Soldier Experiments and Assessments using SPEAR™ speech control system for UGVs

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ABSTRACT

This paper reports on a Soldier Experiment performed by the Army Research Lab's Human Research Engineering Directorate (HRED) Field Element located at the Maneuver Center of Excellence, Ft. Benning, and a Limited Use Assessment conducted by the Marine Corps Forces Pacific Command Experimentation Center (MEC) at Camp Pendleton evaluating the effectiveness of using speech commands to control an Unmanned Ground Vehicle.

SPEAR™, developed by Think-A-Move, Ltd., provides speech control of UGVs. SPEAR detects user speech in the ear canal with an earpiece containing an in-ear microphone. The system design provides up to 30 dB of passive noise reduction, enabling it to work well in high-noise environments, where traditional speech systems, using external microphones, fail; it also utilizes a proprietary speech recognition engine. SPEAR has been integrated with iRobot's PackBot 510 with FasTac Kit, and with Multi-Robot Operator Control Unit (MOCU), developed by SPAWAR Systems Center Pacific. These integrated systems allow speech to supplement the hand-controller for multi-modal control of different UGV functions simultaneously.

HRED's experiment measured the impact of SPEAR on reducing the cognitive load placed on UGV Operators and the time to complete specific tasks. Army NCOs and Officer School Candidates participated in this experiment, which found that speech control was faster than manual control to complete tasks requiring menu navigation, as well as reducing the cognitive load on UGV Operators.

The MEC assessment examined speech commands used for two different missions: Route Clearance and Cordon and Search; participants included Explosive Ordnance Disposal Technicians and Combat Engineers. The majority of the Marines thought it was easier to complete the mission scenarios with SPEAR than with only using manual controls, and that using SPEAR improved their situational awareness.

Overall results of these Assessments are reported in the paper, along with possible applications to autonomous mine detection systems.

Keywords: SPEAR, speech control, UGV control, human-robot interaction, in-ear speech, testing and evaluation

1. INTRODUCTION

This paper reports on a Soldier Experiment performed by the Army Research Lab's Human Research Engineering Directorate (HRED) Field Element located at the Maneuver Center of Excellence, Ft. Benning, GA, and a Limited Use Assessment conducted by the Marine Corps Forces Pacific Command Experimentation Center (MEC) at Camp Pendleton, CA evaluating the effectiveness of using speech commands to control an Unmanned Ground Vehicle for Route Security and Cordon and Search missions.

SPEAR™, developed by Think-A-Move, Ltd., provides speech control of UGVs. SPEAR detects user speech in the ear canal with an earpiece containing an in-ear microphone, as shown in Figure 1. The system design provides 30 dB of passive noise reduction, enabling it to work well in high-noise environments, where the performance of traditional speech systems, using external microphones, degrade significantly; it also utilizes a proprietary speech recognition engine to process the detected signal and additional algorithms enabling it to maintain a high level of accuracy in high noise environments.

