Soldier experiments and assessments using SPEAR™ speech control system for UGVs

SPIE Defense, Security + Sensing

Detection and Sensing of Mines, Explosive Objects, and Obscured Targets XV

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Agenda

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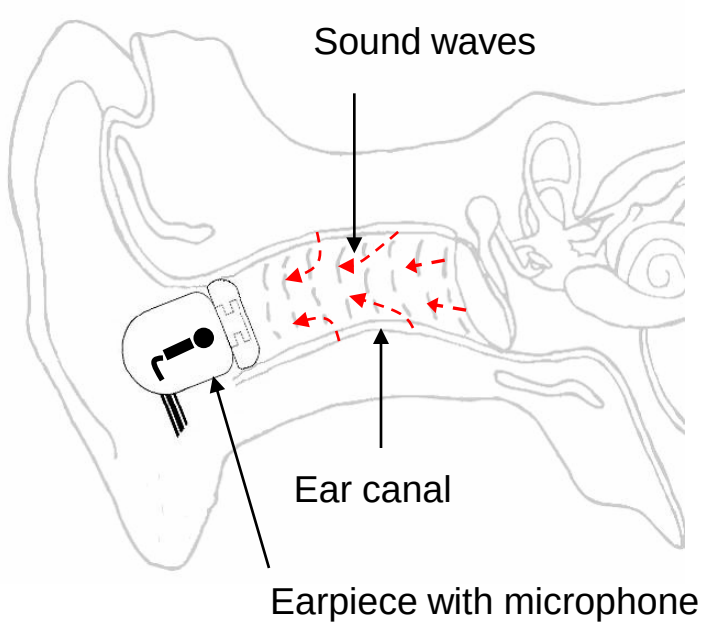
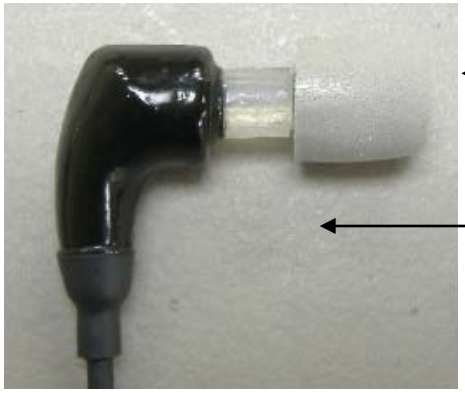
- SPEAR™ Technology and System Configuration
- Concepts of Operation
- Soldier Experiment, HRED Field Element, Ft. Benning
- Limited Use Assessment, MARFORPAC Experimentation Center, Camp Pendleton
- Future Work

SPEAR™ In-ear Sound Capture

- **Speech reaches the ear canal**
- **Quiet place for sound capture**
- **30 dB passive noise reduction**
- **Effective in high-noise environments**
- **Addresses the problem with traditional speech systems**



SPEAR System Configuration



Foam ear tip

Earpiece contains microphone and speaker

OCU

Soundcard

Speech Signal Processing

Speech Command Recognition

Analog microphone signal

Digital speech signal

Processed signal

Recognized command

Algorithms structured as software libraries integrated into OCU

Speech Command Recognition (SCR)

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- **Proprietary SCR engine**
  - **Processes speech input**
  - **Tuned to in-ear speech frequency distribution**
    - Attenuated above 2500 Hz
- **Adaptation to ambient noise level changes**
- **Speaker Dependent**
  - **Basic profile:** **Ten sentences, < 3 minutes**
  - **Advanced profile:** **Thirty five sentences, < 8 minutes**
- **Accuracy Results**

Military Wheeled Vehicle	**90 dBA**	**93.22%**
Machine Gun	**90 dBA**	**92.96%**

PackBot 510 with Advanced EOD Kit Speech Commands

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MOTION COMMANDS

FORWARD SLOW
FORWARD MEDIUM
FORWARD FAST
BACKWARD SLOW
BACKWARD MEDIUM
BACKWARD FAST
RIGHT TURN
RIGHT SMALL
RIGHT MEDIUM
RIGHT LARGE
LEFT TURN
LEFT SMALL
LEFT MEDIUM
LEFT LARGE

