UGV Futures – how soon, how much?

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The RIPSAW-MS1, designed to be an unmanned convoy security vehicle, demonstrates its off-road capabilities during a lanes exercise at the US Army Fort Hood Robotics Rodeo, September, 2009. The RIPSAW is equipped with six claymore mines, can carry 2.3 tonnes of payload and tow multiple military vehicles.

AFTER more than a decade of protracted COunter INsurgency (COIN) operations on the global stage, Uninhabited Ground Vehicles (UGV) are in an explosive growth phase, following much the same pattern observed in Uninhabited Aerial Vehicles (UAV) more than a decade ago. This should come as no surprise, reflecting maturation and commodification across multiple basic technologies, but also the political and economic pressures arising from protracted and manpower intensive COIN campaigns.

Robotic sensor platforms, and increasingly weapons platforms, have found a growing niche in what are commonly termed DDD, D3 or "Dull, Dirty and Dangerous" roles – a parallel pattern to that observed in the penetration of robotic systems in the industrial and other commercial sectors.

Dull tasks are those that are repetitive and frequently involve significant time expenditures with little or no combat activity: surveillance, monitoring and sentry tasks are good examples.

Dirty tasks may be dirty politically or dirty physically. In both instances the robotic system is intended to keep personnel away from environments that are psychologically and/or physically toxic. Denying an opponent the option of capturing personnel and using them as hostages is a good example, as is that of keeping personnel out of hostile climatic environments where heat, humidity, cold, sand, microorganisms or other environmental factors increase the costs of personnel deployment.

Finally, dangerous tasks are those where there is a significant risk of combat casualties. Deaths are politically expensive, deplete the gene pool of talent and deplete organisations of corporate knowledge, while providing opponents with propaganda. Maimings and chronic illnesses incur up to decades of taxpayer funded healthcare costs, and present as a significant deterrent to recruitment.

These 'D3 tasks' thus produce strong imperatives to invest in robotic systems for aerial, maritime or land warfare.

Just how far will robotic systems displace traditional manned systems in land warfare? There is no shortage of 'D3 tasks' in land warfare, especially in Explosive Ordnance Disposal (EOD), mine and Improvised Explosive Device (IED) clearance, urban warfare, surveillance and sentry tasks. The question is not easily answered due to the lack of rational thought often exhibited by players on both sides of the 'robotic weapons' debate.

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Autonomy Problem in Robotic Systems

One of the most fundamental problems encountered in all robotic systems, whether industrial or military, or air/sea/land based, is the problem of limited autonomic decision-making ability.

Autonomy is about the system's ability to make decisions for itself, rather than function simply as a tele-operated remote appendage to a physically removed human mind.

Most contemporary military robotic systems have low levels of autonomy, relying largely on remote control over radio datalinks by human operators. This is especially true in aerial vehicles, where the robotic platform tends to be largely driven by human operators in tasks other than navigation and station keeping. In the United States, even the traditional term 'Remotely Piloted Vehicle' is making a comeback, displacing the politically correct ‘Uninhabited Aerial Vehicle’, and reflecting the realities of ‘dumb’ contemporary robotic technology.

Humans, conversely, are like most biological organisms, highly autonomous. An experienced, highly motivated, well trained and disciplined warrior can in a crisis effectively reorient and ‘improvise, adapt and overcome’ to cite the cliched motto, “to turn disasters into victories.” These are the wanted consequences of autonomy in warriors. Unwanted consequences include the sorry history of cowardice under fire, desertion, mutiny and other improper conduct.

The problem of autonomy in robotic weapons systems is twofold: how much autonomy can be implemented with the technology of the present and foreseeable future, and how much autonomy is appropriate or enough for a given task?

The first problem is very complicated, and the second spans a range of technological, operational, ethical and legal areas.

The reality of all remotely operated and quasi-autonomous weapon systems is that for any given level of intelligence required to perform a task, some is provided by systems internal to the robot, and some is provided by a human mind remote to the system, via a radiofrequency or other communications link.

The more complex the task the greater the amount of information the robot must collect to perform the task, and the greater the amount of and more sophisticated the information processing that must be performed to reach a competent decision, especially in a time-critical combat situation.

In a relatively ‘dumb’ robotic system the collected information must be transmitted in real time to a human remote operator, who performs the necessary information processing to produce a competent decision. Only a robot with human-like Artificial Intelligence (AI) will be capable of operating with complete autonomy, and only if the AI can match the competencies of human operator of suitable training and experience.