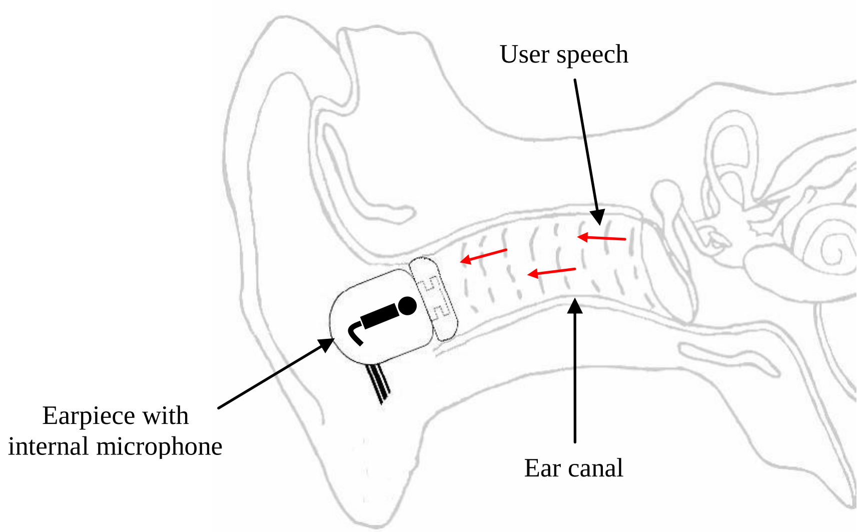

Figure 1: The earpiece fits in the ear and seals the ear canal from the environment. It contains a microphone that points into the ear canal and captures sound waves generated by user speech and transmitted internally.

In the Limited Use Assessment conducted by the MEC, SPEAR was integrated with iRobot's PackBot 510 with FasTac Kit, utilizing the iRobot Aware 2.0 software and AMREL Rocky OCU. For the HRED Soldier Experiment, SPEAR was integrated with Multi-Robot Operator Control Unit (MOCU), developed by SPAWAR Systems Center Pacific. Both of these integrations enable speech to supplement the hand-controller for multi-modal control of different UGV functions simultaneously.

The HRED Soldier Experiment's goals were: 1) Measure the impact on speed of task completion of speech control vs. manual control in performing tasks requiring navigation through different menu levels; 2) Measure the cognitive load on a UGV Operator using speech commands as compared to manual control; and 3) Better understand the intuitiveness of the speech commands implemented on MOCU. This experiment built upon a previous experiment, "Scalability of Robotic Controllers: Speech-Based Robotic Controller Evaluation," which HRED conducted in August, 2008, and which was described in a paper presented at the 2009 SPIE Defense, Security + Security Conference. [1] [2]

Twenty nine soldiers from the Officer Candidate School and Warrior Training Center at Ft. Benning participated in the HRED experiment. Each soldier went through the test twice: once with speech commands and once with manual controls. Approximately half of the subjects performed the first test iteration with speech commands and the other half with manual controls to minimize the training effect. Because of frequency management issues, the experiment was conducted with an Unmanned Ground Vehicle (UGV) simulator, rather than with an actual system.

This experiment showed that it was faster to complete tasks that required navigation through different menu levels with speech commands. And, subjects could complete more of a secondary task performed while simultaneously controlling the UGV when they were using speech commands for UGV control, rather than with manual controls. But, there was no statistically significant difference between speech commands and manual control in the time it took to drive between two waypoints. UGV driving did not require navigating a menu tree. The experiment results also indicate that it is important to use intuitive speech commands that are based on military phrases and which utilize a consistent structure or grammar. [3]

The high level goals of the Limited Use Assessment conducted by the MEC were: 1) Do the speech commands effectively control the UGV system; and 2) Are the speech commands suitable for the warfighter? In addition, the MEC sought to assess: Accuracy of speech commands; Relevance of speech commands; Reductions in workload; Usability; Interoperability and Compatibility; Training; and Characterize maintenance issues.

A total of twenty four EOD Techs and Combat Engineers (twelve each) from the I Marine Expeditionary Force (I MEF) participated in this Assessment. Each Marine completed two iterations for each of two different missions: Route Security and Cordon and Search. Each Marine operated the UGV once with manual controls and then with speech commands in conjunction with manual controls. It should be noted that, as at the Ft. Benning experiment, one-half of the participants used manual controls first and one-half used speech commands first, to minimize any possible training effect. Also, each participant determined which speech commands should be used, and when they wanted to use them.

For the Route Security mission, the Marines were located inside of a High Mobility Multipurpose Wheeled Vehicle (HMMWV), with the engine and air conditioning running. Inside the HMMWV the noise level was measured at 75-76 dBA. The Route Security mission was conducted inside of the Infantry Immersive Trainer at Camp Pendleton, which is essentially a sound stage that had been configured as an Iraqi village. A sound track that had been recorded in Iraq was played at 73-78 dBA to reproduce the sounds that would be encountered in an Operational Environment.

