PREDICTIVE VEHICLE TRACKING & ON-DEMAND PATH RECONSTRUCTION

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Abstract

Vehicle detection & tracking has always been a very crucial problem. Much research has been done on this very problem in the field of Computer Vision with real time data collection of the visual images or snapshots & videos. This approach is certainly computationally much intensive & requires high bandwidth usage for the visual data collection. Techniques using sensor networks as sited in [1] have been deployed, but usually with a perspective of entity detection & tracking in warlike areas where classification of the entity was much of a concern as civilian, soldier or military vehicles. Moreover most of these techniques as used in [1] & [2] makes use of magnetic sensors or the magnetometers for detection purpose which are much costlier. In this work, we focus on the development of a prototype which is comparatively better in terms of cost, bandwidth consumption, computational effort and is more suitable for both warlike & civilian purposes.

CONTENTS

Problem Definition

We focus on two major aspects of the problem which are novel to the Vehicle Detection problem:

- *Predictive Vehicle Tracking*: This refers to the location estimation of the vehicle at a certain point in time & space, using the knowledge of its speed & direction of motion. For a simple topology we can consider a grid arrangement of traffic intersections through which the vehicles are moving. We place the RFID readers at the intersections only, such that they are able to extract out the vehicle id & correspondingly the direction of motion of the vehicle is also registered. So whenever a vehicle passes by the intersection, the RFID readers register an event & information about the vehicle's direction of motion. They also piggyback the time at which they sense the vehicle so that the speed can be calculated at the central tracker using these.

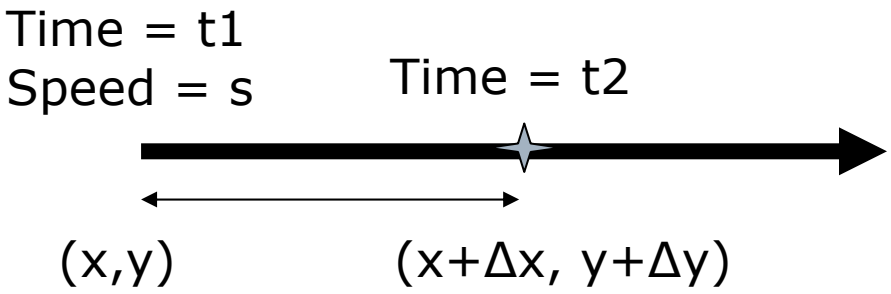

Fig.1 Predictive Tracking of a Vehicle

So when we have to estimate the location of an vehicle then we can use this speed & the previous junction's location to calculate the location at this global time. Hence we need to time synchronize all the components to achieve a notion of global time.

- *On-Demand Path Reconstruction:* We introduce a new notion of vehicle trail which is defined as the sequence of the junctions which it has crossed at or before a particular moment of time. So there can be two types of queries which are usually both either in a case of some anomaly eg. a vehicle does not reach the next junction in a certain amount of time which is a function of the speed of the vehicle, the distance between the two junctions & certain other parameters like congestion or traffic density over the link.
  So if we consider:

L_{ij} = Distance between the junctions i & j
v_i = Speed of the vehicle at the i^{th} junction
ρ_{ij} = Traffic Density between the two junctions i & j

then we can calculate

D_{ij} = Estimated Delay to reach the junction j from I which is f(L_{ij} , v_i , ρ_{ij})
T = Time duration from departure at i till now

If we encounter a situation with $T > D_{ij}$ then we can declare an anomaly, & correspondingly reconstruct the trail of the vehicle & report the same for action.

Similarly if there is a forced query about the trail reconstruction of the vehicle then we can follow the path reconstruction procedure.