DRIVE FASTER
DRIVE SLOWER
DRIVE STEADY

ALL STOP
BRAKE ENGAGE
BRAKE RELEASE

AUDIO CHECK

CHECK ONE

ARM POSES

ARM DRIVE
ARM STAIRS
ARM BOX
LOOK DOWN
LOOK HIGH
LOOK LOW
PICK UP OBJECT
LOAD OBJECT
ARM STOW
LOOK UNDER
LOOK MIDDLE
DRIVE BACKWARDS
LOOK CLOSE

FLIPPER COMMANDS

FLIPPERS FORWARD
FLIPPERS BACK
FLIPPERS STOP

GRIP COMMANDS

GRIP OPEN
GRIP CLOSE
GRIP CLOCKWISE
GRIP COUNTER CLOCKWISE
GRIP STOP

CAMERA COMMANDS

CAMERA RAISE
CAMERA LOWER
CAMERA LEFT
CAMERA RIGHT
CAMERA STOP

CAMERA TURRET
CAMERA UNDERARM
CAMERA OVER ARM

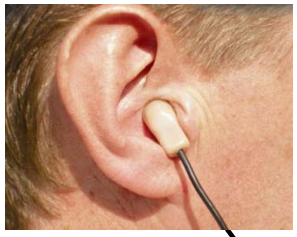
ZOOM IN
ZOOM OUT

OPEN SHEILD
CLOSE SHEILD

LIGHTING COMMANDS

LIGHT FULL
LIGHT OUT
LIGHT BRIGHTER
LIGHT DIMMER

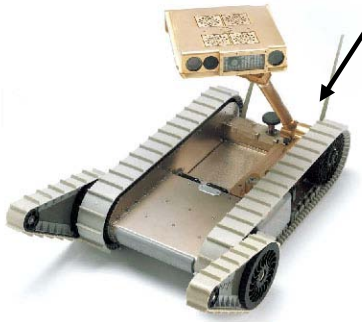
SPEAR Concepts of Operations



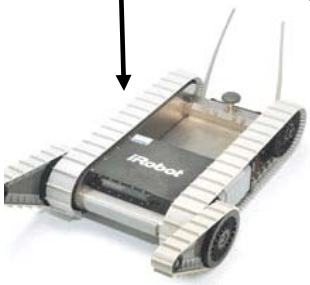
Speech Command Input

Game Controller Input

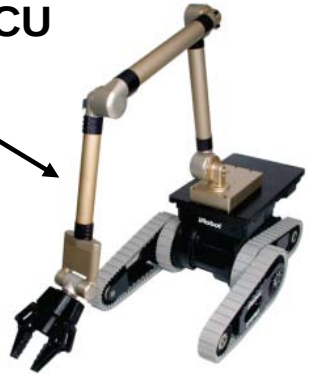
OCU



Camera Control



Motion Control



Manipulator Arm

- **Multi-Modal Control: Simultaneous control using speech commands and OCU**
- **Macros: One speech command actuating multiple functions**
- **Menu Shortcuts**
- **Modes**
- **Hands-free, heads-up control**
- **One Operator: Multiple UXV platforms**

HRED Field Element, Ft. Benning Experiments

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- **"Scalability of Robotic Controllers: Speech-Based Robotic Controller Evaluation" August 2008**
  - Integrated with PackBot 510
  - ARL-TR-4858
  - Decreased time and effort when performing multiple tasks simultaneously

- **"Intuitive Speech-based Robotic Control" September 2009**
  - Integrated with Multi-Robot Operator Control Unit (MOCU)
    - Developed by SPAWAR Systems Center Pacific
    - Autonomous Behaviors
  - Subjects:
    - 29 Soldiers: Officer Candidate School and Warrior Training Center
    - Age Range: 21-47 Mean Military Service Time: 65 months
  - Goals
    - Speed to task completion
    - Cognitive load while performing secondary task
    - Speech command Intuitiveness: Better understand appropriate words
  - Simulator