The Combat Engineers used the UGV to identify and photograph simulated Improvised Explosive Devices (IEDs), and the EOD Techs used the UGV, not only to identify, but also to disarm the simulated IED. This replicates the role that each function would perform on an actual mission.

The majority of the Marines thought it was easier to complete the mission scenarios with SPEAR than with only using manual controls. All of the Combat Engineers and ten of twelve of the EOD Techs indicated that their Situational Awareness improved when using the SPEAR system. All of the Combat Engineers and eight of twelve EOD Techs thought that SPEAR improved their functionality as a UGV Operator. The EOD Techs executed the Cordon and Search mission six minutes faster with SPEAR than with manual controls.

2. SPEAR TECHNOLOGY AND SYSTEM CONFIGURATION

The performance of traditional speech recognition systems, which utilize an external microphone, degrades significantly when ambient noise levels increase. This is because of the decrease in signal-to-noise ratio which results from increase in ambient noise levels. Given the loud noise levels typically experienced in a military operational environment, this significantly limits the practical application of traditional speech recognition systems.

To address this issue, TAM developed SPEAR based on novel concept that when someone speaks, not only does speech emanate from his or her mouth; it also travels back to the ear canal. A proprietary earpiece design, shown in Figure 2 enables passive noise reduction of up to 30 dB. SPEAR then runs the signal through speech processing algorithms that it has developed, including a speech recognition engine, to enable it to recognize speech commands. TAM has structured these algorithms as software libraries, easing integration with 3rd Party platforms. The development of this system was previously described in a paper presented at the 2008 SPIE Defense, Security + Sensing Conference. [4][5][6][7]

Figure 2: SPEAR Earpiece

In the implementations of SPEAR utilized in the HRED Experiment and MEC Assessment described in this paper, the software libraries containing SPEAR were integrated with iRobot Corporation's Aware 2.0 software and MOCU, developed by SPAWAR Systems Center Pacific. Also, in these implementations, when the SPEAR system is activated, the UGV operator can not engage in speech communications with team mates because the system is trying to recognize any detected speech as a command.

Because the frequency distribution of in-ear speech is different from speech that emanates from the mouth, with frequencies above 2500 Hz significantly attenuated, the speech recognition engine utilized by SPEAR has been tuned specifically to work with in-ear speech. In addition, TAM developed algorithms to enable the engine to adapt quickly to significant changes in ambient noise levels.

The SPEAR system utilizes a speaker dependent approach, which means that a speaker profile needs to be trained prior to using the system. For the MEC Assessment, a "Basic Profile" training module was used, requiring the Marines in the assessment to read ten sentences out loud. On average, they completed this in less than three minutes. An "Advanced Profile" training module was utilized in the HRED Experiment, requiring the Soldiers to read thirty five sentences out loud; the average completion time was under eight minutes.

The sentences used in both training modules are phonetically rich, containing all of the phonemes in the English language in diverse contexts. These sentences do not contain any of the speech commands actually used in either implementation of SPEAR. Also, in accordance with written training materials used by the military, these sentences are written at an Eighth Grade level.

TAM has conducted tests in a semi-anechoic chamber at its facility with different types of noise played back at different noise levels. As shown in Table 1 below, in a lab environment, speech command recognition accuracy is approximately 93% with different noise types at 90 dBA.

Noise Type	Noise Level	Speech Command Recognition Accuracy
Military Wheeled Vehicle	90 dBA	93.22%
Machine Gun	90 dBA	92.96%

Table 1: Speech Recognition Accuracy with Different Noise Types at 90 dBA

The chart below (Figure 3), based on internal tests conducted by TAM, shows that speech command recognition accuracy degrades significantly when using an external microphone; it remains high when using an earpiece with an in-ear microphone.

