A Framework to Improve Automobile Design Work Efficiency Using Functional Decomposition Tree and Ontologies

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Abstract

Automobile design work is not being performed efficiently. In particular, when changing the function of a component in a design review, it is necessary to infer and enumerate possible faults of the function or part to be changed from past examples, which is a time-consuming task. Therefore, a framework to infer possible faults exhaustively in the part while viewing the automobile from the perspective of its function is needed. We aim to solve this problem by improving the search system when collecting information about known faults to perform design change work. First, the expected faults are derived from the function of a component. For this purpose, the knowledge of a skilled designer is modeled using functional decomposition tree and ontologies. Furthermore, information can be collected without excesses or deficiencies by using the derived faults as search queries. This paper focuses on efforts to realize "fault reasoning," which enables the derivation of possible faults described above.

Keywords

ontology, functional decomposition tree, fault reasoning,

1. Introduction

The goal of this research is to improve the efficiency of automobile design work.

In recent years, the automotive industry has been undergoing a once-in-a-century transformation [1], and there is a need to improve the efficiency of automobile design work. Currently, however, it is difficult to say that automobile design work is being done efficiently.

Automobile design work can be roughly divided into three categories: information-collecting work, report-writing work, and design change work. Before design change work, the designer collects information on the components to be redesigned in a design review. The designer investigates what kinds of faults have occurred in the past and what kinds of faults are likely to occur if the shape or material is changed. Furthermore, since automobile design work is done by a team, a report is prepared to share the information with the team. Only after the team decides on a policy based on the report can the design change work be done.

According to one automobile manufacturer designer when automobile design work is assumed to be 100%, 40% of the time is spent on collecting information on design changes and 40% on

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[1]https://www.toyota.co.jp/pages/contents/jpn/investors/library/annual/pdf/2018/ar2018_1.pdf

preparing reports on past information on design changes, leaving only about 20% of the time available for automobile design work that should be done by the designer.

Currently, information is collected by searching a database that has accumulated internal documents, patents, and recall information related to past fault examples. However, the search system currently in use outputs not only information related to the part of interest, but also a large amount of information unrelated to the part as search results. This is a cause of inefficiency in automotive design work.

Against this background, we identified two issues. First, there is a lot of know-how required to select appropriate queries for search, and only skilled designers can collect information. Second, irrelevant information (noise) is included in the search results. We thought that these problems could be solved by using functional decomposition tree and ontologies, which are knowledge models.

2. Method

To accomplish two issues, we devised a framework consisting of a two-step process. In the first stage, we create a body of knowledge possessed by a skilled designer. This enables the possible faults from each component to be systematically derived. This is called fault inference. The second stage uses the fault knowledge derived in the first stage. Then, a search query is created that can extract information without excesses or deficiencies. The fault reasoning currently underway with respect to these frameworks will be described in detail.

2.1. Functional decomposition tree and ontologies

Artifacts reflect human intention and have different effects on the external world than natural objects. This effect on the external world is called "function". In this way, understanding an artifact is to know how its internal structure interacts with the external world to produce its function [1]. As can be seen from this, to understand artifacts such as an automobile, it is necessary to know how the artifact works in its function. We believe that one of the approaches of skilled designers is to consider what function each component of an automobile has and to do design change work. Therefore, the body of knowledge to be constructed should be close to the knowledge possessed by skilled designers, so that information can be collected from the perspective of function. The body of knowledge to be constructed is represented by a functional decomposition tree and an ontologies.

A functional decomposition tree is a knowledge model that develops a function to be realized into a series of sub-functions that can achieve it [2]. In this research, a tool called FWTEditor is used based on the idea that each component of an automobile has its own function and that the automobile can run safely when its function is working properly. A functional decomposition tree is created with "The drive is driven. (Transmits power and moves it.)" as the root(Figure 1 left).

