ALGORITHM FOR ASSESSMENT OF TRUCK BRAKES TEMPERATURE EVOLUTION USING SVM

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ABSTRACT

In this paper, an algorithm is proposed for a new system for trucks with heavy loading operating in steep grade conditions. The algorithm proposed in this paper is using SVM (Support Vector Machine) algorithm to predict brakes temperature evolution which is processing previously CFD (Computational Fluid Dynamics) simulation of the brake components' cooling for the truck model. The brake system temperature is estimated and the driver is informed and warned about future dangerous situations. The proposed system is a new feature proposed in ADAS (Advanced Driver Assistance Systems) in this paper dedicated to a truck with heavy loading operating in steep grades.

KEYWORDS: truck brakes, steep grades, temperature evolution, brakes overheating, SVM prediction

1. INTRODUCTION

The increase in road grades and in transport capacity of the trucks has resulted in safety concerns for hauling operations concerning brakes functioning [1] [2].

Nowadays, there is a concern to develop systems to assist the truck driver with safely operating on steep grades. Studies have shown that properly functioning brakes are of foremost importance when operating on steep grades. Other studies have consistently identified the truck air brake system to be a major contributing factor for fault trucks on harsh roads which translated in high cost of transporting the faulty truck and, more importantly blocking roads [3], [4]. It is well understood that commercial vehicle braking system operation in case of steep grades is of utmost importance as a functioning failure might cause accidents. There are many scientists who are studying the brakes system [5], [6], [7].

Properly maintained and performing brakes in extreme conditions are critical in preventing and mitigating crash situations. Although the problem of vehicle's faults on large trucks is not considered in this paper, the excessive heat in the brakes due to harsh conditions might produce not only diminishing breaking performance, producing an onboard fire but also malfunctioning or defective brakes. There is a main problem of the brake system related with thermal conditions - the excessive heat that might lead to onboard fire or brakes malfunctioning. For a heavy truck on steep grades, prolonged power transmitted to the brake pad to stop the rotor disc [8], [9], is required. The friction between the brake pad with brake disc rotor within a considerable amount of time produces excessive heat in brake components. Furthermore, when operating in high temperature climate more thermal stress emerges to the breaking systems. Disk brakes are exposed to large thermal stresses during routine braking and extraordinary thermal stresses during hard braking [10], [11], [12]. The brakes of trucks with heavy loads descending steep grades are known to generate temperatures as high as 800ºC.

When the brakes are applied, the shoes press against the brake drum to convert kinetic energy into thermal energy via friction [1] [14]. The thermal energy occurring in the brakes dissipates the heat. This phenomenon is described by The First Law of Thermodynamics, well known as the law of conservation of energy.

The support vector machine is a supervised learning method which aims to find a function to represent the relationship between variables and to classify variables in classes [16] [17] [18]. This function is also called a model or a pattern. The SVM approach for high temperature variation critical system has become very useful in the prediction of many functioning and failure [21]. The advantage of this approach over other methods lies in the fact that SVM provide a good reliability in predicting function evolution trends.

Today's Advanced Driver Assistance Systems (ADAS) are safety systems designed to warn the driver or even make decisions such as braking to prevent or to mitigate accidents or dangerous situations [18], [19], [20]. Nowadays, there are automotive manufacturer who provide such systems in many car models as well as trucks. These new systems are able to predict dangerous situations using a wide number of sensors such as RADAR, LIDAR, ultrasound, camera, and (thermal) imaging. As a new feature dedicated to trucks with high loading capacity the authors proposed a new system for ADAS.

2. PROBLEM STATEMENT

In case of trucks working in harsh conditions such as steep grades and heavy loading the issue of brakes over-heating is of utmost importance as an overheating will produce malfunctioning of brakes, diminishing brakes capability, lead to onboard fire or even accidents. On-site temperature sensors on brakes components are expensive and prone to failure and they will only inform the driver about actual temperature when there is little to be done in traffic. Out proposed algorithm aims at predicting brakes temperature without sensors on brakes components, but only using information provided by modern trucks' onboard computer. In such a manner the algorithm will warn the driver before dangerous situation occurs as it is able to assess evolution in time of brakes temperature taking into account parameters that are varying.

Such an algorithm can be implemented on an embedded system or as a part of the truck computer.

3. PROBLEM SOLUTION

The main idea of the system and algorithm proposed in this paper is depicted in Fig.2. Let us consider the current location of the tractor. The next steep grade (a) will not cause so much overheating of the brakes system, but the second steep grade (b) will add more heat to the brakes as needed to diminish the speed. So, the system is able to predict the heating and, in the current position, it will warn the driver to take measures (to slow down) for the dangerous (b) part of the road.