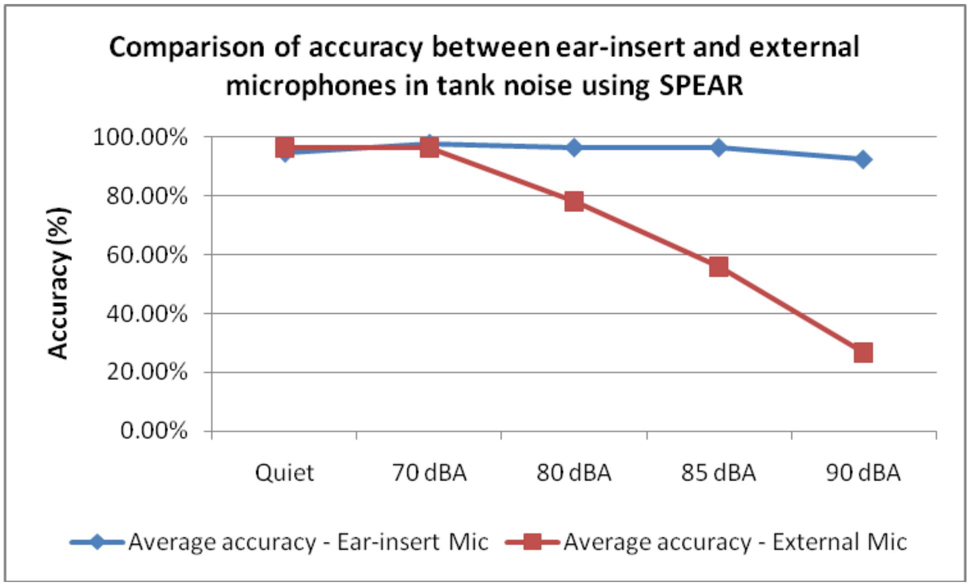

Figure 3: Accuracy Comparison between ear-insert and external microphones

3. CONCEPTS OF OPERATION

Based on feedback that it received from Warfighters during the development of SPEAR, TAM formulated several Concepts of Operation for how speech commands would be used to control a UGV.

1) Multi-Modal Control. Simultaneous control of two different UGV functions with speech commands and a video game-style controller. For example, driving a UGV with the hand controller while using speech commands to control the front flippers or manipulator arm simultaneously. One participant in the MEC Assessment used the phrase "Speech as a Third Hand" to describe this concept.

2) Menu Shortcuts. Speech commands are used to access directly functions that could only otherwise be accessed by navigating through multiple software menus.

3) Macros. One speech command that is programmed to actuate multiple UGV functions at the same time. This might be considered as a way of implementing a simple level of autonomy; an Operator could use one speech command to actuate, in one step, a series of tasks that are performed repetitively and which would otherwise require multiple steps.

4) Heads-Up, Hands-Free UGV Control. Warfighters conducting dismounted operations have expressed an interest in controlling UGVs heads-up and hands-free so that the UGV Operator can maintain his Situational Awareness and be able to maintain his hands on his weapon, while still controlling the UGV.

The HRED Experiment focused on the possible benefits of using speech as menu shortcuts, as a concept of operations. The missions conducted during the MEC Assessment gave insight into how Marines would use speech commands for multi-modal control, as well as for menu shortcuts.

4. HRED EXPERIMENT

The experiment conducted by HRED, as previously noted, was designed to 1) Measure the impact on speed of task completion of speech control vs. manual control in performing tasks requiring navigation through different menu levels; 2) Measure the cognitive load on a UGV Operator using speech commands as compared to manual control; and 3) Better understand the intuitiveness of the speech commands implemented on MOCU. This experiment also built upon a previous experiment, "Scalability of Robotic Controllers: Speech-Based Robotic Controller Evaluation," which HRED conducted in August, 2008. [8][9]

Soldiers from the Officer Candidate School and Non-Commissioned Officers from the Warrior Training Center at Ft. Benning were recruited as test subjects. These subjects ranged from 21-47 years of age, and had a mean military service time of sixty five months. TAM and SPAWAR Systems Center Pacific supported the experiment with personnel, resources, and equipment. The experiment set up and trial runs occurred from September 14-18, 2009, and the experiment itself was conducted September 21-24, 2009. Data was collected from a total of twenty-nine test subjects. Because of frequency management issues, the experiment was performed using a robotic simulator. A TAM representative trained the Soldiers on using the robotic simulator with both manual and speech controls prior to data collection.