This reality exposes the basic ‘intelligence versus datalink bandwidth’ tradeoff inherent in all robotic weapon systems, which is that ‘the smarter the robot, the lesser the datalink bandwidth required, the dumber the robot, the greater the datalink bandwidth required”’.

Dumb tasks may indeed be performed fully autonomously by dumb robots; the problem with many if not most combat problems is that the tasks are frequently challenging enough for most humans to cope with, let alone contemporary AI systems.

EOD robot at Combat Outpost Honaker-Miracle in eastern Afghanistan’s Kunar province, Aug. 1, 2011, used by the 25th Infantry Division’s 129th Ordnance Company, 3rd Brigade Combat Team.

The datalink bandwidth problem is an issue its own right. The ideal datalink has unlimited bandwidth, is resistant to all forms of enemy jamming, is undetectable to the enemy, and can propagate over any distance with no impairments or dropouts. Real datalinks are demonstrably well below the ideal, for reasons inherent in the physics and mathematics of digital communications.

This is especially a problem in land warfare environments in complex or urban terrain where guaranteeing digital connectivity to a force element, whether human or robotic, has been and continues to be a challenge.

Exploring the Datalink Problem

Radiofrequency datalinks typically overcome manmade and natural impairments by using more transmission power (Wattage), more bandwidth (MegaHertz) and antennas with more gain (deciBels), thus improving sensitivity and directionality. The popular notions that smart waveform modulations and data compression can solve these problems, or that exponential growth in bandwidth can make them go away is sadly little more than wishful thinking by those who have never designed radiofrequency hardware, modulations and compression and encoding schemes, and datalink protocols.

A good commonsense calibration is that mobile (cellular) telephones providing Megabits/sec, and WiFi/WiMax wireless digital networks providing tens of Megabits/sec are challenged to operate reliably in suburban environments at ranges of hundreds of metres to kilometres, under conditions which are largely ‘electronically benign’ (no jamming).

The single biggest cause of problems in mobile telephony, WiFi and WiMax are radio frequency propagation effects, specifically fading and radio signal penetration of structures. These are a byproduct of basic wave physics and material properties, and often cannot be fixed easily, if at all. The problem is further complicated by increasing spectral congestion in populated areas, where very little of the radio spectrum is not occupied by various broadcast or other services, and this will only get worse. The convenience of wireless services, and absence of labour intensive cable installation, maintenance and replacement costs, suggests this trend will continue.

How many Megabits/sec are enough for a military robotic application in complex rural or urban terrain? If the robot sensor package is to have a similar situational awareness to a human with binocular vision and hearing, then commercial High Definition 3D TV provides a good benchmark, in which making a lot of assumptions about data encoding and compression is of the order of a continuous data stream of 5 to 10 Megabits/sec.

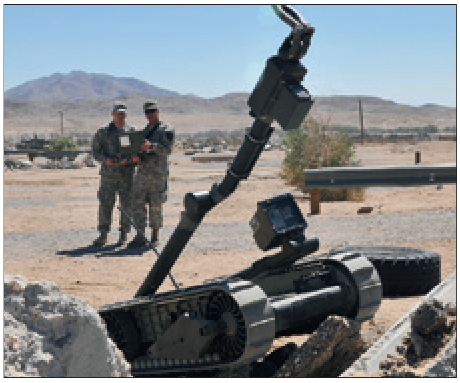
What is often overlooked is that this is the data rate from the robot to the operator, not vice versa. This is asymmetrical, and the exact opposite of commercial WiFi or WiMax, where the ‘fast”’ link is from the more powerful base station to the end user. In a robot application of this kind, the remote transmitter has the much more challenging task.

This may seem to be a reasonable problem, until we consider the realities of radio propagation in complex environments, and the realities of jamming, and hostile geolocation. Getting a signal from outside into a building with lots of metal, concrete and/or stone in its structure is not easy, and may require tenfold or greater increases in transmission power. Going from inside out, for instance if a robot is sent into a building to find hostiles, is no less painful.

Put simply, the realities of radiofrequency physics and inherent demands on bandwidth will be a major obstacle for battlefield robots, one that will be vastly more difficult to overcome where opponents are technically smart peer competitors, who have the technology and understanding to jam and geolocate digital datalinks. This problem is inherently much more challenging than the well known problems in datalinking to and from aerial RPVs.

