Computers in Industry 95 (2018) 81–92

Contents lists available at ScienceDirect

Computers in Industry

journal homepage: www.elsevier.com/locate/compind

Identifying experts for engineering changes using product data analytics

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ARTICLE INFO

Article history:
Received 25 February 2017
Received in revised form 1 September 2017
Accepted 1 December 2017
Available online xxx

Keywords:
Expert identification
Engineering changes (ECs)
Product data analytics (PDA)
Product data management (PDM)
Product lifecycle management (PLM)

ABSTRACT

This paper aims to provide an expert identification procedure in an organization where design engineers share an integrated product data management (PDM) database for their product development and engineering changes (ECs). To identify experts for ECs, the procedure follows a product data analytics (PDA) approach that uses PDM databases as its operational data source to analyze different aspects of product development processes managed by PDM systems. It also employs a two-phase analysis procedure that considers the artefact and actor networks of the PDM system and participating engineers. The procedure also introduces EC history-centered multidimensional data analysis and social network analysis (SNA) for the two phases, respectively. To demonstrate the feasibility of the procedure, this study implemented it using a research-purpose PDM system, extract-transform-load (ETL) module, data cube with on-line analytical processing and SNA engines. It also provides a product design example with multiple engineering changes applied to the implemented prototype system as proof of the implementation and the procedure.

1. Introduction

Engineering changes (ECs) are inevitable processes in manufacturing companies, and their efficient management is a critical factor in maintaining the competitiveness of a company. To reduce the response time to engineering change requests (ECRs) and enhance the quality of ECs, it is important to identify suitable experts for engineering problems related to the current EC. If experts are limited to employees in an organization, they should not only have knowledge of general engineering domains but also experience of specific items such as parts or products developed in the organization.

This paper aims to provide a data analysis procedure to identify suitable experts who can solve engineering problems during ECs in an organization, where design engineers can share an integrated product data management (PDM) database for their product development and ECs. Not only automotive or aerospace manufacturers, but also fabric and fashion companies are introducing PLM or PDM for their competitive product development [1,2]. Thus, many manufacturers use PDM systems to manage product design and ECs, and designers in the company share product design and EC data in PDM databases. The proposed expert identification procedure can be applied to companies that manage product design and ECs using PDM database regardless of specific industries. To support the implementation of this procedure, this paper also provides specifications of Supporting information systems using a system architecture, product data models and prototype implementation.

To identify suitable experts for the current EC, this paper proposes a two-phase analysis procedure. The first phase evaluates and selects similar ECs by comparing EC histories and other EC attributes. The second phase applies social network analysis (SNA) to identify suitable experts for the selected ECs. To provide an effective selection procedure, this paper introduces the following three features, which also differentiate the proposed approach from others.

First, the proposed procedure follows the product data analytics (PDA) concept [3]. PDA is a data analysis approach that uses PDM databases as its operational data to analyze and evaluate different aspects of product development processes. It requires data-driven analysis methods and suitable measures for the analysis and evaluation of product development processes. Following the PDA concept, the proposed procedure uses an integrated PDM database as its source of operational data for analysis. For data analysis, this study uses both multidimensional data analysis and SNA to extract measures to find similar ECs and determine roles in networks of

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https://doi.org/10.1016/j.compind.2017.12.004
0166-3615/

engineers to identify suitable experts, respectively. This study also provides different measures for the two types of analysis.

Second, the proposed procedure uses a two-phase analysis procedure based on the Artefact-Actor-Networks approach [4–6]. This approach views information systems and their users as separate data and human networks that interact with each other. Based on the concept, this study represents an artefact network from the participating old and new product structures in ECs and actor networks from the participating engineers in a set of ECs, and considers a two-phase analysis method that detects similarities using the old and new product structures (the artefact network) and analyzes roles of engineers from the network of participants of the selected ECs (the actor network). The PDM database provides necessary product and participation data to build all the actor and artefact networks.

Third, the proposed procedure introduces an EC history-based approach to detect similarities in ECs. While an existing approach [7] uses simple manual counting of same items in the product structures of participating items, this study use multidimensional data from EC histories in a PDM database to automatically find similarities in ECs. To extract and determine related measures, this study proposes a multidimensional product data model and its data cube using an ETL module for PDM databases. In addition, since the retrieval requires ill-structured and complex query processes, the proposed procedure introduces case-based reasoning (CBR) to detect similar ECs. This paper proposes a CBR method that uses EC history and a set of attribute values of EC objects.

