Future Technologies for Unmanned Ground Vehicles

Antony Waldock from the BAE Systems Advanced Technology Centre outlines the challenges facing the introduction of Unmanned Ground Vehicles onto the battlefield and highlights some industry solutions to the problem

In the last decade, operations in Iraq and Afghanistan have exposed Western forces to increasingly harsh operating environments characterised by the emergence of ever more severe threats from Improvised Explosive Devices. This has encouraged the deployment of remotely-controlled Unmanned Ground Vehicles (UGVs) as a way to enhance force protection by reducing the debilitating effects of exposing soldiers to the three 'Ds'; the dull, dirty and dangerous tasks. An example of how much the US uses UGVs on current operations is that they have created the Joint Robotics Repair Detachment and that it repairs an average of six bomb disposal robots every single day.

Independent of the direct pressures of current operations, technologies have matured to the point where they can allow remotely-controlled, relatively general-purpose platforms to be used for a range of applications that certainly include bomb detection and disposal, but can also extend to short-range surveillance and several aspects of combat engineering. In the UK, BAE Systems is nearing completion of a programme to develop and bring to service the Terrier Combat Engineer Tractor. Terrier includes in its range of capabilities a remote operation function and has within it an electronic architecture that is able to host higher levels of autonomy that might become available from future technology insertion packages; dependent on user doctrine and operational needs that may be developed in due course.

Extending the operation of UGVs to a wider set of applications and more complex environments typically requires an increased level of autonomy. For example, to perform remote reconnaissance operations using purely remote control would require, like current Unmanned Aerial Vehicles (UAVs), the use of expensive and congested satellite communications. To date, the shift from these remotely-operated UGVs to higher levels of autonomy has been relatively cautious, in part, due to the radical impact the technology would have on doctrine. However, UGVs capable of autonomously operating over a wide range of applications and environments potentially offer significant benefits in terms of both operational impact and cost effectiveness. The ability to develop a UGV that is capable of operating autonomously, and, more specifically, navigating, over a wide range of environments requires the maturity of a number of key technologies.

Current development work led by BAE Systems, in collaboration with a range of partners, is addressing some of these key technology areas for future UGVs. This article addresses four such key technology areas that are necessary to enable a UGV to autonomously navigate over a wide range of environments. The first section discusses sensing and modelling the environment and especially overcoming the harsh environmental conditions found on any battlefield. The second section outlines the challenges associate with estimating the location and motion of the vehicle, while the third section discusses the importance of monitoring and assessing the health of the vehicle. The final section discusses the technological challenges involved in the integration of these vehicles into current operations.

Sensing and modelling the environment

The first and most demanding capability required by any autonomous UGV is the capability to automatically sense and then model the surrounding environment with sufficient timeliness and accuracy to make informed decisions. For example, a UGV that is required to autonomously navigate over unknown terrain will require, as a minimum, a limited 'sense and avoid' capability to reliably arrive at the goal location. In the area of 'sense and avoid', many readers will be familiar with the solutions already offered within the civilian sector in a number of high-end cars. These collision-avoidance systems are typically based around short-range radar units, which are engineered to detect obstacles and alert the driver in highly structured environments, such as motorways.

As demonstrated by the Defense Advanced Research Projects Agency's grand and urban challenges, the sensing requirement for a UGV, which is expected to autonomously navigate across an unstructured environment (desert, fields or villages), is far more demanding than that of a more benign structured terrain. Although the competition did not result in a cost-effective solution, a number of sensors and algorithms were developed specifically to address the problem of autonomous navigation, rather than purely relying on those developed for the manufacturing sector. One of the key challenges that remains is the development of modelling algorithms which are capable of handling harsh environmental conditions.

Harsh conditions, such as smoke, dust, mist and rain, are encountered every day on the battlefield. A key development required in this context is not just the development of another improved sensor to overcome a specific environmental condition, but the integration and fusion of sensor data from a variety of common and diverse sources that, collectively, model the environment. The ability to fuse both common and diverse sensor data allows the generated model of the environment to have both redundancy (to sensor failure) and reliability (to varying environmental conditions). Currently, BAE Systems is involved in a partnership

UGVs must be able to operate in the most challenging of environments

The Joint Robotics Repair Detachment repairs an average of six bomb disposal robots a day

with the University of Sydney's Centre for Intelligent Mobile Systems to develop novel fusion algorithms that model harsh environments such as deserts, where conditions such as dust are likely to be the norm rather than a special case.

Estimating the vehicle location and motion

The second technology area required to enable autonomous navigation across a battlefield, is the capability to estimate the location of the vehicle both globally, in relation to the goal location, and locally, in relation to the motion of the vehicle. The capability to accurately estimate the vehicle's location can be achieved using a number of commercially available systems, but these systems are heavily reliant on the use of a global positioning system (GPS) to achieve the accuracy required for autonomous navigation. Within a military context, a positioning system with this level of reliance on weak GPS signals limits their operation to a subset of battlefield environments like, for example, outside built-up areas and locations where active GPS signal jamming is not probable.

