Investigating the Mobility of Unmanned Ground Vehicles

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Abstract

Unmanned Vehicles have to be as capable if not more capable than a human in the same situation, especially when used by the military to serve as an extension of the soldiers capability on the battlefield. All unmanned systems types have obstacles and encounter difficulties when trying to complete their missions, but none more so than the Unmanned Ground Vehicle (UGV). This is because UGV's have to operate in environments with a large amount of variables which includes a range of different obstacles, and terrain types; making the simple task of driving from A to B very hard. This highlights the fact that a UGV's capability is predominantly dependant on its mobility and is seen as one of the most important factors in their development, because the more capable of traversing over all types of terrain the vehicle is, then the less likely it will become stuck and need human assistance. This paper investigates current military UGV's, their mobility capabilities and the future of UGV development.

Keywords: *Unmanned, Autonomous, Mobility, UGV.*

Introduction

Unmanned vehicles are robotic systems which are either employed to carry out repetitive, laborious tasks that humans are unwilling to, or deployed to replace humans in dangerous situations or unreachable areas. These situations can occur in any environment such as on the ground, in the air, under the sea and even out in space. Each environment has a range of conditions and obstacles which make it difficult for the unmanned vehicle to operate in; for example wind speed is a key issue for the Unmanned Aerial Vehicle (UAV), just as keeping electronic components from getting wet is for the Unmanned Underwater Vehicle (UUV); however the Unmanned Ground Vehicle (UGV), whether autonomous or tele-operated, has the hardest job in terms of navigating in its environment. This is because ground conditions include a number of different obstacles, both positive and negative, over a range of different terrain types and UGV's generally have to operate in unknown, unstructured environments which include a large number of unpredictable and dynamic variables, making the seemingly simple task of traversing very hard; and this was demonstrated at the first DARPA Grand Challenge in 2004 where all the unmanned systems failed to complete the course due to not being able to sense and adapt to the environment or any situational changes [1].

The Defence and Security Industry is the largest operator of unmanned vehicles and they also invest the largest funding towards their research and development, in order to make them more capable. This can be seen in the U.S. Army's Future Combat Systems (FCS) program which has cost over US$230bn since it was launched in 2003. The FCS program has recently been disbanded and separated into various smaller projects which includes a number of advanced unmanned systems [2]. The large budgets available in this industry has meant that unmanned vehicles technology has advanced a great deal, especially over the last decade and is now at the forefront of military capabilities.

Unmanned Ground Vehicles (UGV's)

UGV's are used for many applications such as security, exploration, transportation, reconnaissance and rescue; and come in many different configurations, which are usually defined by the task at hand and the environment they must operate in. Again they are used by many different industries, however the military use them to serve as an extension of the soldiers capability on the battlefield and they are used to carry out some of the most critical missions because the warzone is one of the most hostile environments on the planet and if a robot can replace a soldier and gets damaged or destroyed then it is a far smaller price to pay than to risk a human life as seen in Figure 1 below.

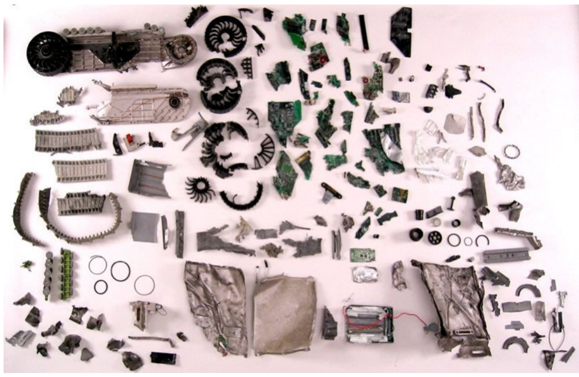

Figure 1. Destroyed Military UGV.

iCasulties.org [3] reports that from 2003-2009, the Iraq war has seen 4,356 coalition fatalities, with over 40% of them (1,812) caused by Improvised Explosive Devices (IED's); making IED's the biggest killer in the Iraq war; this is why bomb disposal or Explosive Ordnance Disposal (EOD) is one of the biggest areas where UGV's are used.

Remotec Wheelbarrow Revolution

Remotec's Wheelbarrow Revolution (see Figure 2) is one of the most successful UGV's used for EOD. The Wheelbarrow was first developed (from a lawnmower and a wheelbarrow, hence the name) by Lieutenant-Colonel Peter Miller to help British Army bomb disposal teams during the 1970's while operating in Northern Island to neutralise the Irish Republican Army (IRA) [4].

