Applied Mathematics and Computation 267 (2015) 758–770

Contents lists available at ScienceDirect

Applied Mathematics and Computation

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

A portable knowledge-based system for car breakdown evaluation

Eugenio Roanes-Lozano [a], José Luis Galán-García [b,*], Gabriel Aguilera-Venegas [b]

[a] Instituto de Matemática Interdisciplinar & Depto. de Algebra, Universidad Complutense de Madrid, Spain
[b] Depto. de Matemática Aplicada, Universidad de Málaga, Spain

ARTICLE INFO

Keywords:
Knowledge-based systems
Groebner bases
Computer algebra
Breakdown diagnosis

ABSTRACT

Modern cars have many dashboard lights and not all drivers recognize or know the importance of all of them. Red symbols usually indicate a safety issue or a serious problem, meanwhile yellow symbols use to indicate a not so urgent problem. Green and blue symbols usually provide information about the systems connected. But not all the red icons require of the same action, and the *user manuals* of most modern cars, with their sophisticated electronic systems, have hundreds of pages. Meanwhile, smart devices have become popular and have an outstanding computing power plus Internet connection. Consequently, the conditions for developing a knowledge-based system that helped the unaware driver in case a dashboard light went on, exist. The application should evaluate the situation and recommend the best actions to be carried out by the driver (regarding the possible repair on site or at a workshop, its urgency or even the need to immobilize the vehicle immediately). We have designed such a knowledge-based system and have developed a simplified one as example. A friendly Graphical User Interface has been developed in order to ease the communication with the application and its use in remote using any smart device with Internet connection.

1. Introduction

This work arises from a real fact: some time ago an aunt of one of the authors kept on driving to the next gas station (to ask for advice) when the *oil pressure* dashboard light of her car went on. As a consequence of this decision, the engine was ruined. The importance of this dashboard light was not correctly evaluated!

Modern cars have many dashboard lights and not all drivers recognize or know the importance of all of them. Applications for smartphones, that help in recognizing the icons are already available [1].

Red symbols usually indicate a safety issue or a serious problem, meanwhile yellow symbols use to indicate a not so urgent problem. Green and blue symbols usually provide information about the systems connected. But not all the red icons require of the same action (for instance, to *stop the car immediately* is not always required, although it can be the best option sometimes). We should take into account that the *user manuals* of most modern cars, with their sophisticated electronic systems, have hundreds of pages, and their terminology is not always mastered by the driver.

* Corresponding author.
E-mail addresses: eroanes@mat.ucm.es (E. Roanes-Lozano), jlgalan@uma.es (J.L. Galán-García), gabri@ctima.uma.es (G. Aguilera-Venegas).

http://dx.doi.org/10.1016/j.amc.2014.12.001
0096-3003/

We had previously developed knowledge-based systems (KBS), whose underlying logic was Boolean or many-valued modal, for different tasks such as managing medical appropriateness criteria [2] and the early detection of illnesses [3–5]. In all cases we used computational techniques borrowed from computer algebra (Groebner bases) [6,7].

Meanwhile, smart devices have become popular and have an outstanding computing power plus Internet connection. Consequently, the conditions for developing a KBS that helped the unaware driver in case a dashboard light went on, exist.

The application should evaluate the situation and recommend the best actions to be carried out (regarding the possible repair on site or at a workshop, its urgency or even the need to immobilize the vehicle immediately).

We have designed and developed such a KBS. It returns explanations about the repairs to be made such as *substitute brake pads*, and recommendations such as

$$\textit{drive carefully and smoothly} \wedge \textit{increase safety distance} \; (\textit{breaking distance possibly increased})$$

and suggestions about where to have the car to be repaired such as have the car repaired at a workshop ∨ DIY repair at home

The underlying idea of this work, together with others' cars diagnosis research, are stated in Section 2. The KBS has been structured in three subsystems (Section 3). The inference engine is based on the use of Groebner bases of polynomial ideals (Section 4). An example of use of the KBS is described in Section 5. In order to compute the Groebner basis, the Computer Algebra System (CAS) CoCoA has been used (Section 6). To ease the communication between the user and the application, a friendly Graphical User Interface (GUI) has been developed (Section 7). This GUI allows to execute the application in remote with any smart device with Internet connection. It also makes transparent to the user both: the use of CoCoA and the management of the different subsystems of the KBS. In Section 8 a brief study of execution times is presented. Finally, acknowledgments and conclusions are stated in Sections 9 and 9, respectively.

2. About the underlying idea, the way it has been developed and others' cars diagnosis research

Let us emphasize that this KBS is not inspired by repair manuals such as the famous *Haynes* series [8], devoted to expert users or auto mechanics, that can dive into the complexities of cars repairs. It is a decision making tool for a driver that suddenly faces a problem when driving, reported by a dashboard light. What it proposes is an *ad hoc* on site acting protocol instead (that can, for instance, suggest a way to keep on driving or alert that the car should be immobilized immediately). As it is neither intended for DIY work at home nor for workshop repairs, it should be accessible from smart mobile devices.

There are several KBS devoted to the problem of finding out the reasons for a malfunction and how to proceed, more in the line of a repair manual for an amateur or professional workshop. Examples can be found in [9–14]. But we do not know of any comparable KBS.

Let us remark that there are many approaches to perform effective computations in logics and KBS. We have chosen a Groebner bases based because of our experience with this approach, its very reasonable performance and, mainly, because of the possibility to choose different logics when designing the KBS (for instance, although this prototype uses Boolean logic, it would be straightforward to change the underlying logic to, for instance, Kleene's or Łukasiewicz's three-valued logic, if desired).

No changes in the rules would be required, only the code of the algebraic inference engine had to be changed, if the logic was changed. This is not the case in other approaches, such as the KBS development environment CLIPS [15] (this is the approach used, for instance, in [9]). When we started developing the rules, we were not sure if it would be better to work with a modal three-valued logic or if a simpler Boolean logic could be used.

The approach followed presents no operating system compatibility disadvantage w.r.t. other KBS development approaches, as it is designed as an Internet service (computations take place at a server).

We finally preferred to choose Boolean logic as the underlying logic because of its much better performance compared to many-valued modal logics (for instance, using the algebraic approach detailed below, the polynomial translation of the logical connectives grow significantly in the many-valued modal, case) as we desired to receive answers almost instantly. This choice could be made since:

- if the driver cannot answer a question, the worst case is considered,
- if we are not sure about the diagnosis, a "take the car to a specialist for further investigation" recommendation is included.

Nevertheless, if in a future enhancement of the prototype presented here, a many-valued logic was preferred, for instance, for one of the subsystems, it would be straightforward to adapt the whole KBS. This is not possible in all approaches to KBS development.

3. KBS structure

The process begins with a dashboard light on (or gauge out of margins). The KBS is divided into three subsystems (what is also good for the performance of the whole KBS):