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ADP010324

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UK Experience with Unmanned Land Vehicles for Combat Engineer Applications

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Abstract

DERA is currently conducting applied research in support of the UK MOD programme for Combat Engineer Equipments which includes Robotic Land Vehicles.

Three examples of research into remote operation of combat engineer equipment are described, the Scatterable Mine Clearance Device (SMCD) on a 15 tonne truck, Chieftain Armoured Vehicle Royal Engineers (CHAVRE) with mine plough and fascines, and Combat Engineer Tractor (CET) fitted with 4-in-1 bucket. The paper addresses the advantages and limitations of operating via remote control and suggests techniques that alleviate some of these problems. All of the systems described used appliqué kits on in-service vehicles with no vehicle modifications and were intended to be capable of use in operational environments. Adaptation was achievable in less than a day and there was minimum interference with normal operation, change-over to remote control being near instantaneous. The presentation includes a short video clip of aspects such as tele-operation from moving vehicles, vision needs and problems encountered when undertaking specific tasks such as digging and obstacle negotiation. Results of our trials are summarized and pointers given to future research and features that should be incorporated in future systems. Mr. Peter Gibson - Robotics Technical Expert,
Defence Evaluation and Research Agency (DERA), Land Systems, Chobham Lane, Chertsey, Surrey, KT16 0EE, UK

Introduction

UK MoD has much experience with robot vehicles, including bomb disposal systems such as Wheelbarrow. The paper discusses three examples of full size vehicles that we have converted for remote operation. None of these has been used in military engagements though all were prepared with the potential for urgent operational requirements in mind. There is a considerable logistic burden associated with the deployment of a special remote control vehicle. Dedicated troops are needed and there are problems in getting vehicles to the right place in time to do a useful task. We have developed a philosophy of adaptation, which uses an appliqué kit to convert a conventional vehicle and allow remote operation, without undue interference to normal operation. It is envisaged that these kits would be made available in appropriate theatres of action and that vehicles would be pre-prepared to allow remote operation if the circumstances required it.

Driving Remotely In Following Truck (DRIFT)

The adoption of air or rocket deployed surface scattered mines and bomblets led to the investigation of a Scatterable Mine Clearance Device (SMCD), this is similar to a snow-plough and sweeps the road surface clear of sub-munitions. This task is very hazardous when the plough is attached to a logistic vehicle. We were asked to devise a simple tele-operation scheme that would remove the driver from the immediate danger zone. As convoys are in continuous motion it is necessary to find somewhere to put the driver, we chose the passenger seat of the following vehicle.

Paper presented at the RTO SCI Symposium on "Warfare Automation: Procedures and Techniques for Unmanned Vehicles", held in Ankara, Turkey, 26-28 April 1999 and published in RTO MP-44.

FIG 1 - DRIFT tele-operated Truck

Teleoperation controls are fitted in the following vehicle. These include steering wheel, pedals and a video screen giving the remote operator familiar controls to work with. The lead vehicle is fitted with a temporary pedal actuation frame (similar to dual controls for driver instruction), and a steering wheel servo. These do not prevent conventional operation of the controls (though the steering servo is removable for normal use).

FIG 2 - Control Actuators

Communication is by means of a wire tether fitted to a constant tension reeling system. This avoids the need for slip-rings and gives up to 30 metres vehicle separation. Open loop control was chosen for all driver inputs, with a local position servo on the steering wheel. Compressed air was used to control throttle and brakes with electricity for steering and SMCD controls. A wide-angle camera mounted above the windscreen feeding back over the cable link to the operator's screen provides vision. It is possible to view the truck directly if required. Tele-operation is straightforward when the rear vehicle is stationary; the controls are conventional though lacking in feel and the multi-turn steering damps the control input. Motion cues from the following vehicle can be falsely interpreted as tele-operation feedback; this illusion can be powerful though inappropriate responses can be avoided with training.

Armoured Vehicle Royal Engineers

AVRE is a main battle tank chassis equipped with overhead platforms for ditch filling fascines (bundles of plastic pipes) and the vehicle has the normal mounting for the mine plough. This vehicle can be used in hazardous areas such as when breaching a minefield under enemy fire. We were tasked with making a tele-operation kit that would enable rapid (less than one day) adaptation with near full functionality of the Chieftain version (CHAVRE) to include minefield breaching and gap filling with fascines.

