Poster: Smart Networked Bicycles with Platoon Cooperation

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***Abstract*—Urban roads are venues of social interaction where many actors try to accomplish their transportation-related individual goals. It has been demonstrated that when individuals act with scarce contextual information they offer resistance to one another's programs of action hindering coordination. In this work we address the problem of smart networked bicycles assisting cyclist coordination. Coordination is based on vehicular communications together with a cooperative adaptive cruise control. We propose to combine effective dissemination mechanisms in mesh-networks, a platoon cooperation logic, and a novel cyclist-bicycle interface to adapt the behaviour of cyclists while driving. Initial simulations and experimental results demonstrate that our cooperation mechanism helps cyclists achieve individual and collective goals, such as moving fluidly at the best possible speed while maintaining a safe distance to other cyclists.**

I. Introduction

Transportation systems are contexts in which humans are required to have social interaction under specific traffic rules and regulations. When actors involved in such a system collectively try to accomplish their goals with scarce contextual information, they perform uneven flows of action that jeopardize the system's coordination and reciprocity. As a result, they mutually resist to each other's actions exhibiting social viscosity [1] and often overriding the systems rules.

In this work, we apply the findings of previous behavioral studies [1] in the design of smart bicycles for a group of cyclists that cooperate with each other. In our proposed scheme, cyclists riding smart bicycles are connected in a mesh-network that involves sensors, actuators, vehicle-to-vehicle (V2V) communications, and an interface for human-machine interaction (HMI) between cyclists and bicycles. Our model can be instantiated as a group of professional cyclists that need to coordinate platoon arrangements or extended further to a group of urban tourists driving two-wheeled scooters centrally coordinated by a docent.

We propose to mediate the actions of cyclists through a Cooperative Adaptive Cruise Control (CACC) [2]. Different from CACC employed with a platoon of vehicles, in our scheme it is not possible to automatize the bicycle's reaction to an instruction indicated by the CACC mechanism. Hence, a special HMI is designed to communicate the program of action (i.e., acceleration, deceleration, and recommended speed) to each cyclist. The success of our proposed scheme depends on: *i)* the effectiveness of the exchange of information in the mesh-network formed by bicycles; *ii)* the effectiveness of the HMI mechanism to generate the proper reaction from cyclists at the moment they adapt their individual programs of action; and *iii*) the reduction of social viscosity in the whole system of cyclists.

II. Proposed Platoon Cooperation

The system model is illustrated in Fig. 1. We consider a group of cyclists traveling together. The individual goals within the group can be defined in different ways, depending on what is important for each cyclist, e.g., to arrive at the point of destination in the shortest time, to flow fluidly through bottlenecks, to avoid congested paths, to travel in the most secure way, etc. In our system model, we are considering the combination of two goals: to travel according to an objective velocity (i.e., the necessary speed to arrive at the point of destination in a given time), and to maintain a specific distance with respect to the bicycle in front.

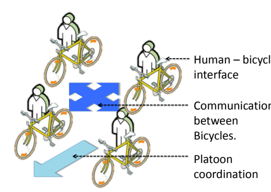

Fig. 1. Model for Coordinated Smart Bicycles

We employ a Cooperative Adaptive Cruise Control (CACC) [3] to define the programs of action of each bicycle. In the CACC, every node requires motion information from the node in front and from the leader of the group. As a result, the CACC calculates the positive or negative acceleration that needs to be applied for the cyclist. The CACC guarantees a minimum spacing error, which is estimated from the information recieved from other bicycles including the group leader.

Since V2V communications may be implemented with short-range technologies, such as ZigBee, the scheme does not only relies in pure broadcasting, but also employs an intelligent dissemination. The dissemination is of the beaconing type, so the beacons are also useful for appending information received from other nodes. In our case, only the beacons sent by the leading bicycle need to be disseminated to the rest of the group. Furthermore, by employing a low-power technology, the bicycles can communicate with no additional sources of power other than small batteries. Upon reception of information, each smart bicycle recalculates its acceleration and adjusts the program of action to be adopted by its cyclist. Then, the bicycle codifies the adjusted acceleration and deceleration information as tactile stimuli transmitted to the cyclists, who could consequently adjust their speed and relative position in the platoon.