For the speech command intuitiveness test, the Soldiers were told eleven different tasks and asked to provide the speech command they would use to perform each task. Because of the work that SPAWAR Systems Center Pacific had completed in developing and implementing autonomous behaviors, these tasks included a variety of behaviors as well as tele-operated functions. Examples of these tasks included:

- "You're in a remote location from the robot and see an item that may be of military interest on the screen. You're not sure that you recognize the item and you want to save the image of it to look at it later. What do you tell the robot to do?"
- "You want to place a line on the map to show that you want the robot to travel along the line from waypoint 'A' to waypoint 'B.' What do you tell the robot to do?"

The speech commands included in the intuitiveness test were: Take picture, Label alpha, Activate exclusion zone, Execute exclusion zone, Add route, Remove goal, Skip a goal, Activate self exploration, Locate the position of the robot on the map, Return home, Right turn. The soldiers were given this test prior to being told what the actual speech commands were, and then again after they had completed using the robotic simulator for the speech control tasks, which required them to use a number of these speech commands.

In the speech command intuitiveness test given after the soldiers had used the robotic simulator, only 34% of the Soldiers remembered the correct commands. Speech commands, such as "Take Picture and "Label Alpha," which were considered intuitive were correctly recalled by 72% of Soldiers and 83% of Soldiers respectively. Those commands had been used during the experiments.

This test showed the importance of using speech commands that are based on military phrases that the Soldiers are familiar with, as well as a consistent structure and grammar. And, based on these results, Soldiers would benefit from having an on-screen menu prompting them for likely speech commands based on the most recent function that the UGV performed.

The Soldiers then completed a series of tasks to better understand the impact of the use of speech commands. Using a robotic simulator, the Soldiers needed to execute the following tasks, using both speech commands and manual control: Take Picture, Label Picture, Enlarge Picture, and Shrink Picture. The Soldiers also drove the robot to a series of waypoints, with either manual controls or speech commands, while simultaneously writing down on paper sequential numbers. The Soldiers were timed as they completed each of these tasks, and approximately one half of the subjects used speech commands for their first iteration and one half used manual controls to minimize any possible training effect.

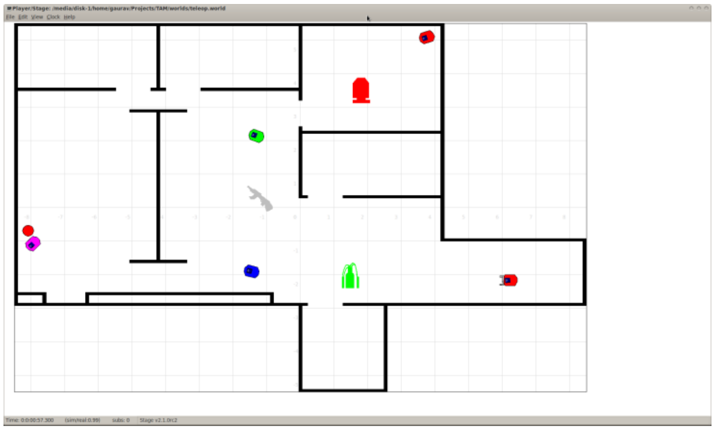

Figure 4: Screenshot of the Simulation Map

The results of this test, seen in Tables 2 and 3 below, showed that it was faster to use speech commands to actuate those functions requiring navigation through multiple menu levels. The one function that did not require navigating through different menu levels was "Take a picture," which was faster to complete with manual controls. There was no significant difference between manual and speech control in the time required to navigate between waypoints. It should be noted that it was quicker to use speech commands to drive between two waypoints requiring less maneuvering of the UGV compared to driving between two waypoints requiring more maneuvering of the UGV.