To accurately predict the brakes temperature evolution is difficult in practice since there are several factors in a complex system with many parameters involved. To obtain enough historical data of heat levels and to find out an approach to predict them become mandatory as installing sensors on brakes is costly and also prone to failure. The implementation of sensors on brakes components or on the chassis will imply also communication with the truck computer. Also, for driver, most important is not only inform about, but, also to predict the evolution of the temperature, in order to allow taking necessary measures such as using engine breaking, further minimizing the speed or even take a brake in a parking to allow the breaking system to cool down. In this paper, we propose an algorithm with the aim of predicting brakes temperature aiming to warn the driver if dangerous situations will occur. Support vector machines method is applied to obtain the prediction model. The model uses previously CFD (computational fluid dynamics) simulation for brakes heating distribution.

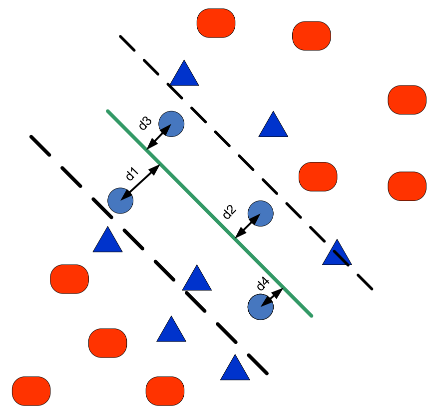

Fig. 1. *SVM principle*

The principle of SVM classification is as described above (Fig.1). The task is to separate two or multiple classes of objects indicated by circles and ellipses. Triangles represent non-class samples (usually called noisy information) and blue circles are "positive examples" class members. d1, d2...dn is the decision function defining class.

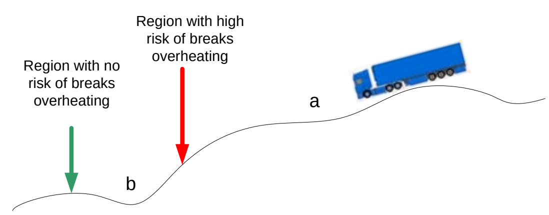

Fig. 2. *Scenario of steep grades*

The separate class of positive solutions represented by blue circles is indicated by dotted lines. Red ellipses are negative examples, which are not a part of the class and blue triangles are not part of any class of interest for the current experiment. Once enough experimental data are available, the descriptors can be separated in classes. So once a reliable class description is established, we can use this method to predict the evolution of a system. This approach can lead us to establish which factors may play an important role in the evolution of the system, the brakes heating level in our case. Our approach is based on the assumption that the air flow to the truck is relatively low, as in the case of steep grades, the truck speed is under 40 km/h. The variation of the grades of the road ahead using map information and GPS current location allows to predict brake temperature taking into account the future behavior of the system. After performing several CFD simulations for different heating level scenarios, which depend on the 3d model of the truck as well as on the materials used, the SVM can be used.

The SVM takes into account several input variables (Fig.3) such as outside temperature, engine revolution, period in seconds of last or current brakes activating (which are read from truck computer via a OBD2 USB interface), inclination (read from an Arduino board), incoming steep grades (read using Google Map API and collaborated with a GPS locator antenna). The SVM algorithm should decide whether to warn the driver about a dangerous brake temperature evolution.

Support vector machines (SVMs) are a popular method for classification aiming to find a hyperplane that separates the data. The margin of the region of found data shows the area near the hyperplane. The distance to the hyperplane shows the weight point in the dataset. The proposed algorithm takes into account several steps. Firstly, CFD simulation for the level of heating of the braking system needs to be performed. The authors performed simulations for values from 300 to 800 degrees Celsius with a step of 50 degrees Celsius (10 simulations).

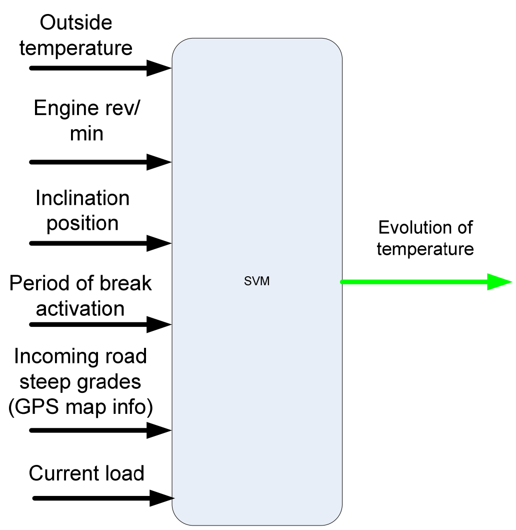

Fig. 3. *SVM input variables*

The data obtained are used in the system onboard the truck by the SVM algorithm. A computer reads the data from a GPS locator and also, by means of an OBD2 interface, namely ELM326, it reads data from the truck computer.

Using a serial interface the computer reads the data from an inclination sensor that is able to send data concerning forward inclination and the amount of inclination.

