs managed in the past and similar to the current request could be analysed in order to evaluate the best solution and to avoid repeating the same mistakes made in the past. In order to explore the existence of similarity between the different ECRs texts, the first step is to verify the potential clustering present in the analysed dataset. Text clustering theory and SOM algorithm are detailed in the next section.

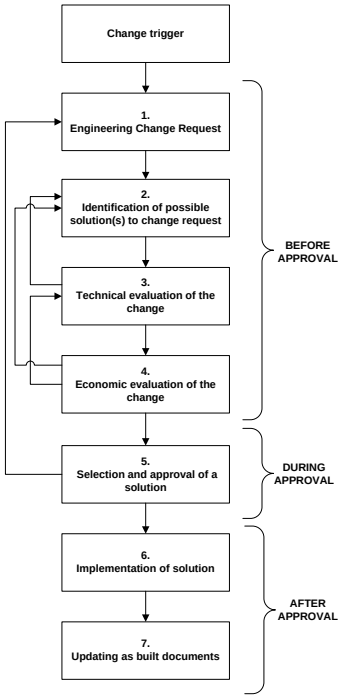

Fig. 1. The real Engineering Change process in complex products environments. Adapted from [4].

3. Text clustering

Text clustering is an unsupervised process used to