Cyclists' auditory and visual perception channels are highly demanded while riding. Hence, the most suitable modality for signaling additional contextual information is via the tactile channel. Following exploratory projects of haptic interfaces for

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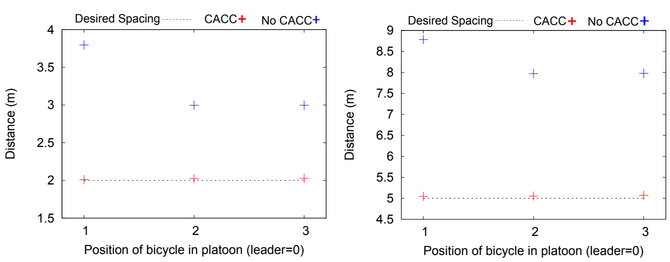
the assistance of cyclists' navigation [4] [5] we propose a novel speed signaling interface based on streams of high frequency scratches that lightly stimulate the cyclists' right hand palm. An eccentric 12 mm wheel with twelve blunt spikes spinning at 280 rpm generates the stimuli. The wheel spinning forwards signals positive acceleration and backwards negative acceleration. The signal ceases once the cyclist achieves the intended speed target. Each cyclist receives independent instructions that better fit the effective achievement of collective goals.

III. Preliminary Results

We have implemented a simulation of the system model and platoon cooperation in OMNeT++. Nodes with IEEE802.15.4 interfaces and the CACC logic are employed to represent a group of 4 smart networked bicycles. Two scenarios are implemented: with and without CACC. In the CACC scenario, the leading bicycle's speed varies randomly in a range around the objective velocity. This variation forces the followers to constantly recalculate their acceleration to maintain both the safe distance and the best allowed speed. In the no-CACC scenario, all bicycles' speeds vary randomly around the objective velocity. Although nodes know what is the intended desired spacing, the no-CACC scenario does not have the means for the nodes to coordinate, so they try to reach their goals independently.

Simulation results show that, for both scenarios, the traveling times are very close to the individual objectives. However, when we observe two example scenarios in Fig. 2a and Fig. 2b, it is clear that bicycles with no CACC have much larger spacing errors. That means bicycles do not always maintain the desired spacing between bicycles, which may decrease safety during travel or may result in bottlenecks due to uncoordinated advances within the group.



(a) Desired spacing 2m (b) Desired spacing 5m

Fig. 2. Distance to bicycle in front

We have also validated that the group coordination remains stable despite of large variations in the leading bicycle's speed. In Fig. 3 we observe the behavior of the actual average spacing with respect to the desired spacing. The results show the spacing remains very close to the expected, even under sharp speed changes of the leader. According to the aforementioned results, the CACC demonstrates that it may help the achievement of collective goals and reduce the social viscosity as expected.

In addition to simulations, a working prototype of the HMI has been tested informally with two male subjects in a controlled environment. The prototype is illustrated in Fig. 4. Both subjects were instructed to independently ride the smart bicycle on a paved circuit and speed-up or slowdown as they perceive twenty randomly signaled stimuli. No specific speed target was required. The remotely monitored results

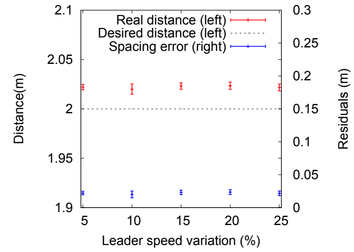


Fig. 3. Actual spacing vs. Desired spacing

showed 2% error occurrence and a response time of M=2,2 seconds, SD=1,2. These promising results will be confirmed in further experiments designed to evaluate individual behavior and group coordination. Our test also showed the need of complementary visual cues to discard false-positive perceptions caused by road roughness.

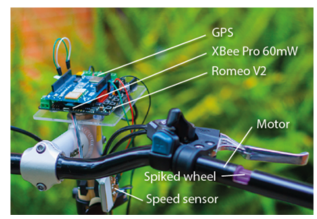


Fig. 4. Detailed prototype configuration of communication elements, motor controller, sensors, and actuators

IV. Conclusion

In this work we have proposed a platoon cooperation for cyclist riding smart networked bicycles. We have employed V2V communications for collecting information, so that each smart bicycle affects the cyclist behavior with the purpose of achieving collective and individual goals (e.g., to maintain a desired spacing and to achieve a desired travel time). Through simulations we have found that the cooperative adaptive cruise control may help in two forms: to facilitate the achievement of collective goals and to reduce the social viscosity resultant of resistive forces elicited by selfish individuals pursuing independent goals. Furthermore, early experiments have been carried out to test cyclists response to speed control information transmitted via a tactile-based human-machine interface (HMI). Results have shown that cyclists riding smart bicycles respond quickly and accurately to haptic signals. In the future work we will carry out additional simulations with intelligent flooding and will make further comparisons with the real testbed that integrates the platoon logic and the HMI.

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