Figure 2. Remotec Wheelbarrow Revolution.

Since then many versions have been introduced of the remotely controlled tracked vehicle. The current model, named Revolution, is the most capable in the range and is being put into service worldwide by many police and military organisations to fight terrorism.

iRobot Packbot

Alongside EOD robots are another breed of rugged, highly capable UGV's used mainly in warzones by the U.S. Army who need to be able to look and operate in unsafe or unreachable areas such as caves in Afghanistan or cluttered urban cities in Iraq. The most famous of these is the man-portable Packbot developed by iRobot (see Figure 3), which has become the most successful UGV used by today's military with more than 2,500 systems currently in service in Iraq and Afghanistan. Many orders have been placed worldwide for this highly capable system and iRobot have many large contracts, the most recent being a US$6.1 million contract to supply spare parts to the U.S. Army [5].

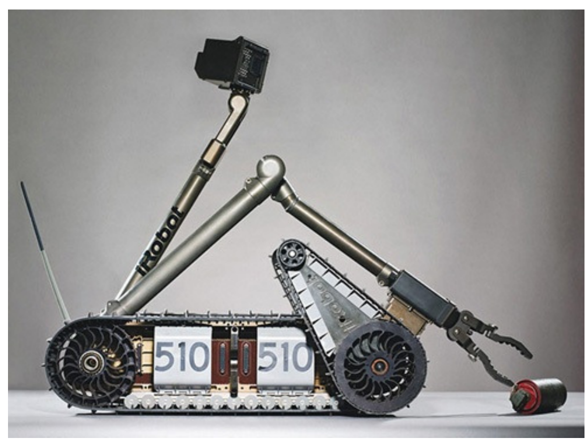

Figure 3. iRobot Packbot.

Foster-Miller TALON

Another system used by the U.S. Army is the TALON developed by Foster-Miller, a subsidiary of QinetiQ. This vehicle is larger than the Packbot, predominantly because it is used for heavier mission payloads such as the very controversial SWORDS payload as seen in Figure 4; making the TALON the first combat capable UGV with full weapon capability. Payload options include M16, M240 and M249 machine guns; a Barrett 50-calibre rifle; a 40mm grenade launcher, and a M202 anti-tank rocket system [6]. These systems are currently being deployed in warzones to carry out tasks such as guarding and patrolling front line buildings from attack.

Figure 4. Foster-Miller Talon.

Summary

The UGV's discussed here show how unmanned systems are used to replace humans in dangerous situations, ultimately saving lives on the battlefield. The deployment of these systems (as well as others) has been highly publicised during the conflicts in Iraq and Afghanistan, however remotely controlled vehicles have been used to carry out military operations as early as the First World War.

UGV operators and vendors have realised that these systems are rapidly becoming dated and starting to reach their limitations, because they are required to carry out more than the tasks they were originally designed for. With this in mind and the technology available today, UGV's need to be developed to be more capable.

Next Generation UGV's

The UGV's discussed in the previous section have successfully met their requirements for a long time and are still quite capable, however the tasks that UGV's are required for have changed along with the environments they need to operate in; meaning that there is a need for a new generation of vehicles. UGV vendors know this and have all developed systems ready for service, which will offer operators more capabilities than are available on their other systems.

Remotec Cutlass

The first example of the new generation of UGV's is Remotec's Cutlass (see Figure 5), which offers greater speed and accuracy compared to its counterpart. On this vehicle they have opted for a six-wheeled chassis instead of tracks which offers greater speed, mobility and efficiency. The system also includes an intelligent manipulator arm which has 9 degrees of freedom and includes a tool rack so that the operator can remotely select from a range of end effectors, offering greater payload options in the field. Remotec have won a £65 million contract to supply 80 Cutlass units by 2010 to the U.K. Ministry of Defence (MoD), who will use them for anti-terrorism operations worldwide [7].

Figure 5. Remotec Cutlass.

iRobot Warrior

iRobot have also developed a new UGV named Warrior (see Figure 6). Much larger than the Packbot, it offers greater payload capabilities, is faster and more capable. The Warrior will be used for various missions such as EOD, route clearance and even battlefield casualty extraction. Since the Warrior program was announced, iRobot have received a US$3.75 million contract to further develop two platforms for the U.S. Army [8].

