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Challenges on the Way Towards Explainable Behavior of Adaptive Cooperative Mobile Systems

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We live in the age of mobile computer-controlled systems. Car and truck manufacturers are working on autonomous vehicles, removing a central human element from the control loop that governs road traffic and allowing a computer to directly process and act upon sensor data. Such computer-controlled cars and trucks will form the fabric of ground transportation in future smart cities. Similarly, in the air, modern multirotor helicopter systems are moving from employing computers for no more than simple flight stability calculations to fully autonomous flight modes, targeting both goods delivery and passenger transport.

The true evolutionary leap of such systems, however, will come not when the human operator is simply replaced by a computer (though this in itself will be a remarkable feat). Rather, it will come at the point where such computer-controlled mobile systems move from targeting autonomy to embracing cooperation, forming *Cooperative Mobile Systems*.

Cooperation of such mobile systems can take all forms from simple sharing of sensor data, to communicating intent, to cooperative planning, to sharing experiences, and to cooperative learning. Many of the challenges of cooperative mobile systems are rooted in classical disciplines of vehicular networks, from challenges in *wireless networking, to system design, and to the simulation of such systems*: Cooperative mobile systems resemble a wireless network of extreme topology dynamics and scale, using heterogeneous communication technologies.

If we look at applications like platooning (vehicles following at tight distances, closely coordinating their control input for longitudinal movement) or intersection control (vehicles coordinating for collision avoidance in a shared space without sacrificing on throughput), however, it becomes obvious that new challenges are emerging.

First, we are now looking at a field of research where control theory meets wireless networking. Here, issues range from modeling uncertainty in control inputs to distinguishing simple wireless outages from misbehaving participants of the network, and from outside attacks.

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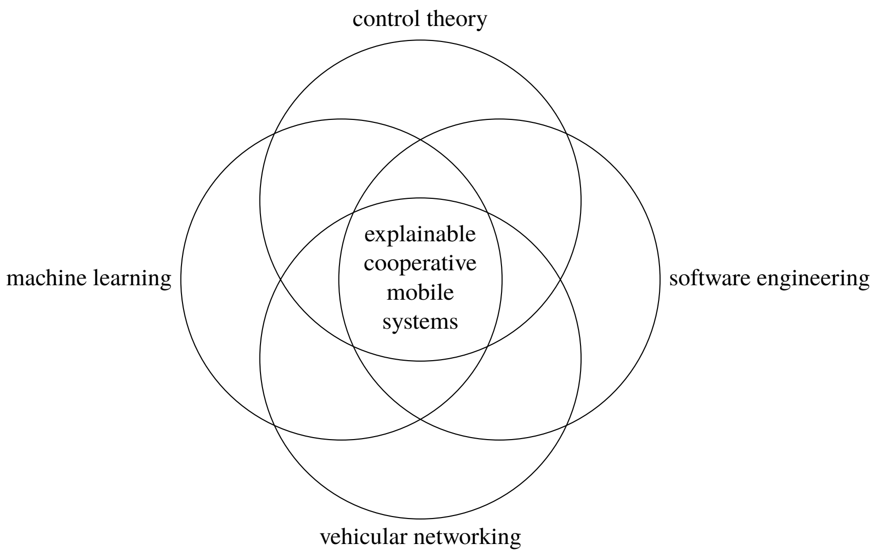

Fig. 1: Explainable Cooperative Mobile Systems as an intersection of the fields of vehicular networking, control theory, machine learning, and software engineering.

Second, autonomous control of vehicles is often tightly interwoven with machine learning approaches (both offline and online, to support self-adaptive behavior) thus adding another dimension to an already complex field.

Finally, and taking both challenges together, because of the huge complexity of such systems, issues of *explainability* will play a central role in their design and operation. Was a sudden brake maneuver triggered by a network outage? Was it the result of trust in the network participants having been eroded by unexpected behavior of one of the nodes? Was it the result of the driving situation being recognized as a potential hazard by a collaborative learning process? (Not) having a good answer to questions like this can easily be imagined to make-or-break real-world deployment of cooperative driving – from the perspectives of all of potential users, of regulatory bodies, and of law enforcement.

Tackling these challenges requires the pooling of resources from experts in all of the concerned fields (graphically illustrated in Fig. 1): from wireless networking, simulation, control theory, machine learning, and software engineering.