HRED Field Element, Ft. Benning Experiment Design

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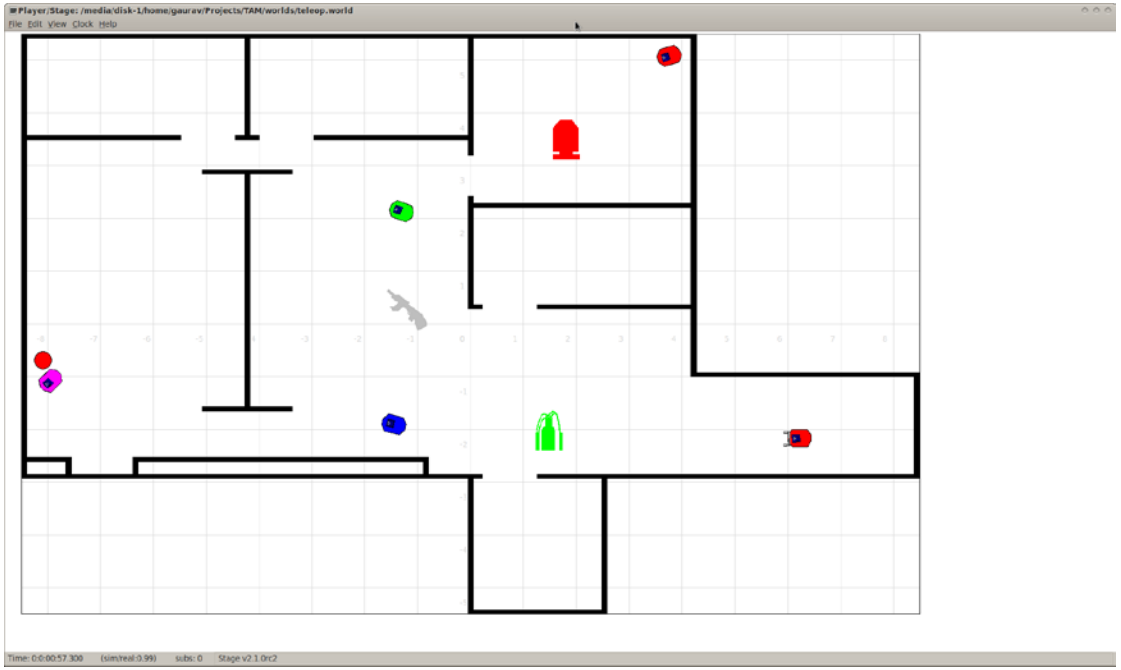
- **Speech Control Tasks**
  - **Payload Functions: Take Picture, Label Picture, Enlarge and Shrink Picture**
  - **Driving Function: Driving to two waypoints while performing Secondary Task**
    - Secondary Task: Writing sequence of numbers

Screenshot of Simulation Map



HRED Field Element, Ft. Benning Experiment: Results

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- **Speech control faster for functions requiring navigation through menu levels**
- **No significant difference for driving between two waypoints**

Mean times (sec) to complete tasks

Task	Verbal		Manual	
	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*

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*

HRED Field Element, Ft. Benning Experiment: Results

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- **Speech control reduced cognitive load**

Mean numbers written per second while driving

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

Summary of paired-sample *t*-test

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

**p < .05, 2-tailed*

- **Speech command Intuitiveness: 11 different controls/behaviors**
  - **Described function and asked for appropriate speech command:**
  - **Pre- and Post- simulator use**
  - **Post-simulator use, only 34% of soldiers remembered correct commands**
- **Recommendations/Lessons Learned**
  - **Develop intuitive speech commands based on military phrases**
  - **Implement consistent speech command structure/grammar**
  - **Provide "Most likely speech command" prompts via screen menu**

MARFORPAC Experimentation Center (MEC)