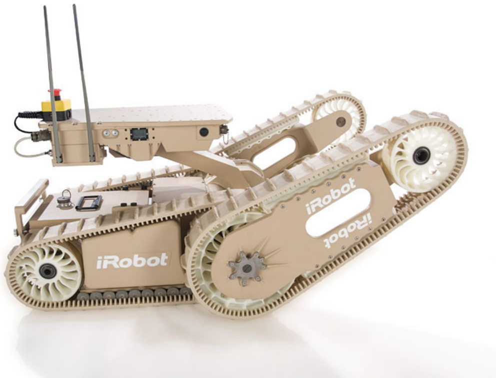

Figure 6. iRobot Warrior.

Foster-Miller MAARS

Another new system currently being offered is Foster-Miller's latest version of the TALON platform. It is called the Modular Advanced Armed Robotic System (MAARS) as seen in Figure 7, which is a reconfigurable system offering multiple mission payloads; meaning that it can be used for more than just a weapons platform. It has a stronger chassis, is heavier but faster and includes the option of a manipulator arm together with more weapon capabilities. Foster-Miller also offer a much smaller UGV (which can be seen as a competitor to the Packbot) known as the Dragon Runner, developed to offer the user a vehicle that can go and look into areas that the TALON cannot.

Figure 7. Foster-Miller MAARS.

Summary

This new generation of UGV's show that there are many developments being carried out to create better vehicles; and also that there is a need for systems to become more capable in order to not only meet, but exceed their requirements. This is because older systems were task specific and could only carry out certain missions. This was mainly because they were designed and developed to set requirements which dictated their size and capabilities, but this led to other important attributes being overlooked such as mobility and portability. This has been realised by UGV vendors who now offer a range of vehicles which can be selected depending on the mission, however, this doesn't only give the customer another option but it actually offers another vehicle not a more capable system. For UGV's to become more capable they must be designed to be adaptable, because the range of missions they must complete and the unpredictability of the environments they are deployed in requires a more versatile approach. This has started to appear in UGV's, for example, the ability to remotely change tools during the mission on Remotec's Cutlass makes it more flexible and able to cope with situational changes, as does the modularity of Foster-Miller's MAARS platform which gives the user the option to have a lethal or non-lethal system.

UGV Development Areas

There are many R&D projects being carried out worldwide on creating better UGV's and systems are becoming more capable as seen in the next generation of UGV's. Future systems will need to be a lot more capable in order to meet a new type of user requirements. The main development areas that will spur the future breed of UGV's are discussed here.

Autonomy

Current UGV's are seen to be more capable than the systems they have replaced but they are far from 'state of the art' as they all still require a lot of input from the operator, creating a number of issues. Firstly, the operator must be fully trained to use the system using up resources, secondly these vehicles are limited in operational range meaning that even though the operator is out of the direct 'line of fire' they are still not too far away from danger; and finally the operator will most of the time be driving the vehicle from where it cannot be seen, guessing on the environmental conditions, possibly creating more confusion to the situation. This highlights the need for the system to have more awareness and intelligence in order to reduce the burden on the operator. This was realised by the U.S. Defense Advanced Research Projects Agency (DARPA) who started a research and development program called the Grand Challenge, with the goal of developing autonomous system technology that will keep war-fighters off the battlefield and out of harms way.

The development of autonomous systems can be split into sub-sections. These are Planning, Perception, Behavior Skills, Navigation and finally Learning/Adaptation. Of all these areas, perception is the most important in making an autonomous system because a UGV's ability to perceive its surroundings is critical to the achievement of autonomous mobility. Perception relies heavily on the systems' ability to sense and interpret information about the environment. However, once the system becomes highly perceptive and becomes more knowledgeable about its environment, then it needs the hardware capabilities to carry out its mission. This is important when looking at a UGV's mobility, because the primary objective of any mission for a UGV is to be able to successfully drive from A to B and to do this they must not only be more perceptive but they must have a high degree of mobility.