Exploring the Artificial Intelligence Problem

Advocates of military robots are frequently besotted with the argument promoted by American futurist and author Raymond Kurzweil. Kurzweil’s hypothesis is simple, and is centred in the idea that ‘Moore’s Law’ driven exponential growth in computer hardware density and performance will continue unabated, and that once computers can



iRobot Packbot 510 during a robotics class at Fort Irwin, California, in June, 2012.

Soldiers from the US Army 95th Chemical Company set up the CUGR (Chemical, Biological, Radiological and Nuclear Unmanned Ground Reconnaissance) robot control station.

be built with a comparable number of internal switches to the number of neurons in the human brain, computing machines with human-like Artifical Intelligence will soon if not immediately follow. Kurzweil's book "The Singularity Is Near: When Humans Transcend Biology" is so popular, it has been made into a movie, to be released this year.

Kurzweil's argument is an appealing and optimistic view of the future, which has become immensely popular. In fact so popular that it appeared in a recent formal Defence Science and Technology Organisation Powerpoint briefing, presented as scientific fact.

Unfortunately, the scientific basis for Kurweil's predictions is weak, at best. Exponential growth in hardware is beginning to slow, as basic physics limits are encountered in chip fabrication. The ability to interconnect chips fast enough in compact equipment is becoming increasingly difficult, again due to basic physics. Will computer chips that rival human brains in switching complexity soon be feasible? Likely yes, but it is apt to prove irrelevant.

The principal obstacle to machine intelligence today is in software, not hardware. Software algorithms do not improve in performance exponentially over time, in fact, the 'bloatware' problem produces the opposite effect, to the extent that today Moore's Law driven hardware performance gains are usually negated by performance losses produced by ever increasing software bloat.

More importantly, AI researchers have struggled since the 1950s to unravel how human cognitive functions work, and to date there have been none of the dramatic breakthroughs in understanding required to produce a robotic mind which can reason and understand in the manner a human does. The most pessimistic in the AI research community suggest decades or centuries may be required to produce machine intelligences that can match humans.

The ongoing quest to develop 'human-like' machine intelligence has not been matched in enthusiasm by the study of whether it is even a smart or good idea to produce such self aware and autonomous machines.

Hollywood has made millions with franchises like James Cameron's 'Terminator,' and films like Asimov's "I – Robot" and Dick's "Screamers" exploring the dark side of robotic weapons and control systems running out of control and producing destructive effects.

This is a real problem, which has been of much concern to academic AI researchers. If we can construct robots with human-like reasoning ability, why should they not turn on us? A military robot designed to match human tactical deviousness, and the human need to survive in combat, could well be just as susceptible to all of the human failings, which result in the dark side of autonomous human behaviour in combat.

To date most if not all formal study of machine intelligence for robotic weapons has not crossed into this domain. If the pessimists in the AI research community are indeed right, this may not present as a practical problem in our lifetimes.

This does however underscore some deeper conceptual and practical problems that will have to be solved in robotic weapons systems.

Let us consider a robotic tank destroyer, essentially a basic AI equipped light tank with a directive to kill any enemy tanks entering its patrol area, and evade and survive attacks. Ostensibly a simple problem, assuming that Identification Friend Foe (IFF) systems work perfectly all of the time, and non-combatants do not stray into the patrol area, and command links are not jammed, and collateral damage to infrastructure and environment are not of importance. Factor in the latter, and what seems a simple 'Rules of Engagement' logic problem becomes very complicated very quickly. If human warriors are perplexed, confused and frustrated by poorly constructed RoEs, the potential for a robotic system to get into difficulty is even greater.

A good example of this problem is a case study. In October, 2001, a Sibir Airlines Tu-154 airliner with 78 onboard was hit and destroyed over the Black Sea by a 140 nautical mile range SA-5B Gammon strategic Surface to Air Missile (SAM), launched by a Ukrainian missile battery at a target drone over the Black Sea. The missile ignored the drone, autonomously acquired the airliner, flew itself past the shooting range boundary, and the rest is tragic history. The SA-5B was specifically designed without the radio command uplink used by all long range Soviet SAM pre- and postdating this design. The intent was to remove vulnerability to NATO airborne jammers. With an unsophisticated guidance radar and inexperienced shooters, it is likely they had no idea the missile seeker decided the airliner was a more attractive target than the intended but small signature drone. The airliner passed through the illuminator beam, and the missile's insect level decision logic decided to switch targets.

