WTEC ROBOTICS WORKSHOP

RESEARCH AREA SUMMARY
Space, Field, Military, Underwater, and Aerial Robotic Systems

By

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There has been substantial progress and enormous increases in funding for "outdoor" robotics, where the robot needs to operate in a relatively unstructured, natural environment. While the challenges of operating in natural environments can be much greater than in the controlled (and in many cases optimized) environments of a factory or laboratory, often in return there is a willingness to relax the constraints on overall system performance and the degree of human involvement. For example, the Mars Exploration Rovers (MERs) operate on Mars with typically one human command sequence received each day, and they are only expected to do in a day what a human might do in a few minutes. The converse is a factory robot, which must operate reliably without human input for very long periods while performing as fast or faster than a human doing the same task.

Some outdoor environments are much easier than others for a robot to survive in and operate effectively. For example, there has been an explosion in the number and funding for operational Unmanned Aerial Vehicles (UAVs) such as the Global Hawk and Predator. A major reason for this is that the interactions between the robot and the atmospheric environment are relatively easy to characterize and model, position determination is trivial based on the Global Positioning System (GPS), hazards are either easy to sense and avoid or are sufficiently improbable that they can be ignored, and high-bandwidth, low-latency communications allows human teleoperation for critical operations such as landing.

There has been significant progress in applications intermediate between MER and UAVs, such as agricultural robots or military Unmanned Ground Vehicles (UGVs) that must operate in a very complex environment while autonomously avoiding hazards without the benefit of continuous or high-bandwidth monitoring by a human operator. Real-time 3-D mapping of complex terrain around the vehicles is now possible at useful frame rates and characterization and abstraction of the hazards and safe routes for the vehicle through that terrain is relatively reliable. While some were disappointed that the best vehicles in the 2004 DARPA "Grand Challenge" autonomous vehicle race from Barstow to Las Vegas went only ~10 km, in fact experts in the field were very impressed with the tremendous progress it represented over the extremely fragile and slow systems under test only a few years ago. As Moore's law continues to increase processing speed by roughly an order of magnitude every 5 years, we can expect "human equivalent" driving performance within a decade (excepting those situations that require very astute judgment, such as a "dynamically-forced" decision between hitting a tumbleweed and a child).

In summary, it is possible to characterize outdoor robots roughly into a 3-dimensional design space: the complexity of the environment, the relative ease of high-bandwidth low-latency communications and localization aids, and the relative need to eliminate human involvement. UAVs operate in a simple environment, have relatively easy communications and localization, and have substantial utility even if continuous human oversight is required. MER operates in a more complex environment, has much more difficulty with communications and localization, has a large number of human operators, but can work very slowly and still be vastly less expensive than mission alternatives. Agricultural robots operate in an intermediate complexity environment (between UAVs and MER), have simple communications and localization, but to be affordable must not require continuous human oversight. Underwater robots also operate in an intermediate complexity environment, but usually have very poor communications bandwidth, latency, and communications aids, and consequently must operate (at least while submerged) without human guidance. Military robots in urban or heavily-vegetated terrain operate in even more complex environments than MER, often have little or no access to communications or localization aids, and hence must operate without human input. We can expect systems to be fielded in an order roughly inverse to the relative difficulty as identified with these metrics, which explains why UAVs are the first to become widely available as operational systems. But given the relatively rapid pace of Moore's law, we can expect all areas to have useful examples of fielded systems within a decade or two.