Mobility

Mobility, in robotic terms, can be defined as the vehicles ability to transverse over a type of terrain (its trafficability), or how it copes with obstacles. The Committee on Army Unmanned Ground Vehicle Technology [9] discuss how the U.S. Army state that a UGV must have a high degree of mobility because:

- A high degree of mobility minimizes the perception burden.
- Timely mission accomplishment cannot be achieved if the platform has to spend its time searching for an easy path through difficult terrain.
- The best route for covert missions will most likely not coincide with the easiest mobility route.
- A high degree of mobility will keep the vehicle from becoming stuck, thus requiring less human assistance.

Summary

Perception is essential to autonomous operation, however, mobility is equally as vital because a high degree of mobility minimizes the perception burden, and the more mobile the vehicle is, then the less likely it will become stuck. Systems are generally designed with specific hardware depending on what task they are to be used for, however, they are then limited to that use and therefore, as previously discussed, they must become more versatile and be adaptable to situational changes. If this is applied to the area of mobility, paired with increased perception, this would create a more capable vehicle.

Discussions and Conclusions

For the Defence and Security Industry, UGV's are integral to saving lives and therefore need to be extremely capable. All the systems discussed in this paper show that current systems, as well as the next generation of UGV's are very useful to the user, and also demonstrate the amount of development going into this area; however, these vehicles aren't capable enough for an ever changing warzone, such as the unpredictable urban environment where current conflicts are situated (Iraq for example). Also highlighted are the most important areas of UGV development which are autonomy and mobility. They are both as important as each other and their simultaneous development will see the future advancement of highly capable, highly intelligent systems.

Our Work

We believe UGV's must have a very high degree of adaptable mobility, as well as increased perception of the environment, in order to successfully and efficiently complete their missions. We see this as a parallel problem; the vehicle needs a higher degree of perception about its environment to create a more knowledgeable system, but also the system must have increased mobility capabilities in order to decrease its limitations. Together these developments will create a more autonomously capable system.

Vehicle-Terrain Interaction

Terrain is an important element in autonomous driving because if a vehicle cannot travel over a certain terrain type and does not know this, then it will become stuck and ultimately fail its mission, therefore, the system needs to increase its perception in this area and for this it must have the ability to sense the wheel-terrain interaction. Current systems use a range of passive LIDAR, vision and radar sensors to gain information about the environment and help build a 3D map of the area. These systems look ahead at the terrain and make decisions on what the terrain type is from its appearance, but this isn't necessarily an accurate picture as to what the vehicle will actually encounter.

We propose that to sense the terrain, the system must use on-board sensors to take measurements of the drive systems' slippage and sinkage, which are the main conditions of the wheel-terrain interface (see Figure 8), giving real-time information on what is actually happening at the physical interaction.

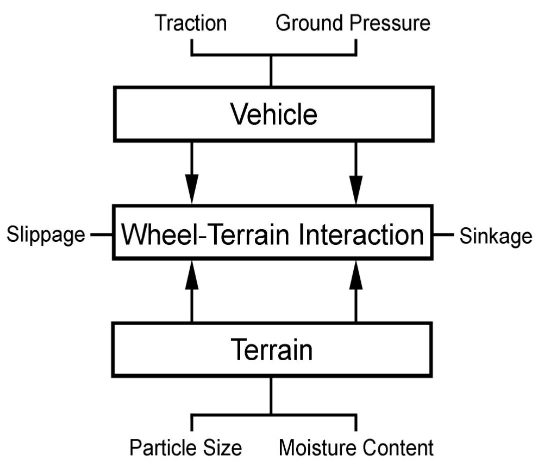

Figure 8. Wheel-Terrain interaction parameters.

This concept is not proposed to replace the other sensors but instead compliment them as part of a three-phase system. Phase one will use previously gathered data about the environment from sources such as reconnaissance images or Google Maps, which will help to determine what will happen before getting there. Phase two will be medium range sensing, using data from an array of passive sensors to look ahead to determine what is going to happen next. Finally, phase three (our concept), which will use real-time data from on-board sensors to determine what is happening right now so that the system can verify whether the previous predictions were correct or not.

Further Work

Once the system has real-time information on what is actually happening at the wheel-terrain interface, there are two decisions the autonomous system can make. The first, which is a process that all current systems follow, is to look ahead and predict that the vehicle cannot cope with a certain terrain type and therefore avoid it, creating a system limited to where it can go and a system that needs to spend time finding a safe path. The second solution, which forms the second part of our proposed system, is a system that can use the data from the on-board sensors to reconfigure its drive system in order to adapt to situational changes, which would ultimately create a versatile system with less limitations [10].

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