The program will suggest solutions such as minimizing speed to further allow the brakes to cool, or even stopping in a parking if available. As shown in Fig. 2, the incoming steep grades are considered for brake temperature evolution.

Also, the driver must input the current load into the system (Fig.6). The SVM algorithm will decide whether a warning will be issued to the driver about a critical evolution of temperature in the next 60 minutes.

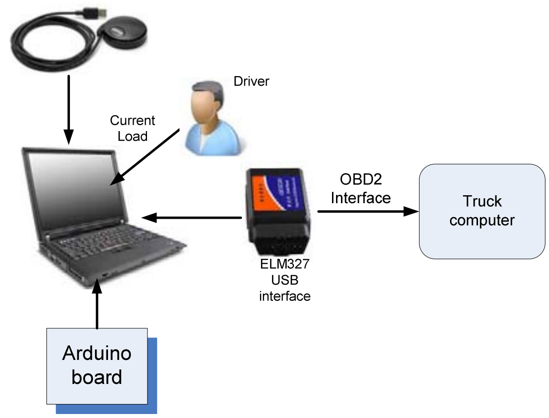

Fig. 4. *Hardware setup*

The hardware setup we used is an IBM ThinkPal T34 computer with serial interface, ELM327 usb OBD2 interface, an Arduino board with inclination sensor (Tilt Sensor using MMA7260Q accelerometer).

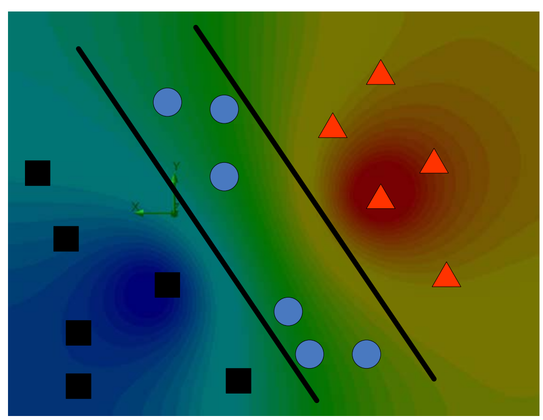

Fig. 5. *Projection of dangerous situations (red) and not dangerous (blue) in the principal plan of the SVM algorithm*

The software was developed in Visual C 2008 using Google API and TinySVM API. The SVM algorithm is noted to need low computation resources so we conclude that this algorithm can be easily implemented in the truck computer or in an attached embedded device with low computational resources.

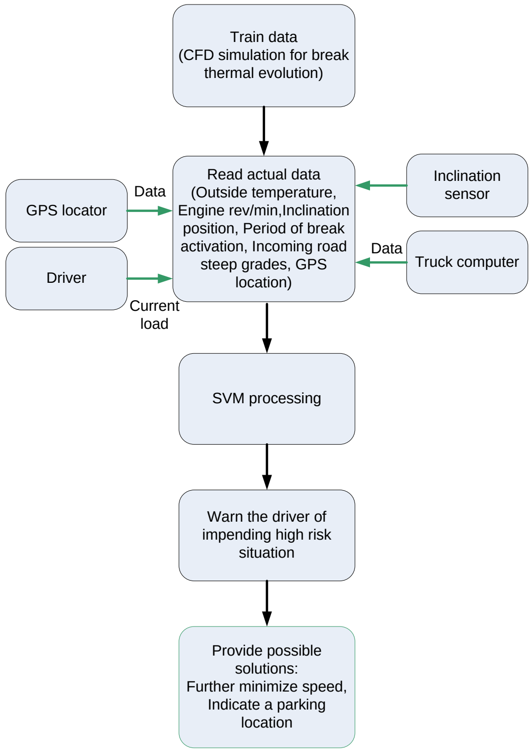

Fig. 6. *The algorithm proposed*

At the moment the authors have not compared the simulated results with real data. We tested the algorithm using other data than those inputted in the training phase of the SVM and estimated the heating level function of steep grades. The hardware setup was tested using a VW Transporter van to test OBD2 communications and real time processing capability.

4. CONCLUSIONS

Mitigating the impact of truck brakes overheating in harsh conditions is possible if accurate predictions are provided. CFD simulations, information from the truck computer, and GPS information can be used to predict thermal evolution of the truck brake components and limit the impact of brakes overheating. Such a system, as proposed in this paper, is especially important for trucks with a high load in steep grades that experience a higher rate of brakes failure or even onboard fire due to the overheating. However, providing accurate predictions with sufficient lead time remains a challenging problem. The proposed system is a new feature in ADAS (Advanced Driver Assistance Systems), proposed in this paper, and dedicated to trucks with heavy loading operating in steep grades. The proposed algorithm needs real situation testing and improvement.

Future development for such a system might include development of the algorithm for an embedded device to be attached to the truck computer.

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