Table 2: Mean times (sec) to complete tasks

	Verbal		**Manual**	
Task	**Mean**	***SD***	**Mean**	***SD***
Take a picture	15.5	*3.1*	13.4	*3.2*
Label the picture	3.8	*1.4*	7.7	*3.3*
Enlarge the picture	2.8	*1.7*	5.7	*1.7*
Shrink the picture	2.1	*.9*	6.2	*2.6*
Drive to two waypoints	133.6	*47.3*	119.4	*21.0*

Table 3: Summary of paired-sample *t*-tests

Task	***t***	***df***	***p***	***d***
Take a picture	2.87	28	.008*	0.65
Label the picture	-5.23	28	< .001*	1.54
Enlarge the picture	-7.74	28	< .001*	1.78
Shrink the picture	-7.83	28	< .001*	2.11
Drive to two waypoints	1.60	28	.120	0.39

$^*p < .05$, 2-tailed

The Soldiers performance was significantly better when performing a secondary task while using speech commands to drive the robot between waypoints, as shown in Tables 4 and 5 below. This suggests that speech commands impose a lower cognitive load on the Soldier when operating the UGV than manual controls do.

Table 4: Mean numbers written per second while driving

	Verbal		**Manual**	
	Mean	***SD***	**Mean**	***SD***
Numbers per sec	0.47	*0.14*	0.39	*0.13*

Table 5: Summary of paired-sample *t*-test

Task	***t***	***df***	***p***	***d***
Numbers per sec	3.671	28	.001*	0.59

$^*p < .05$, 2-tailed

5. MEC LIMITED USE ASSESSMENT

The goals of the Limited Use Assessment conducted by the MEC were: 1) Do the speech commands effectively control the UGV system; and 2) Are the speech commands suitable for the warfighter? In addition, the MEC sought to assess: Accuracy of speech commands; Relevance of speech commands; Reductions in workload; Usability; Interoperability and compatibility; Training; and Characterize maintenance issues.

For the MEC Assessment SPEAR was used with an iRobot Corporation PackBot 510 with FasTac Kit, and integrated with the Aware 2.0 software and AMREL Rocky Operator Control Unit (PackBot). The Assessment occurred September 28-October 2, 2009. Twelve EOD Techs and twelve Combat Engineers from the I MEF participated in it. Many of these participants had served multiple tours of duty in Theater, and the EOD Techs were familiar with the iRobot PackBot platform. The Combat Engineers did not have previous experience controlling the PackBot or other UGVs. All of the Marines were provided with training on the PackBot, using manual controls alone and speech controls combined with manual controls, prior to performing the simulated missions.

The speech commands used in the MEC Assessment are shown in Table 6. The Basic Profile Training Module, comprised of ten sentences, was used in this implementation of SPEAR. On average, the Marines trained their speech profiles in under three minutes.

Two simulated missions using the PackBot were conducted: Route Security and Cordon and Search. In keeping with the roles that they perform in Theater, the EOD Techs identified and disarmed simulated IEDs, and the Combat Engineers identified and photographed the simulated IEDs on these missions.

