Contribution Title*

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Abstract. The abstract should briefly summarize the contents of the paper in 150–250 words.

Keywords: First keyword · Second keyword · Another keyword.

1 Roadmap Planning with Pigouvian Pricing

Roadmap planning involves an approximation of the workspace by a set of states which are outside every obstacle. These states form the nodes of the roadmap graph. The links of the graph encode whether a single feasible manoeuvre can be found between a pair of states. The roadmap representation enables resolution optimal paths to be found through complex environments using the A* algorithm. By weighting the links according to their length, A* will return the shortest sequence of links. Each link may be associated with a complex path shape which is feasible given the differential constraints arising from the vehicle kinematics.

Pigouvian pricing is a concept from road transport economics which sets the price for a road section according to the social costs arising from an additional vehicle using that section [5]. Drivers may be assumed to be rational agents who choose a route minimising the total cost of their trip, comprising the cost of their own travel time (converted into monetary units with a certain value of time £ per minute), plus the monetary cost resulting from the tolls on all the road sections they used. If the road pricing is Pigouvian the cost of a link will be set to the sum of all the delays experienced by every other road user. If the prices are set with perfect information, selfish drivers will independently choose routes to reach a "user equilibrium" which minimizes the total travel time [6].

The assumption of rational agents should be valid for Automated Guided Vehicles selecting a route using the A* algorithm, with the links weighted according to the centrally designed road price. Recent work has made clear that intersections are the bottleneck on road system capacity in many cases [3]. For

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this reason it has been proposed to set a price for traversing an intersection, rather than for a link. This leads to a simple method for calculating the Pigouvian price for an intersection at any future time for which a traffic forecast is available. The social cost of one user crossing the intersection is given by the time they take to cross it, multiplied by the anticipated number of arrivals in the cross lane in this time.

2 Distributed Task Assignment with Contract Tendering

Task assignment is the problem of selecting which job (sometimes consisting of a pick location, a drop location and some constraints e.g. completion time, item size) to perform first, and which AMR from the fleet should perform it. This can be completed using an auction mechanism described by [1]. The task list is stored on a central server, which broadcasts a job contract specifying the particulars of each one in turn to every AMR in the fleet. When an AMR receives the job spec, it computes a trajectory plan to get from its current position to the pick location, and then to the drop location, without talking account of any other vehicles. The expected time of completion of this plan is submitted to the auctioneer as a bid. The auctioneer needs only to wait a fixed time to collect the bids, and then select the lowest and send a job award message to that AMR.

The results of this system are improved if the AMR always produce a bid for every job contract, even if they are currently busy [4]. As long as they add the expected time for completion of their current in progress task to the bid they send to the auctioneer, tasks will be allocated efficiently.

The combination of auction based assignment and conflict-free routing is investigated in [2].

3 Method

One possible publish/subscribe message interface is shown in Figure 1.

The Pigouvian price for an intersection is approxiated by Equation 1. The social cost of one user crossing the intersection is given by the time they take to cross it T, multiplied by anticipated length of the queue in the cross lane q plus the number of arrivals in the cross lane at this time n multiplied by their average waiting time τ.

$$p_i = qT + n\tau \tag{1}$$

The price is broadcast in the Link Price Labels message to which all AMR subscribe.

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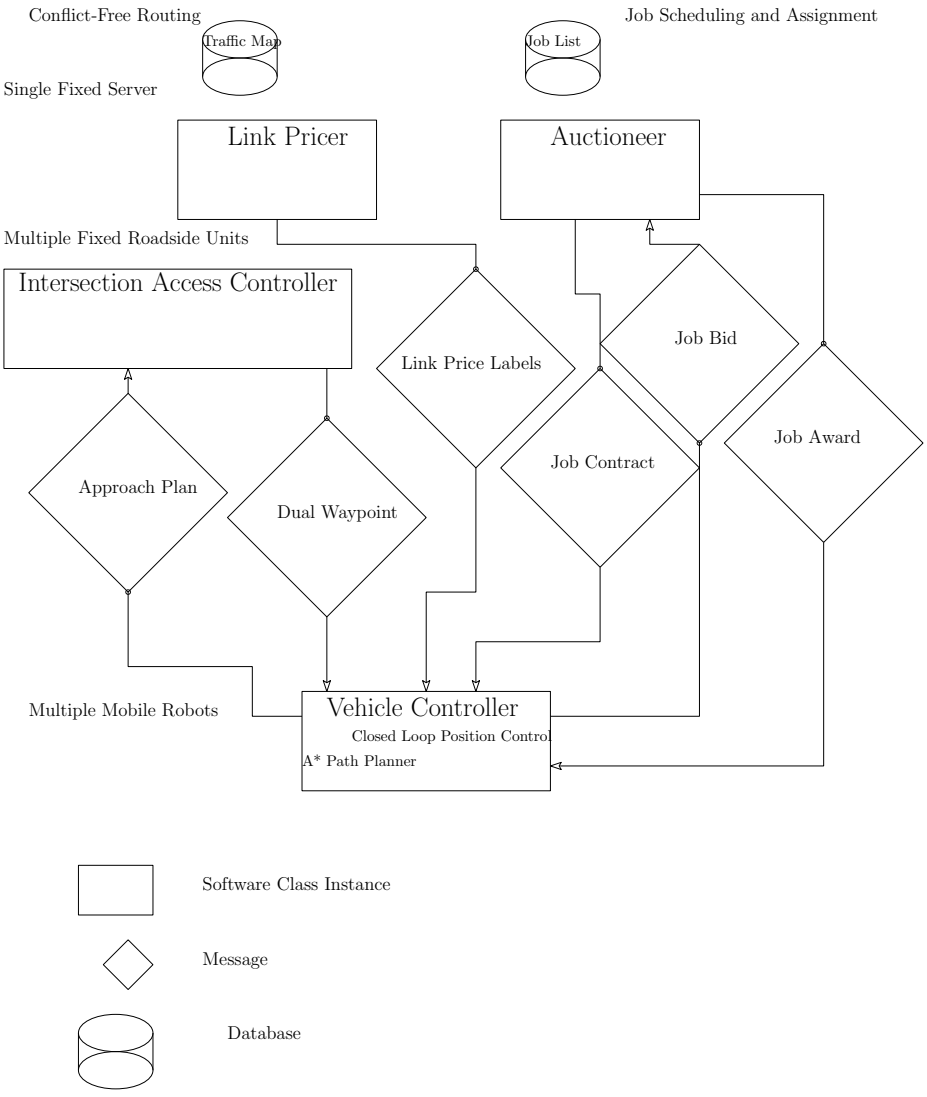

Fig. 1. Objects and messages for proposed decenralized control scheme.

plan (according to the latest link price labels) is submitted to the auctioneer as a bid. The auctioneer needs only to wait a fixed time to collect the bids, and then select the lowest and send a job award message to that AMR.

The interface shown assumes all conflicts can be resolved locally using an independent intersection manager for each intersection. The intersection controller is responsible for speed selection on all approach lanes to an extended conflict zone where multiple path cross or come closer than a safe distance. Each AMR must submit an approach plan indicating the exact path it will take through the intersection. The intersection controller solves a local optimization to find the highest set of speeds which will ensure safe separation between each AMR in the conflict zone.

4 Simulation Results

5 Concluding Remarks and Further Work

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