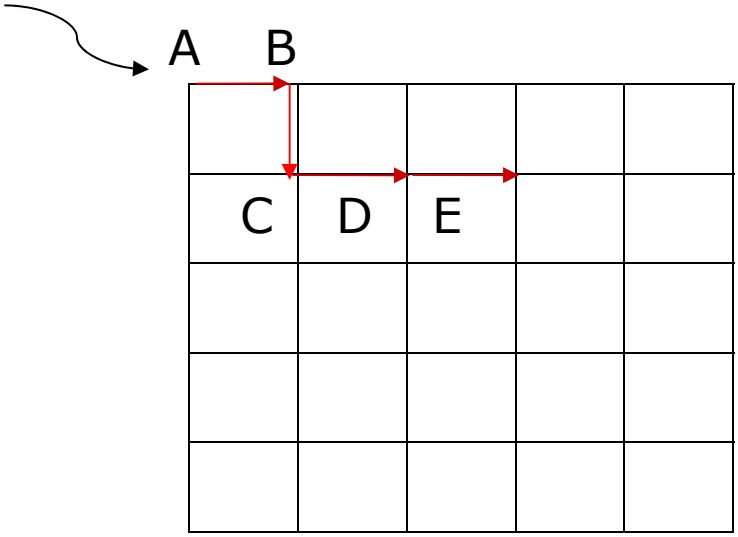

Fig.2 On-Demand Path Reconstruction: A Vehicle Trail

Background Study

The major motivation for this work has been the projects ongoing in the field of Computer Vision trying to solve the problem, but which prove to be much more expensive in terms of computational effort with bulky algorithms working and giving an offline diagnosis of the traffic scene. As the approach envisaged by us is more network-oriented & probably less computational intensive, we try to solve two major aspects of the problem.

In the literature the work which inspired us the most was by the Prof. Anish Arora et al in their project *A Line in the Sand* where they approach the problem using magnetic sensors

but also restricting their focus more on the issue of influence field or the methods to detect the classify the object in motion as a person, soldier or an enemy vehicle.

Another work in this area was [2], which also uses the idea of magnetic sensors done at University of Berkley. But they also focused their work more or less on the vehicle classification problem into various categories. They also measured the parameters like inter-vehicle spacing, speed & direction of motion to calculate the traffic densities. Their results are based on two experiments conducted, one at Hearst Avenue in Berkley but the second experiment was only preliminary.

Work on location estimation using spread-based heuristics for sensor selection in tracking moving objects, done in our department, also let us focus on this problem to track objects in motion. A lot of literature available on the web helped us to refine the problem to a much more extent.

APPROACH TO BE EMPLOYED AND HARDWARE REQUIREMENTS

1. Predictive Tracking

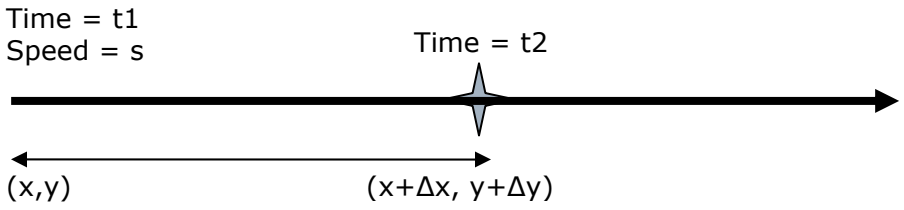

Figure 1: Location Estimation with Predictive Tracking

To estimate the location of the vehicle in a grid of 'streets' and 'avenues', we register checkpoints for the vehicle at various crossings. Suppose the vehicle registers a checkpoint at the crossing *(x,y)* and time t_1 and we have an estimate of its speed at this crossing, as well as the direction. Then we can easily predict the location of the vehicle at time t_2 ($> t_1$). E.g., in figure 1, since the vehicle is traveling in +X direction with speed *s*, thus, at time t_2, the location of the vehicle is $(x+\Delta x, y+\Delta y)$, where

$\Delta x = s * (t_2 - t_1)$

$\Delta y = 0$

Of course, the important issues to address here are how to obtain the speed and direction at any crossing. We'd handle these two issues using a RFID sensors at the crossings:

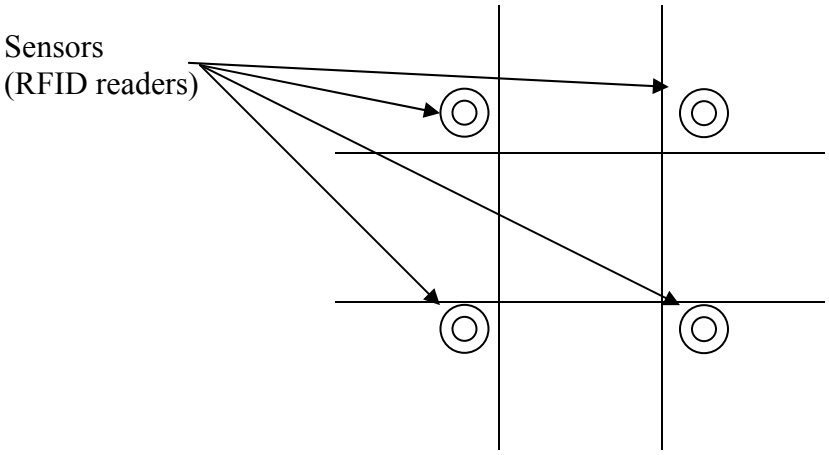

Figure 2: RFID readers at the sensors to detect the direction of motion of the vehicle while leaving the crossing

The arrangement of the sensors at the crossing as had been suggested in figure 2 can help us in determining from which of the four roads, which meet at the crossing, the vehicle is leaving. To estimate speed of the vehicle at the crossing, we use the knowledge of the last checkpoint of the vehicle, which gives us the time when that last checkpoint was registered as well as the location of the last checkpoint (the last crossing the vehicle went through). This knowledge can be used to estimate the current speed of the vehicle.

But this kind of speed estimation poses a problem. It creates, what we call, the *dark regions*. The dark regions are the regions in the grid where the location of the vehicle cannot be predicted. Basically, these regions are created when the vehicle has just entered the grid. At that point we do not have an estimate of the speed of the vehicle so we cannot predict the location of the vehicle, "until" the next checkpoint is registered, when we find our first estimate of the speed of the vehicle.

2. *On Demand Path Reconstruction*

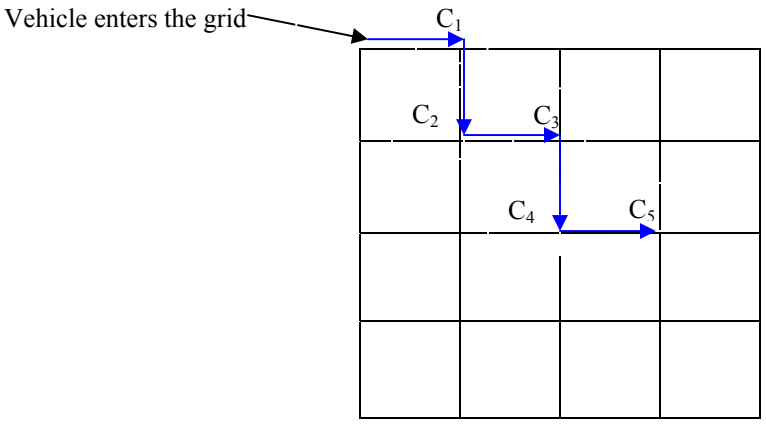

Figure 3: ODPR Example

On Demand Path Reconstruction (ODPR) involves reconstruction of the path followed by the vehicle after having entered the grid. This is done using the data stored at the Central Tracker (CT) as checkpoints registered by the vehicle at the crossings. In the example demonstrated in figure 3, C1, C2, C3, etc., are the checkpoints which were registered by the vehicle at the sensors at each of these crossings and were collated at the CT.

Hardware Requirements

The most important hardware requirements in this project are RFID tags and readers which can interact within distances up to 2-3 meters and at speeds of 60-70 mph. These challenges can however be met since such powerful RFID equipment is now available in the market [6].

CURRENT STATUS

- ✓ Currently we have studied some of the target detection and tracking implementations. Some such implementations [1] have also provided with a vehicle classification system, but we can provide narrower classification with RFID technology.
- ✓ We have defined the problem that we'll be dealing with in our project and the scheme has also been developed at an abstract level.
- ✓ The hardware that will be required has also been identified.
- ✓ Initial literature survey is complete.

WORK PLAN

Following are the tasks that we will be taking up (post midterm)

- Procurement of RFID tags and readers
- Once these tags and readers are acquired, the next step is to get acquainted with these RFID sensors and identification of implementation issues
- After the testing, the next stage will be to develop a prototype for the initial demonstration of the project
- For the final demonstration, we intend to improve our strategies and try to minimize on our assumptions.

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