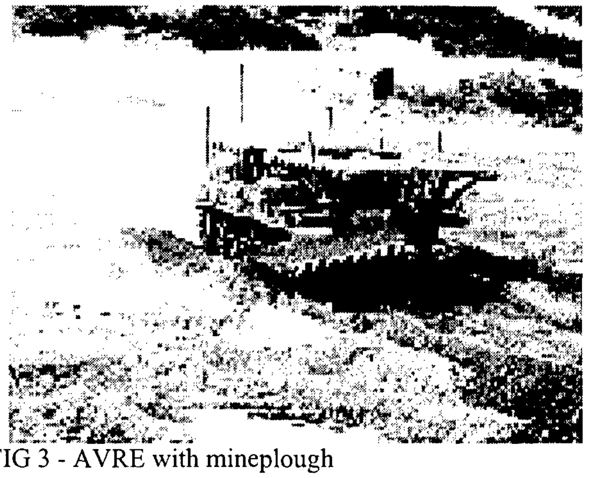

FIG 3 - AVRE with mineplough

Remote control is by data at 4.8k Baud rate and modulated onto a voice channel of the standard combat radio. To ease multipath problems, two switchable antennas are used, one positioned out of phase with the other. The single one way video-link from the remote vehicle to the command vehicle has its input switched according to the camera selected. We use a 1.3GHz FM commercial microwave links (Gigawave Antennas UK) with circular polarized antenna to avoid multi-path interference as the vehicle moves. This equipment was developed for Formula 1 in-car video for TV broadcasts. Radio communication generally requires line of sight communication to transmit these high bandwidth video images though fibre optic links, which offer even higher bandwidth, can be used if the vulnerability of a tether can be tolerated.

The control data contains embedded safety codewords that are decoded by hardware at the remote vehicle and used to enable all safety critical vehicle and weapon systems. Two independent methods were used to avoid the chance of a single mode failure. Software was deemed to be not safety critical and allowed the use of high level languages even though they could not be verified error free. Military Ordnance Board approval was needed and given for this application due to the use of explosive bolts to release the fascines.

The appliqué kit philosophy was followed with "Y" pieces interconnecting the standard wiring harness to the control system. Hydraulic power from the vehicle power brakes was used to apply the steering and brakes (non proportional – on/off) with a servo pressing on the throttle pedal linkage and gear selection and other functions carried out by directly energising the wiring harness. This was arranged to be transparent to the normal crew though there is a safety switch to disable the remote operation when not wanted. Several video cameras were provided; normal driver's view, wide angle view over the plough, reversing and wing mounted manoeuvre cameras. All the electrical equipment was mounted in an area vacated by the crew's storage compartment.

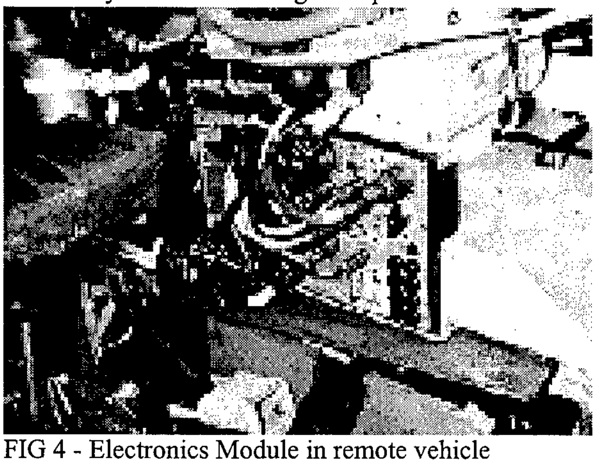
FIG 4 - Electronics Module in remote vehicle

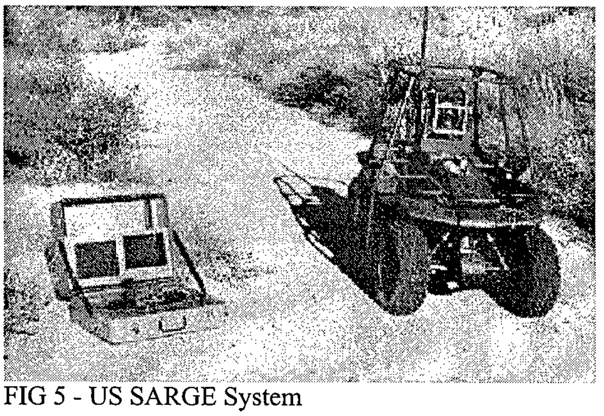
FIG 5 - US SARGE System

The operator console was a suitcase based PC, derived from the US Sarge remote control programme, with touch screen for command menu and flat screen for video. Audio feedback and data throughput measures were provided. Message counts on command and tell-back data were displayed and gave a measure of the robustness of the communications links. It was found necessary to use short data words in noisy environments to avoid all signals being rejected as corrupt. Rates of 20 messages per second represented perfect conditions, values below 10 showed that half were being lost and some action should be taken to avoid being cut-off. In most cases the video degraded quicker than the command and it was possible to drive out of bad reception areas. The safety circuits would prevent operation if command messages were not received within one second of each other.

