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Big Data-Based Robust Transportation Systems for Disaster Management

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Large-scale transportation systems (e.g., road networks) may suffer significant disruptions routinely (e.g., during severe rush hour traffic) or occasionally (e.g., during a natural disaster such as earthquakes). This problem has been addressed by traditional intelligent transportation systems (ITS) and new traffic information tools using large scale sensor networks, e.g., Google Maps with Traffic and Inrix [<inrix.com>]. These new traffic information tools are clearly CPS-related, since they used sensor information (physical) and aggregate big data from many sources (cyber).

There is a major difference between these new traffic information tools and typical CPS projects funded by NSF: the sources of traffic information are smartphones, not specialized sensors built for each project. One could imagine a CPS panel rejecting a proposal for building such "generic-sensor" systems as "*not relevant to* CPS program" (according to the current definition of prevailing CPS panels). We argue that the current definition of narrow scope of CPS program may need broadening. In fact, there are good reasons the CPS program should consider embracing systems and projects that use generic sensors such as smartphones and social networks.

The first reason for including these generic sensors is intellectual challenges arising from the integration of many sensors. Using the common "big data 4V framework" (volume, velocity, variety, veracity), the integration of many generic sensors becomes a significant challenge when the variety of sensors increases and the veracity of sensor data decreases. In emergency situations, data from many kinds of sensors may become useful (e.g., Twitter tweets, Instagam photos, YouTube videos), beyond the movement data from smartphone location sensors. There are significant noise problems with these social sensors, which are examples of intellectual challenges in the research to integrate those sensor sources.

The second reason for including these generic sensors is their potential broad impact. In these new traffic information systems, individual movement information is collected from volunteer smartphones (in an anonymous way) and integrated by an information aggregator (Google and Inrix in our examples) to provide an accurate picture of the traffic situation for each metropolitan area they track. We believe the same (or substantially similar) sensor information collection services can provide invaluable help for non-routine emergencies such as earthquakes. A salient difficulty of emergencies is the small number of active smartphones available in affected areas, a situation very different from routine traffic jams. If we are able to collect sufficient information from the active smartphones in affected areas, we could quickly assemble a map of currently passable roads after a disaster. This crowdsourcing approach, used by Google and Inrix, could provide broad, immediate, and free information on critical transportation infrastructure after a disaster.

Transportation CPS is an area in which generic sensors have already demonstrated their usefulness and impact, since many millions of users rely on Google Maps and Inrix for their daily commute. It is to the advantage of the CPS community to broaden the definition of CPS and embrace such generic sensors as legitimate components of CPS. Disaster management (DM) is an application area that has benefited from CPS technology such as robotic first responders. As outlined above, DM is an area that can benefit even more from broadly defined transportation CPS based on big data from generic sensors.

Illustrative worthwhile research challenges that arise from integration of smartphone location big data include:

- Variety: syntactic and semantic heterogeneity of various physical and social sensors,
- Veracity: high noise-to-signal ratio of many social sensors, and
- DM Application: building practical tools that can assist both first responders and citizens in need during a disaster.