Capturing Engineering Process Knowledge

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ABSTRACT

When manual engineering analysis processes are being automated it is crucial that the expert knowledge and insights be correctly captured. This paper details the experience and knowledge elicitation methodology used to capture mechanical loads analysis (MLA) engineering expertise and processes in order to automate the MLA process for turbine suitability checks in a wind farm.

Key Words: Knowledge management, Knowledge capture, Knowledge generation, Elicitation of expert knowledge

BACKGROUND

The siting of a wind farm involves multiple analysis steps to determine the feasibility of installing wind turbines in specific locations. In addition to considering government, environmental and legal policies, it is essential to determine the engineering feasibility of installing wind turbines of a selected make and model. The engineering feasibility of a specific wind turbine is based on ambient wind conditions, turbulence and geographical data in the selected location and the capabilities of the selected wind turbine model. This engineering evaluation involves site-specific loads analysis.

The existing process for analysis was run by individual engineers on their local desktop computers. The process required multiple isolated software applications to be run separately, each application requiring multiple lengthy input files that were produced manually using tools such as Excel, Access, and Notepad. The expertise for determining turbine-suitability at the site was spread among multiple engineers in a number of global locations.

The available documentation for running the isolated analysis tools and combining their results was minimal. An overall design practice document provided the engineering justification for the processes, although it was not to the level required to perform an end-to-end analysis. Learning the complete analysis process was time consuming for new engineers. It involved working with experienced engineers on the individual tools, in addition to assimilating the information in the various documents.

The existing process was tedious, distributed and time consuming, and needed an infusion of technology to improve accuracy, consistency and speed to market.

Prior to the knowledge elicitation described in this paper the existing engineering process was documented through standard software requirements capture processes, such as documenting fields, use cases and mock-ups. That work however failed to gather the detailed domain knowledge required to automate these complicated multi-step engineering analyses.

APPROACH

The goal of this work was three-fold - document the existing processes, drive simplification/unification of the processes and automate the processes.

Elicitation Process

The first requirement for automating the processes was to elicit and document the expert's methodology; this is called a problem solving elicitation as described by

Myers & Booker [1]. The analysis processes were initially gathered from experts through a variety of elicitation techniques. Typically, elicitations require a combination of several techniques in order to produce quality results [2]. The techniques used in this case were

a. Telephone conference calls - These were held on a weekly basis with experts. These calls ran over the course of several months for each type of analysis. The calls had the advantage of being inexpensive to conduct with rapid feedback. The conference calls also were able to elicit data from a globally dispersed set of experts. As part of these meetings, documentation was developed in Microsoft Visio describing the data flows within each analysis process. Textual documentation was created at the same time in Microsoft Word to augment the description of the individual steps.
b. Document reviews - Interspersed with the conference calls were documentation reviews to verify the content and representation accuracy of the information gathered during the conference calls.
c. Email communication – This addressed specific issues that needed immediate clarification and could not have been delayed until the scheduled calls or reviews.
d. In-person meetings – Three such meetings were held, one at a customer location in the US, a second at GE's Global Research Center and the third at a customer location in India. These meetings allowed personal interactions with a large set of domain experts for each type of analysis gathered in the elicitation. Given the fine granularity required to automate the engineering process the face to face interviews turned out to be a critical method of elicitation. The face-to-face meetings consisted of a team of two performing the elicitation typically with one domain expert. Multiple interview sessions were held at each location with various domain experts.

The knowledge elicitation process was not without its challenges. It turned out to be lengthier and more difficult than initially expected. This was due to a number of factors. First, there were many different types of analyses performed, each one having a separate and distinct process. Second, different experts often performed the same analysis differently. While these differences sometimes had minimal effect on determining suitability they made the procedure more difficult to document and often slowed the process while best practices were being determined. Third, bias was sometimes introduced as some of the experts described the desired process instead of the current one, particularly when the existing processes were sub-optimal. This resulted in the conditioning effect [1], leading to confusion when recreating the existing analysis steps. Fourth, cultural and language differences made interaction more time consuming than expected. Although all the participants spoke English in some cases accents and interpretations of common terms interfered with communication. In other cases, cultural norms prevented some of the experts from admitting the shortcomings of the existing processes and a consequent reluctance in embracing change. Fifth, the face-to-face meetings with multiple domain experts revealed inconsistencies and diversity in the processes.
This required questions to be repeated or reworded and quite often the same topic needed to be revisited a number of times until a full understanding was gained and documented.

Having worked through the challenges, the knowledge elicitation was completed for each type of analysis, the process fully documented and expert sign-offs obtained.

Discovery Process

Our team then entered a discovery phase where we incorporated the engineering process knowledge by learning how to run the processes manually. This required creating manual inputs and running each stand-alone tool. As part of this manual process we created a set of detailed instructions which we called 'run-through notes'. This gave a cook book approach to performing a manual analysis. The run-though notes for each tool were reviewed by the domain experts to assure their accuracy. The standalone tools were then executed by following the run-through notes to validate our knowledge. The accuracy of the outputs was ensured by comparing our results to verified examples supplied by the experts. This discovery process pointed out a few issues in building the automated system.

First, this pointed out specific pitfalls that we might encounter in automating a set of steps. An example of this type of issue is that when we ran a tool that performed a relative loads analysis between turbines at a site, we determined that the tool did not end the process cleanly. Instead, it generated a message on the console that required a user to manually terminate the process. For a manual process this was not an issue but since this was to be one of many automated steps, it necessitated the determination of when and how to force the termination of the process step.

Second, the discovery process found a number of discrepancies between the stated process and the actual working of the tools. When these occurred the elicitation team went back to the domain experts and worked to reconcile what they described with what we actually found during the automation. In some cases, management needed to become involved to help drive unification of inconsistent processes between engineers.

Third, some processes included non-deterministic steps that could not be easily automated. An example of this was a process that discarded outliers in the data by visual observation of a plot of the data. Working with the experts and management we developed a formal defined method to identify the outliers and replace the 'visual' methods.

The knowledge elicitation and discovery work were followed by modeling, development and quality assurance phases in implementing an automated and elastic system for wind turbine siting analysis. These phases have been briefly discussed in the following two sections.

Modeling Process

After the engineering process was fully understood the automated process was modeled and a GUI prototype created using EASA software[3], a modeling tool that supports automation of legacy software. The software was then developed using EASA and an iterative adaptive software development approach [4] which allowed for rapid incremental addition of capabilities to the user community.

Quality Process

To ensure the correctness of the automated process, automated results were compared against a set of verified manual runs created by the experts. When differences occurred the team worked with the experts to identify the cause of the discrepancies. Bugs in the automated system were fixed and the process differences reconciled. These steps were iterated until exact matches of the results were achieved. This was followed by a period of user acceptance testing where the engineers exercised all the features of the system and verified that it was ready for implementation.

CONCLUSION

Eliciting knowledge to capture and automate a complicated engineering expertise for analyses such mechanical loads analysis for wind turbine site suitability is a time consuming and challenging process that requires a number of different methodologies to gather a complete understanding of the knowledge. It required a combination of human interaction, process engineering, technology infusion and the use of appropriate tools.

Further work needs to be done to improve the elicitation and knowledge representation processes. Areas of interest include building semantics models from documents and design practices; representing knowledge as executable models and automated code generation.

References

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