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- **Limited Use Assessment, Camp Pendleton October 2009**
  - **SPEAR Integrated with iRobot PackBot 510 with FasTac Kit**
    - Aware 2.0
    - AMREL Rocky OCU
  - **Goals**
    - Do speech commands effectively control UGV?
    - Are speech commands suitable for the warfighter?
  - **EOD Techs and Combat Engineers, I MEF**
    - 12 each, 24 total subjects
    - Identified and photographed or disarmed simulated IEDs
    - Speech commands used in conjunction with hand controller
  - **Route Security Mission**
    - Operated from inside of a HMMWV
    - Noise level: 75-76dBA
  - **Cordon and Search Mission**
    - Infantry Immersive Trainer → Simulated Iraqi village
    - Noise level: 73-78 dBA
    - Simulated stress and physical exertion

MARFORPAC Experimentation Center (MEC): Results

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- **Speech Recognition Accuracy**
  - Cordon and Search: 87%
  - Route Security: 93%
  - Overall: 90%
- **Reduced time to mission completion**
  - EOD Marines executed Cordon and Search Mission 6 minutes faster with SPEAR
  - No significant difference with other missions
- **Improved Situational Awareness**
  - All Combat Engineers and 10/12 EOD Techs indicated improved SA with SPEAR
- **Impact on Operator Functionality:**
  - Ability to conduct other tasks and operate robot simultaneously
    - Combat Engineers: 100%
    - EOD Techs: 67%
- **Overall training straightforward and easy to learn**
- **Ease of Use**
  - 100% agreed that SPEAR was easy to use

MARFORPAC Experimentation Center (MEC): Recommendations

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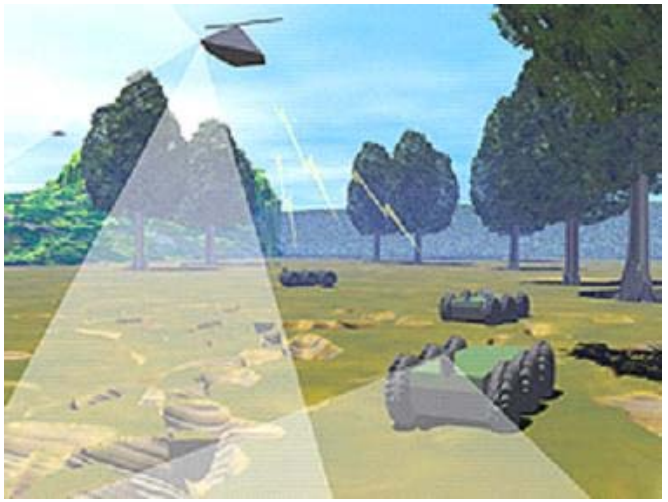
- **Improve training module**
  - Increase number of speech profile training sentences
  - Earpiece seal check test
- **Convene "Warfighter Workshop"**
  - Validate words used for speech commands
  - Define additional functionality
- **Further assess impact on mission completion time**
- **Implement means to communicate easily with squad members**
- **Include weapons fire and explosions during future assessments**

Future work and AMDS applications

- **Audio messages from sensor inputs**
  - **Speaker integrated into earpiece**
  - **Text-to-speech system**
  - **Audio message examples**
    - Low Battery Status
    - Raw audio feed from Unmanned System
    - Payload Sensors



- **Integration with Torc Technologies' WaySight™**
  - **Hand held OCU with 'Sight and Click' functionality**
- **Autonomous Mine Detection System applications**
  - **Speech commands used to execute autonomous behaviors**
  - **Audio messages provided to Operator**
    - Completion of autonomous behavior or waypoint reached
    - Mine detection and marking payload
    - Chemical & Explosive detector
  - **Possible benefits:**
    - Improved Situational Awareness
    - Time to mission completion decreased
    - Cognitive load decreased
- **Questions?**

Acknowledgements

- Center for Commercialization of Advanced Technologies (CCAT)
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- Maneuver Center of Excellence, Ft. Benning
  - Human Research Engineering Directorate (HRED) Field Element
  - Maneuver Battle Lab
  - Officer's Candidate School and Warrior Training Center
- Marine Forces Pacific Experimentation Center (MEC)
- Space and Naval Warfare Systems Center Pacific (SPAWAR)
- Tank-Automotive Research Development and Engineering Center (TARDEC)

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