FWTEditor is a tool for building functional decomposition trees and performing fault inference. The fault inference mechanism is explained in Section 2.2. FWTEditor represents a function as a square node. By developing the functions in detail to a granularity that is captured by skilled designers, it is possible to describe what functions each component of an automobile has.
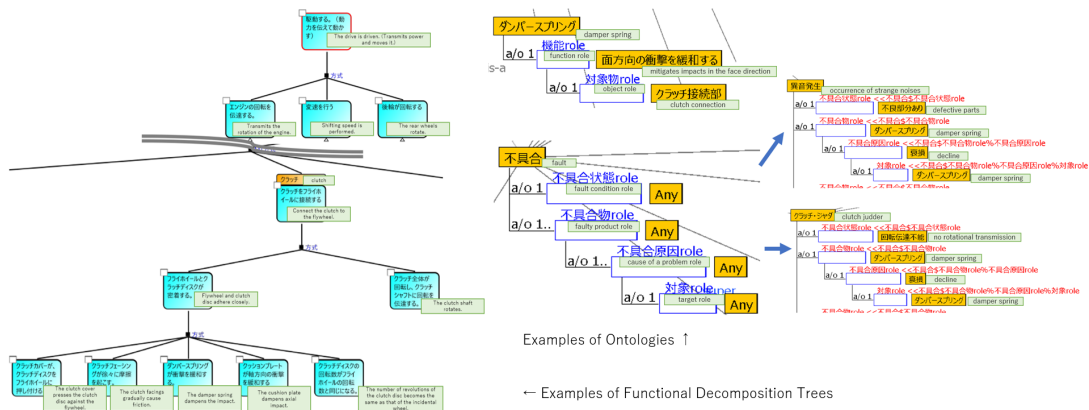
Figure 1: Functional Decomposition Tree and Ontologies(This research is being conducted in Japanese, and some of the figures in this paper have been translated into English for explanation purposes.)

We create ontologies using HOZO [2] to define detailed behaviors and subject to functional effects concerning the components described in the functional decomposition tree. A fault is a function that is not working properly and defines which component is at fault and for what cause(Figure 1 right).

The following process is used to create the functional decomposition tree and ontologies. First, we extract knowledge from technical books on automobiles. The extracted knowledge reflects on the functional decomposition tree and the ontologies. The reflected functional decomposition tree and ontologies will be discussed and refined by skilled designers. By repeating this process, we create the knowledge of skilled designers.

Currently, 389 basic conceptual ontologies have been defined.

2.2. Fault reasoning

Fault reasoning is performed using FWTEditor and HOZO. When a node in FWTEditor is selected, the sentence in the selected node is subjected to morphological analysis to extract word groups. The word groups is then used to perform an OR search on the ontologies described in HOZO. The possible faults are systematically derived from the word groups. When a fault name is reached, the search is terminated and the results are displayed in a circle.

Figure 2 is used as an example. Morphological analysis of "The damper spring dampens the impact." extracts three words: "damper spring," "impact," and "dampens". Using these three words, we search for possible faults. As a result, the faults "occurrence of strange noises" and "clutch judder" are derived.

Currently, we have not yet had any discussions with the designers. Therefore, we will continue to improve the knowledge model to bring it closer to the knowledge of experienced designers. We also plan to evaluate the method and content of presenting the fault knowledge resulting from fault reasoning.

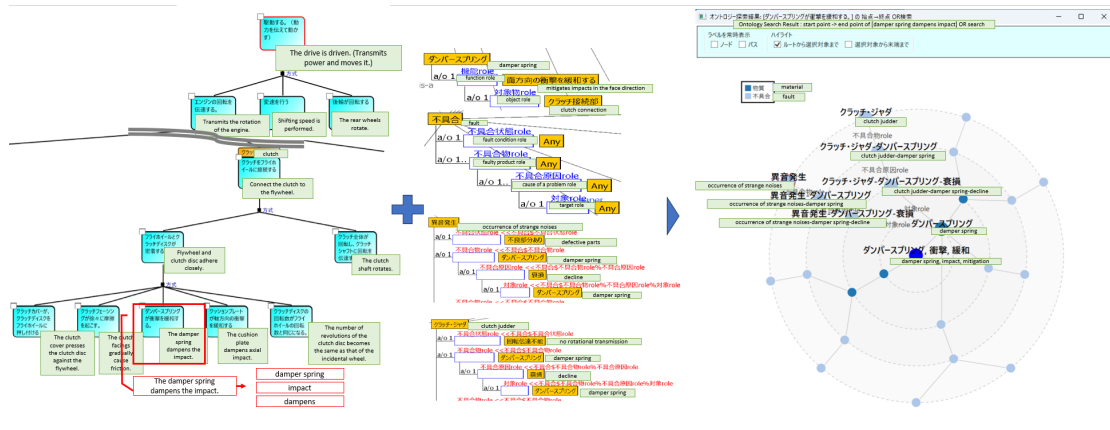[2] http://www.hozo.jp/index_jp.html

Figure 2: Example of Fault Reasoning Execution(This research is being conducted in Japanese, and some of the figures in this paper have been translated into English for explanation purposes.)

3. CONCLUSION

This research considers a framework for improving the efficiency of Automobile Design Work, which consists of two steps: fault reasoning and search query generation, using functional decomposition tree and ontologies. In this paper, we describe our work on fault reasoning. In the future, we will consider how to use the components and fault knowledge retrieved by fault reasoning in the search query. And we plan to continue our research through discussions with designers.

Acknowledgments

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