ABSTRACT

Smartphones have put video communications, computation, and proprioceptive sensing (e.g., accelerometers and gyroscopes) into the hands of hundreds of millions of consumers. These small, microelectromechanical systems can be used in many applications, including remote control. This study proposes using smartphones with proprioception as handheld robot controllers and aims to determine feasibility of accelerometers as control inputs for tele-operation while defining heuristics for use. Initial results indicate accelerometers are suitable for tele-operation commands, but identify specific design characteristics meriting further investigation.

Categories and Subject Descriptors
A.0 [General]; H.5.2 [User Interfaces]: Input devices and strategies; I.2.9 [Robotics]: Operator interfaces

General Terms
Human Factors, Experimentation

Keywords
Smartphone, Tele-operation, Unmanned Ground Vehicles

1. INTRODUCTION

Hundreds of millions of smartphones have been sold since their introduction, possessing impressive computational power and a suite of microelectromechanical systems (MEMs) on board. Accelerometers, used to detect and measure motion, are one of these MEMs, and contribute to the user experience by switching orientations, self-orienting maps, and more [1]. Developers have used the commercial availability of these sensors to tailor them for use in handheld gaming platforms, pedometers, and remote control.

Aside from commercial uses for smartphone technology, government and industry are also taking note of smartphones’ tailorable design. The U.S. Army is examining the feasibility of equipping all soldiers with smartphones, as they are uniquely suited for dispersed and varying military missions due to their size, expanding capabilities, common platforms (iOS and Android), and agility [7]. Unmanned ground vehicles (UGVs) are one of the fastest growing segments of the U.S. military, and are almost always tele-operated, meaning “manually controlled by an operator at a distance that is too great for the operator to see what the robot is doing” [3]. In these situations, the operator can rely only upon the robot’s sensors; in contrast, remote control occurs within line of sight of the robot and the operator can make his/her own judgments based on direct sensory input. Tele-operation tasks generally require more from an operator control unit (OCU) since tele-presence via video screen is necessary.

2. RELEVANT RESEARCH

Military labs have explored the feasibility of smartphones as UGV controllers, and so have a number of civilian institutions [4, 9]. Researchers at the University of South Florida demonstrated tele-operated smartphone control of the most popular military UGV, the iRobot PackBot. The controller uses a push button interface, not attitude control, but did prove video tele-presence via mobile device [5]. Commercially, the popular hobbyist quadcopter, AR.Drone (manufactured by the Parrot company), has done the same. Using an ad hoc wireless connection, the iPhone acts as both controller and video screen (for the on board camera); their interface supports both tilt inputs and push buttons to maneuver the quadcopter [11]. Given the available video feedback, it is possible that the AR.Drone could be tele-operated; however, it is almost always demonstrated where the operator maintains line of sight to the quadcopter and/or flies in large open areas where obstacles are limited.

While demonstrating various capabilities, these systems provide no real comparison of the advantages and/or disadvantages of using the OCU’s attitude as a control input versus push buttons, joysticks and other traditional means. Tilt control has a number of perceived advantages over tactile or push-button interfaces: 1) it’s more intuitive for users, especially in lieu of appropriate training, 2) it permits one-handed operation – important for multi-tasking users, and 3) it requires less attention i.e. time spent looking at the screen. Additionally, using tilt controls prevents unnecessary buttons from cluttering the small display, maximizing the area available for video feedback.

3. APPROACH

Touchscreen interfaces have been around long enough for basic heuristics to exist regarding button size, spacing, and menu display [10, 8]; however, few heuristics exist defining use of the device’s MEMs e.g., accelerometers and gyroscopes. Apple provides a strong set of guidelines in their
serious movement should translate to vehicle motion; there-
teristics tied to the usability of an accelerometer equipped
ation. The research described below strives to identify heuristics, such as the one just defined, to in-
form future controller development using accelerometers in tele-operated robot control.

3.1 Preliminary Work

Preliminary work has focused on controller design and ex-
periment set-up while the researchers await IRB approval. The test robot is a modified HPI Racing Crawler King, where a webcam has been added to provide the video feedback necessary for tele-operation (Figure 1(a)). The controller will be presented on an iPod Touch in landscape mode using the iPhly hardware to generate RF control signals from the application output [6]. Video is displayed in near full-
screen, and a cross hair with floating bubble denotes the current tilt of the device when the dead man switch (touch anywhere on the screen) is active (Figure 1(b)).

Initial feedback from a small subset of users indicates that accelerometer control is feasible in tele-operated unmanned ground systems; however, there are some design issues that merit further consideration, e.g. accelerometer sensitivity. Individual operators have different expectations for how a “small” movement should translate to vehicle motion; therefore, formal testing should include a readily-available interface to adjust the sensitivity setting. Additional areas of focus for experimentation are described in the following section.

3.2 Proposed Experiment

The authors propose to study the following major characteristics tied to the usability of an accelerometer equipped smartphone as a controller for a tele-operated vehicle.

1. Compare the efficiency and user feedback of the standard RC controller while viewing video feedback on the iPhone.
2. Conduct trials using the iPhone as both video screen and controller with a simple push button interface to control the robot.
3. Assess efficiency and user feedback when video is viewed on the iPhone and the robot is controlled via accelerometer input. A dead man switch will activate accelerometers, and operators will tilt forward, backward, and

side to side to control the four-wheeled vehicle. A possible variation on this could test other methods for steering control e.g., rotation vs. tilt.

4. Compare/contrast the controller described in item 3 with two different “leveling” points. In one, the zero point would be a defined point in space i.e. user must hold device at a 45 degree angle to activate the dead man switch and therefore the accelerometers; alternatively, the device could self-level meaning the zero point is wherever the user activates the dead man switch. The results of this comparison have important usability implications, especially for users that require a more heads up controller environment. It will also help inform the researchers as to how users’ mental models are built and how they perceive the controller should function and react.

Ideally, the results of these tests will help answer a number of questions. Aside from learning more about how users expect a controller to act, data collected will also measure general suitability (efficiency, precision of operation) of accelerometers in tele-operation. Do users prefer a tilt interface over other conventional interfaces, and if so how is accelerator control best implemented? We hope to identify appropriate settings regarding the zero point, accelerometer sensitivity, and video display size/resolution.

4. REFERENCES


The zero point is defined as the origin for the accelerometer output. Normally the iPhone is considered at 0,0,0 when resting flat on a table.