Table 6: Speech commands used in MEC Assessment

Motion Commands	Arm Poses	Camera Commands
Forward Slow	Arm Drive	Camera Raise
Forward Medium	Arm Stairs	Camera Lower
Forward Fast	Look High	Camera Left
Backward Slow	Pick Up Object	Camera Right
Backward Medium	Arm Stow	Camera Stop
Backward Fast		
Right Turn	**Flipper Commands**	Zoom In
Right Small		Zoom Out
Right Medium	Flippers Forward	
Right Large	Flippers Back	Open Shield
Left Turn	Flippers Stop	Close Shield
Left Small		
Left Medium	**Grip Commands**	**Light Commands**
Left Large		
	Grip Open	Light Full
Inch Forward	Grip Close	Light Out
	Grip Clockwise	Light Brighter
Drive Faster	Grip Counter Clockwise	Light Dimmer
Drive Slower		
Drive Steady	Grip Stop	**Audio Check**
All Stop		Check One
Brake Engage		
Brake Release		

For the Route Security mission, the UGV operator sat in one of the rear seats inside of a HMMWV that had its engine running and air conditioning turned on. TAM personnel measured the ambient noise level inside the HMMWV at 75-76 dBA. Anecdotally, TAM personnel noted that when they were seating in the front passenger seat of the HMMWV they could not hear the speech commands given by the PackBot operator because of the ambient noise. The HMMWV was located on a dirt road, as shown in Figure 5. The Marines were told to drive the PackBot along the dirt road searching for possible IEDs. As can be seen in Figure 6, the Marines used the PackBot to remove debris or material used to camouflage the IED.

The Cordon and Search mission was conducted from inside the Infantry Immersive Trainer, shown in Figure 7, essentially a soundstage that had been configured as an Iraqi village. A number of the Marines commented that it was so realistic that felt that they were back in Theater. A soundtrack of noise that had been recorded in Iraq was played over loudspeakers during the Cordon and Search mission. This sound track included significant amounts of street noise, such as car and truck sounds and honking, and was measured at 73-78 dBA. To simulate physical stress and exertion, each Marine started the Cordon and Search mission from a point approximately 100 meters outside of the building, and then ran from that starting point to a secure position inside the Trainer from which they controlled the PackBot. The Marines were given some intelligence regarding the possible location of IEDs. Figure 8 shows a PackBot interrogating a target for a suspected IED during the Cordon and Search mission.

Each Marine conducted two iterations, one with manual controls and one with speech commands supplementing manual controls, for each of these missions. One-half of the participants completed the first iteration using manual controls, and one-half with speech controls, to minimize any possible training effect. A data collector from the MEC sat next to the Assessment participants as they were performing each mission.

For both missions, during the iteration that required the use of speech commands, each Marine decided when and how they wanted to use speech commands.

Figure 5: Route Security Mission Road

Figure 6: Route Security IED

Figure 7: Infantry Immersive Trainer

Figure 8: Cordon and Search IED

TAM observers noted that the Marines used speech commands in a variety of ways, not all of which had been anticipated. A number of them used speech commands to actuate predefined poses to position the manipulator arm and camera while approaching the suspected IED. They also used speech commands to open, close and maneuver the gripper while performing other tasks simultaneously with manual controls. Also, one speech command, "Inch Forward," and which drives the PackBot forward approximately six inches, was used while by the Marines as they were controlling the manipulator arm. When using only manual controls these functions must be performed sequentially, and not simultaneously.

The majority of the Marines thought it easier to complete the mission scenarios with SPEAR than with only using manual controls, and that the SPEAR system itself was easy to use. All of the Combat Engineers and ten of twelve of the EOD Techs indicated that their Situational Awareness improved when using the SPEAR system. They did suggest, though, that TAM incorporate a system that would enable them to communicate with other squad members while using SPEAR.

All of the Combat Engineers and eight of twelve EOD Techs thought that SPEAR improved their functionality as a UGV Operator. The EOD Techs executed the Cordon and Search mission six minutes faster with SPEAR than with manual controls. It was recommended that additional work be done to assess the impact of speech commands on mission completion time.

Based on the data that was collected during this Assessment, 90% overall speech command recognition accuracy was achieved. The accuracy rate on the Route Security mission was 93% and on the Cordon and Search mission was 87%. The Marines suggested that using the Advanced Profile training module, which is comprised of thirty five sentences, would improve this accuracy. They also recommended incorporating live weapons fire and explosion noises in future operational assessments, to replicate the environment in which the system would be used.