Hence, a key challenge to enable autonomous navigation for future UGVs is to extend the availability of positioning systems by reducing their reliance on GPS. The approach taken within BAE Systems is not simply to replace GPS but to augment the current positioning systems with myriad alternative positioning sensors. For example, BAE Systems has been working closely with the University of Oxford, under the auspices of the

Like the BAE Systems Multi-Operated All Terrain Vehicle, the Terrier Engineer Vehicle can operate in both manned and unmanned configurations

Systems Engineering for Autonomous Systems (SEAS) Defence Technology Centre (DTC), to develop and evaluate how visual features in a set of camera images can be used as a positional sensor to aid the availability and accuracy of localisation information in both a global and local frame of reference. These technologies have been demonstrated in the civil sector and appear to show significant promise with the recent acquisition of Plink Art Ltd (a spin-off company from this SEAS DTC research) by Google after only six months in existence. These vision-based technologies are on the cusp of being sufficiently mature to be inserted within an unmanned vehicle to enable positioning and localisation in an intermittent GPS environment and hence extend the availability and capabilities of UGVs to built-up and potentially GPS-jammed areas.

Monitoring and assessing the health of the vehicle

The third technology area on the horizon for future UGVs relates to the necessity of an onboard health monitoring capability. The introduction of comprehensive health-monitoring systems is already underway on manned vehicles such as the Terrier as a means of continuously monitoring the performance of individual sub-systems and the vehicle as a whole.

In order to reduce the reliance on a human operator while increasing the level of autonomy of a UGV, it is necessary to understand the state of the vehicle and how failures may affect the mission. For example, an onboard operator is typically capable of interpreting minute changes that can be sensed in the vehicle's vibration, noise or its handling that infer the current state of performance or health of the vehicle.

In the context of a UGV, the system will need to be capable of autonomously monitoring the health of the various systems and inferring the likely impact on the mission in real-time. For example, increased vibration in the vertical motion typically indicates that the vehicle is traversing over rutted ground at a significant speed and hence the structure of the vehicle could be damaged if this is continued for a prolonged period, which, in turn, may place a risk on the likelihood of a successful completion of the mission in question. Currently, BAE Systems is actively using and developing algorithms to interpret the health of different, in-service, platforms in order to build a profile of usage which will be used to predict likely failures. The next step for UGVs is to evolve these capabilities to perform health impact assessments onboard the vehicle in real time. These algorithms will have to be tightly coupled with the functionality of the vehicle and hence these capabilities must be integrated into the design of the vehicles from conception. Fortunately, the models of sub-systems, generated by BAE Systems, for off-line analysis

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of manned vehicles is likely to provide a promising starting point with which to tackle this challenge.

Integration into the modern battlefield

In tandem with health monitoring, the fourth key area that will shape the development of UGVs, especially when performing autonomous navigation, is their integration into a battlefield. It is anticipated that in the foreseeable future, the battlefield is likely to contain both manned and unmanned vehicles from a range of providers alongside dismounted soldiers.

Firstly, and most importantly, when integrating UGVs into the battlefield is the safety of personnel. As with health monitoring, unmanned platforms can not rely on the situational awareness of an onboard operator who is likely to be aware of the vehicle's surroundings and to mitigate the risk of an accident or injury to personnel in close proximity. As a result, any deployed UGV requires highly developed safety systems. BAE Systems has been actively involved in the development of advanced safety cases for unmanned vehicles. In recent trials of the BAE Systems Multi-Operated All Terrain Vehicle (MO-ATV) the safety systems and case were sufficiently robust to enable an unmanned vehicle to be safely operated by Ministry of Defence (MoD) personnel in close proximity. These systems were evolved using a combination of built-in safety systems and operational procedures. The continuing challenge in this area is the translation of trials safety cases to real battlefield situations.

The next step is the integration of a UGV with existing legacy systems, both manned and unmanned, on the battlefield. The UGVs of the future will be required to interact with both humans and other UGVs to be able to complete the desired mission. Hence, a wider 'system of systems' approach is required when deploying a UGV, to prevent the addition of another vehicle degrading the performance rather than acting as a force multiplier. This challenge requires a common architecture across the fleet, which not only enables communication, but information to be transferred between assets to enable co-operation and co-ordination. A common architecture and interoperability standards are likely to require collaboration between industry and the end user. An example of such

BAE Systems Multi-Operated All Terrain Vehicle trials conducted in 2009

a consortium was formed by the United States Department of Defense called the Joint Architecture for Unmanned Systems (JAUS). JAUS was established to tackle the interoperability of unmanned systems and is currently well supported by academia, small- and medium-sized enterprises (SMEs) and global defence companies including BAE Systems.

The deployment of remotely operated vehicles has shown the potential benefits of UGVs in being able to reduce the exposure of military personnel to dull, dirty and dangerous tasks. The current focus is on experimentation with autonomous capabilities on larger-scale vehicles, which has the potential to provide improved operational impact and cost effectiveness across the land domain. To be able to meet this challenge, BAE Systems in collaboration with a range of partners, has been addressing key technology areas to enable an unmanned vehicle to navigate and operate across a wide range of harsh environments, which are typical of the modern battlefield. With the maturation of these key technology areas underway and the introduction of 'autonomy-ready' vehicles, the possibility of deploying full-scale unmanned ground vehicles within the next decade looks likely to become a reality. ■