Highly autonomous weapons without sophisticated and robust failsafe internal decision logic are an accident waiting to happen.

Future for UGVs

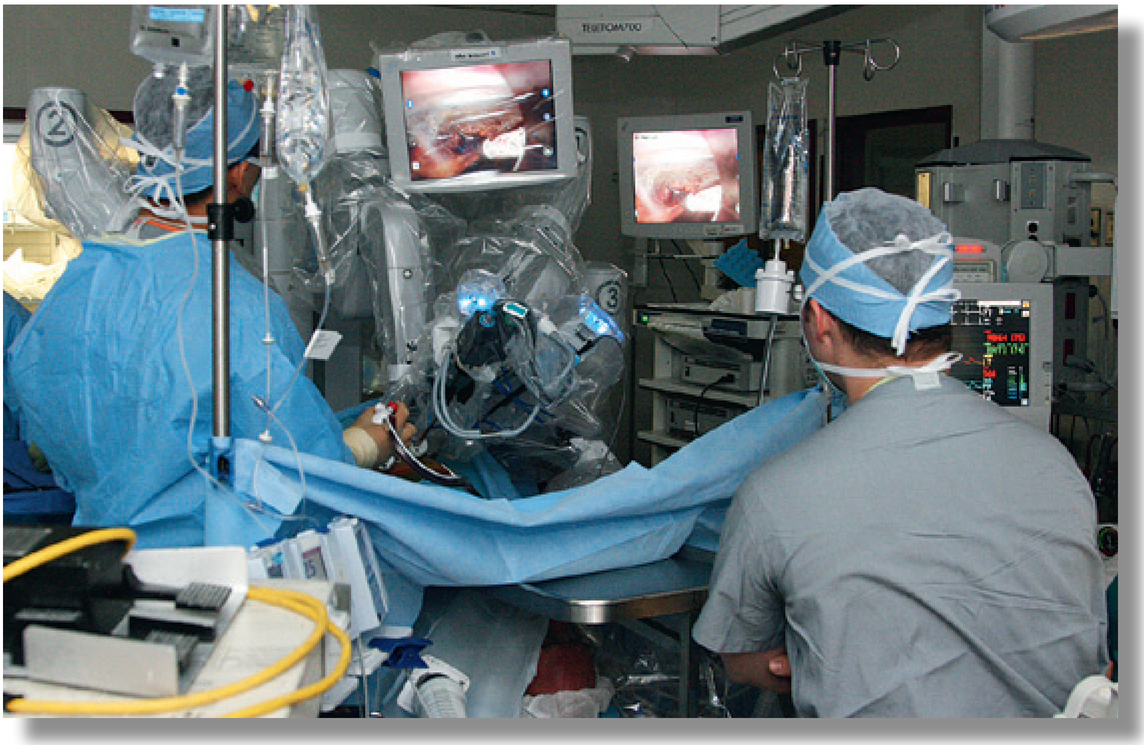
It is abundantly clear that UGVs will become of increasing importance in performing a great many classical "'Dull, Dirty and Dangerous' roles. There is little doubt that they will become valuable assets for high risk human dominated roles in areas such as EOD / mine clearance.

There are many other valuable applications; for instance robotic 'pack mules' could be used to resupply forward deployed units, and with even modest intelligence could be programmed to autonomously evade enemy patrols.

Robotic sensor platforms for sentry tasks, or hazardous reconnaissance, will be valuable due to persistence on station, but also as they will have the vantage point of a reconnaissance patrol, seeing under camouflage nets built to defeat aerial reconnaissance.

Advances in software, and battery and fuel cell technology will be the key drivers in such systems, as commodity sensors and processors are easily already good enough.

Armed remote control UGVs will also emerge, but their usefulness will depend on the sophistication of the opponent. Autonomous armed UGVs present a great many operational risks, many of which may outweigh the intended benefits - whether they ever become mainstream weapons systems remains to be seen.



Surgeons at United States Walter Reed Army Medical Center in Washington, D.C., using a robotic surgical station. Remote control of surgical robots permits specialist surgeons to treat injuries in theatre which would otherwise require the patient be flown out of theatre.