Cracked Pipes Alert System for Autonomous Vehicles

Yair Wiseman[1],

[1] Computer Science Department
Ramat-Gan 52900, Israel
wiseman@cs.biu.ac.il

Abstract. Autonomous vehicles will not be driven by a human being. The missing of the human being will make the vehicles less inspected because a human being often listens to the engine and its sounds. A passenger in an autonomous vehicle usually does other things and even sleeps, so the human inspection on the engine and on the pipes system will not be effective. This paper suggests a system that alerts about cracked pipes before they malfunctions.

Keywords: SkyTran, Discrete Cosine Transform, JPEG

1 Introduction

Any vehicle has several kinds of pipes for several kinds of materials like gas, air, brake fluid, oil and more [1]. Like every mechanical parts, these pipes are also liable to wear and tear [2]. A worn out pipe can cause various problems depending on the pipe that has been torn [3].

There are pipes that even a large tear will not be a problem in specific cases like the pipe that supplies hot air to the carburetor in hot countries; whereas there are pipes that are very critical like the pipes of the brake fluids [4].

The goal of this paper is a system alerting about torn pipes. Autonomous vehicles are less supervised because there is no driver to pay attention for the engine and its sound. Also, many of the autonomous vehicles will be shared by more than a few users [5,6]. These users will not be familiar with the typical sounds and the typical performance of the engine, so they will not be able to notice different sounds; nor will they be able to become aware of performance degradation.

The concept of automatic detection of faulty parts of means of transportation has been suggested in the past. E.g. fuselage damage detection [7,8], damaged tires detection [9,10,11] or SkyTran tracks computerized inspection [12,13]. This paper suggests an automatic system that will be able to detect a torn pipe with the aim of warning the passenger that a pipe is going to be unusable before the pipe is indeed torn and the vehicle is out of use.

Polygons are simple shapes that can simulate the real objects. It is very common to generate models of real objects using simple polygons. This practice is usually called Spatial Data Structures [14].

When it comes to simulation of vehicle pipe systems, Spatial Data Structures are implemented in order to find the weak spots that are about to crack and realizing which polygons contain these weak spots. There are several methods to reduce the number of polygon checks when using Spatial Data Structures [15,16].

Spatial Data Structures are the basis for Space Partitioning [17] and Bounding Volumes [18]. Space Partitioning is a method of space sub-partitioning into convex regions. These convex regions are named "cells". Each of these cells maintains a list of objects that it comprises of. By employing these cells, the algorithm knows how to sift out polygons that have no connection to a pipe.

The other method is Bounding Volume. This method breaks an object into small components; then the algorithm finds a fitted bounding volume for each of the small component. After that, the algorithm checks for suspected components. It should be noted that the sifting out is less demanding in this method, because the algorithm just have to detect the at least partly cover bounding volumes.

Bounding Volumes applications have been intensely studied over the years and many variations of the method have been suggested: Bounding Spheres [19], K-DOPs - Discrete orientation polytopes [20], OBB - Oriented Bounding Boxes [21], AABB - Axis Aligned Bounding Boxes [22] and Hierarchical Spherical Distance Fields [23].

In this paper we have used the AABB approach which is one of the most well-known approaches. In AABB each of the bounding volume in the object model is represented by its minimum and its maximum values [24]. Compared to the "Bounding Sphere" approach, AABB has an advantage and a disadvantage. AABB encompasses the components of the model more tightly which probably yield less checks and also the split of the object into its bounding volumes is faster [25]. The algorithm first checks each of the basic elements that a bounding volume consists of and projects the element on the axes and then finds the minimum and the maximum values for each axis. The fast operation is very essential in real time systems like checking pipes of autonomous vehicle.

However, AABB has also a disadvantage. Saving the data for AABB takes more memory space which in the past was very costly and it has to be even on a remote machine [26], but nowadays, memory space is much less costly and even simple computers have a plenty of memory space [27,28], so this disadvantage is not so acute; therefore, we have chosen the AABB approach.

Since our system is a real time system and the computation time is very essential we have decided to implement the AABB approach. We generated the bounding volume tree in a recursive manner. In each step, the algorithm generates bounding volumes for the remaining triangles and splits the triangle set into two sub-graphs. Then, it recursively calls itself to do the same for each of these sub-graphs.

Bounding volume hierarchies are actually a tree symbolizes a model of an object [29]. The basic components are the leaves of the tree and each sub-tree rooted by an internal node represents a segment of the model.

Such trees have only one leave for each basic component, so the size of the storage needed for each vehicle model is linear in the number of the basic components. This also impacts on the check time which is therefore quite fast.

The construction time however is longer. This can be a significant disadvantage when the model is flexible and a reconstruction is frequently needed whenever the object changes its shape; however a vehicle is a rigid object and no changes are made, so the construction can be done only once and the tree will fit for the entire life of the vehicle, so this disadvantage is irrelevant for the objective of this paper.

When the algorithm checks for cracks, it will begin to check the roots of the model trees and then in a recursive manner it will go down the trees.

2. Evaluation

As was explained above, the implementation of the method was in a recursive manner. We used triangles as it is a very common in such implementations [30].

Actually, the bounding volume algorithms and the triangle split algorithms greatly shape the bounding volume tree generation algorithm and its efficiency. We have employed "Fitting points with Gaussian distribution" [31] to as the basis for the algorithm for generating the bounding volumes.

The proposed system has been tested on several photos of pipes. An example can be seen in Figure 1.

Figure 1. Examples of pipes

The left photos show a pipe that has been torn in the left side. This rift can be easily noticed by human eyes; however, computers need a clear-cut denotation and the triangular split can facilitate this. The second photo is a triangulated drawing of the pipe that can be better handled by a computer.

The technique also has a limitation when false positive circumstances occur. The pipe in right side is actually unflawed; however, some sorts of liquids have been leaked on this pipe and because their color is very different, the stains are very noticeable and the algorithm considers this pipe as a torn pipe.

Because of these false positive occurrences, any alert of the system should be checked by a human so as to observe whether the alert is genuine or just a false positive warning.

In the rightest photo, a triangulated drawing of the pipe can be seen. Many triangles' colors have been changed because of the stains. These color changes can be misinterpreted by the system as a torn pipe whereas this pipe is just very uncleanly.

3 Conclusions

Continuous checkup is an ordinary task of computers along with real time decision making. Autonomous vehicle is no exception and continuous checkup along with real time decision making is certainly done by a computer [32,33,34].

This paper presents a technique to handle the inspection of damaged tires by an automatic system. This system is very important for autonomous vehicles where the passengers are not so aware to the vehicle reverberations and also typically often changed.

The proposed system is designed to detect the damage before it becomes tangible and the vehicle cannot go on. An earlier alert can avoid unpleasant circumstances like vehicle that is abruptly unable to move.

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