To demonstrate the feasibility of the procedure and Supporting information systems, this study implements a prototype system consisting of a PDM database, ETL module, data cube and data analysis and visualization tools. Then, an example configuration control process with a PDM database is applied to the implemented system to show how to select suitable experts from analyzed PDM databases. The prototype system is based on the on-line analytical mining (OLAM) framework [8] as its Supporting information system architecture. OLAM integrates data cubes and on-line analytical processing (OLAP) for flexible multidimensional data analysis with data mining models. It supports exploratory data analysis, and preparation of data sets for different data mining models. The proposed procedure uses OLAM to prepare input data for EC analysis and SNA models for suitable expert identification, respectively. It shows the potential of the proposed procedure, which is expanded to analyze similar ECs as well as the individual contributions of the participants of selected ECs.

The remainder of this paper is organized as follows: in Section 2, this study reviews related work. Section 3 introduces the overall process for identifying experts for ECs. Section 4 proposes a Supporting information systems architecture with product and multidimensional data models. It also describes details of the analysis procedure. Section 5 describes implementation of a prototype supporting system including an experimental PDM system with application examples as proof of the suggested concept. Section 6 concludes the study with further research topics.

2. Related work

Topics related to this study are expert identification (or expert location), engineering change analysis (ECA) and product data analytics (PDA). Fig. 1 shows that this study associates several features from each topic (see the features in each topic in Fig. 1). It considers internal and two-phase expert identification procedures. It uses EC history objects to analyze similarities in ECs through ECA. Through PDA, it uses an integrated PDM database as its operational database and multidimensional data analysis and SNA as its data-driven data analysis methods. This section reviews related work regarding the three topics.

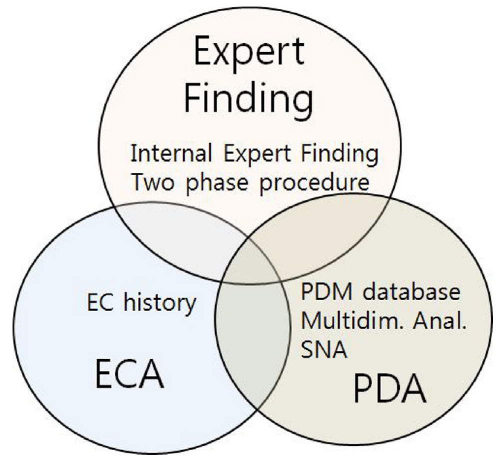

Fig. 1. Related topic.

2.1. Expert identification

Lappas et al. [9] define an expert as a person or agent with a high degree of skill or knowledge of a certain subject, and expert identification as the exercise of efficiently identifying the right expert (or set of experts) that can perform the given task from a set of candidates. Yiman-Seid and Kobsa [10] identified two main motives for seeking an expert, namely as a source of information (information need) and as someone who can perform a given organizational or social function (expertise need). In addition, they mentioned the needs of internal expert seeking while the existing approach focused on external expert seeking issues.

To support expert identification, many automated supporting systems based on different information and communication technologies have been proposed [10]. One of these is a group approach based on networks among a pool of experts. They evaluate measures for suitable experts through score propagation, weighting or constraints of networks. For example, Song et al. [11] supported an expert identification method based on expertise networks with relationship and evolutionary representations. Smallblue [12] also supported expert identification using networks built from emails of participants in an organization. They use an agent system that analyzes emails of each user and gather analysis data from distributed agents to build networks between participants.

The expert identification procedure proposed in this study is an internal expert identification and network-based method. It is different from existing approaches in that its application domain is EC analysis, and it uses a two-phase analysis approach that considers not only participating experts but also associated EC objects manipulated by them based on the Artefact-Actor-Network approach [5].

2.2. Engineering change analysis

Engineering changes (ECs) are modifications to dimensions, fits, forms, functions and materials in products or components after the product design has been released [13,14]. In order to maintain product data consistency, manufacturers establish a strict company-wide engineering change management (ECM) procedure that controls the processes and associated product data for ECs.

Engineering change analysis (ECA) is a base data processing system for evaluation of ECs and predicting EC propagations, which