Trials

Trials were carried out using an experienced military crew who very quickly became familiar with the functions and were operating at full speed. They claimed that it was better than normal due to the improved viewpoints made possible by the freedom in positioning the cameras, and the lack of motion due to not being in the vehicle! On most occasions a safety driver was carried though all armoured hatches had to be shut when live explosive bolts were in place. An interesting point is that although there was a remote engine start there was no remote stop facility, as engine power is needed to ensure brake pressure supply. Several runs were carried out without a safety driver on board; a safety procedure was needed to ensure that the vehicle could not move when live crew are approaching. Operation of this vehicle was quite undramatic; in fact it was impossible to tell from external viewing if the vehicle was under remote or manual control.

The same appliqué kit was used to provide an unmanned target tank for missile trials (a Chieftain tank scrapped as part of the arms limitation treaty). This was operated at 2Km range on Salisbury Plain and suffered 19 encounters with Swingfire wire guided missiles. Although dummies, the warheads caused considerable damage due to explosives and unspent propellant and it was fortunate that we managed to keep the target mobile through the trial. A latter night trial against TRIGAT missiles was also successful with no hold-ups due to target malfunction. This work stretched the capabilities of the video and command links and confirmed the graceful degradation of the system.

Combat Engineer Tractor

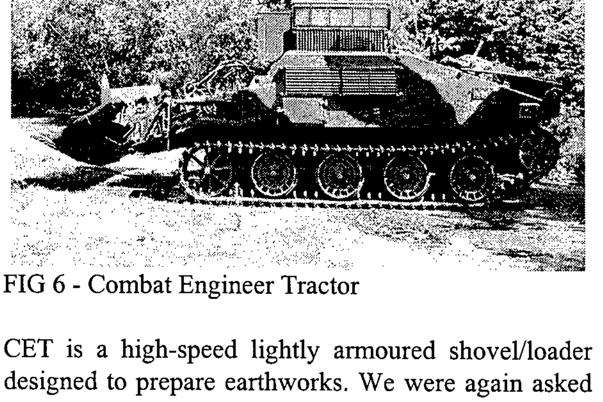
FIG 6 - Combat Engineer Tractor

CET is a high-speed lightly armoured shovel/loader designed to prepare earthworks. We were again asked to demonstrate a simple adaptation for remote operation though the conversion time constraints were less severe than we had imposed on ourselves for the first two examples. We followed a minimalist approach interacting with the vehicle controls in the simplest way practical. All controls except throttle were on/off with additional hydraulic valves bypassing the manual controls to provide the digging functions. The valves and hoses fitted were rated for ½ the flow rate to minimise the added bulk (continuous digging was not anticipated). Electronic control was similar to the AVRE example described earlier with minor modifications to accommodate stereo vision and the bucket controls. It was found that tele-operated driving presented no unexpected problems but it was difficult to sense the shape of terrain features during earth moving, this resulted in inaccurate excavations and higher risks when breaching anti-tank ditches. This indicates that more 3D cues may be needed for slow moving duties such as digging where features may be difficult to recognize.

Discussion

Vision seems to be the key feature in adapting conventional military vehicles to remote control. Lack of control finesse did not cause problems even though we did not use proportional valves or similar servo control techniques when we believed on/off control might work. Military vehicles are designed to tolerate a degree of abuse especially in these hazardous environments. CET braking was somewhat abrupt and uncomfortable for the safety driver but did not cause control problems. Visibility from conventional manned vehicles is highly compromised when "closed down" with all the armoured hatches shut. Forward vision is very limited for AVRE fitted with mineplough and there was a noticeable reluctance to demonstrate digging closed down in CET. Tele-awareness suffers with remote operation and it may be that this degradation makes some tasks fall below the "do-able" borderline without special attention to operator needs. Priority should be given to appropriate views for the task in hand; this is quite easy with multiple video cameras. Devices such as laser rangefinding systems might help understanding of the environment but care would be needed to present this to the operator in a meaningful way.

Conclusions

The three vehicle adaptation systems described were useable, reliable and did not interfere with normal operation. The simple technology used to make the systems affordable did not cause problems, visual resolution appeared to be the technology limitation to performance. Image flow helps make sense of the video and driving at speed is not difficult, a wide field of view aids tele-presence but makes distant objects difficult to see. The workload can be high, especially for an unassisted novice operator and there would seem to be reason to consider a two-man team with both command and driving functions.

A short video is shown at the conference depicting driving and ploughing of the remote AVRE by tele-operation and shows the difficulties associated with CET remote obstacle clearance tasks.