TAM personnel who listened to the audio files that had been recorded during the Assessment noted that a key contributor to misrecognitions was poor insertion of the SPEAR earpiece. TAM is in the process of developing a diagnostic test to ensure that the earpiece is inserted correctly.

The Marines thought that the speech commands themselves on the PackBot were easy to use, and had a number of suggestions regarding additional functionality that they wanted to see speech commands used to control. Examples of this include: Inch Backward, Zoom All In and Zoom All Out, and Pivot or Turn 180°. In addition, they suggested convening a “Warfighter Workshop” to gain more feedback regarding appropriate speech controls.

6. CONCLUSIONS, FUTURE WORK, & APPLICATIONS TO AUTONOMOUS MINE DETCTION SYSTEMS

The HRED Experiment and MEC Assessment demonstrated that the SPEAR speech control system for UGVs has the potential for increasing Warfighter capabilities when performing Route Security and Cordon and Search missions, and merits continued development as well as additional evaluation. A better understanding is needed of the potential impact of using speech commands on increasing the Warfighter’s situational awareness, and decreasing both mission completion time and the Warfighter’s cognitive workload.

Additional assessments of SPEAR should focus on gathering more objective data to measure the impact that speech control has on the Warfighter’s ability to use a UGV for different missions. One possible benefit, explored in this paper, is whether SPEAR enables a Warfighter to control a UGV heads-up and hands-free. This could enable the use of UGVs by dismounted soldiers without reducing their effective firing power.

TAM has continued its development work based on what it learned as a result of the HRED Experiment and MEC Assessment. It is in the process of developing an improved speaker profile training module, which would incorporate a diagnostic test to ensure that the earpiece has been inserted correctly. It is also implementing a mechanism so that users can easily communicate with their fellow Warfighters while using the SPEAR system. As mentioned above, TAM is proceeding with work to provide an on-screen menu prompting users for likely speech commands based on the most recent function that the UGV performed.

Other work that TAM has done includes integrating a speaker into the SPEAR earpiece to provide audio messages based on sensor inputs. As part of this work, TAM implemented a text-to-speech system used to convert the sensor inputs into audio messages. Examples of these messages include: Low Battery Life, messages based on Unattended Ground Sensors, as well as the raw audio feed from the UGV. These messages would be customized based on the payloads and sensors on a UGV.

TAM has also begun a project to integrate SPEAR with the WaySight™ system from Torc Technologies. WaySight is a hand held OCU with "sight and click" functionality. By looking through a monocular scope, users place the cross-hairs on a target and click a button to wirelessly command an autonomous vehicle to the target location.

This feature may also prove to be of benefit for Autonomous Mine Detection Systems (AMDS). Speech commands could be used, for example, to execute different autonomous behaviors controlling the AMDS. Audio messages could then be provided upon completion of an autonomous behavior, or when the AMDS has reached a defined waypoint. This functionality could reduce time to mission completion. Also, audio messages to the Operator could be triggered by different payload sensors that are on the system. Examples of these payloads or sensors would include a mine detection and marking payload and a chemical and explosive detector that might be part of an AMDS. These messages could reduce the cognitively load for the Operator or increase the Operator's situational awareness.

ACKNOWLEDGEMENTS

Center for Commercialization of Advanced Technologies; San Diego, CA
iRobot Corporation; Bedford, MA
I Marine Expeditionary Force; Camp Pendleton, CA
Joint Ground Robotics Enterprise; Washington, DC
Maneuver Center of Excellence; Ft. Benning, GA
Human Research Engineering Directorate Field Element
Maneuver Battle Lab
Marine Forces Pacific Experimentation Center; Camp Smith, HI
SPAWAR Systems Center Pacific; Sand Diego, CA
Tank-Automotive Research, Development and Engineering Center; Warren, MI

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