# Wireless Data Glove for Gesture-Based Robotic Control

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**Abstract.** A wireless data glove was developed to control a Talon robot. Sensors mounted on the glove send signals to a processing unit, worn on the user's forearm that translates hand postures into data. An RF transceiver, also mounted on the user, transmits the encoded signals representing the hand postures and dynamic gestures to the robot via RF link. Commands to control the robot's position, camera, claw, and arm include "activate mobility," "hold on," "point camera," and "grab object."

**Keywords:** Communications, conveying intentions, distributed environment, gestures, human-computer interactions, human-robot interactions, military battlefield applications, non-verbal interface, robot, wireless data glove, wireless motion sensing.

## 1 Introduction

Robots are becoming increasingly useful on the battlefield because they can be armed [5] and sent into dangerous areas to perform critical missions. Controlling robots using traditional methods may not be possible during covert or hazardous missions. A wireless data glove was developed for communications in these extreme environments where typing on a keyboard is either impractical or impossible [2]. This paper reports an adaptation of this communications glove for transmitting gestures to a military robot to control its functions.

Novel remote control of robots has been an active area of research and technology, especially over the past decade. (See, for example [1, 4, 5, 6, 7, 9, 10]) For example, a wearable, wireless tele-operation system was developed for controlling robot with a multi-modal display [5]. Remotely controlled robots have been used in environments where conditions are hazardous to humans [4]. Gestures were used to control a flying manta-ray model [1]. A glove apparatus was used to control a wheelchair using robotic technology [7].

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## 2 Talon Robot

The Talon US Army robot [5], (Figure 1) serves several purposes from mine detection and removal to attack missions on battlefields. Civilian applications can include the assessment of unstable or hazardous areas. The Talon robot can negotiate a variety of terrain with its tank-track mobility system. It is equipped with surveillance devices, a pan-and-tilt camera, and a general-purpose robot arm. The original control method includes joysticks, mechanical switches, and push buttons housed in a large, heavy case.

## 3 Data-Glove Operation

The data glove (Figure 1) has motion sensors (e.g., accelerometer, gyros, and magnetic bend sensors) on the back of the hand and on the fingertips to provide information regarding motion and orientation of the hand and fingers. Bend sensors detect finger postures whereas the gyros detect hand rotations. In a similar application, flying robots have been controlled using wireless gloves with bend sensors [1].

With Talon robot and control module the data-processing unit on the glove reads and analyzes the sensor data and translates the raw data into control commands equivalent to those produced by the Talon robot's joystick and switch. Then the data-processing unit sends the commands to the Talon's controller wirelessly via radio frequency. The Talon controller assembles all commands from the data glove and

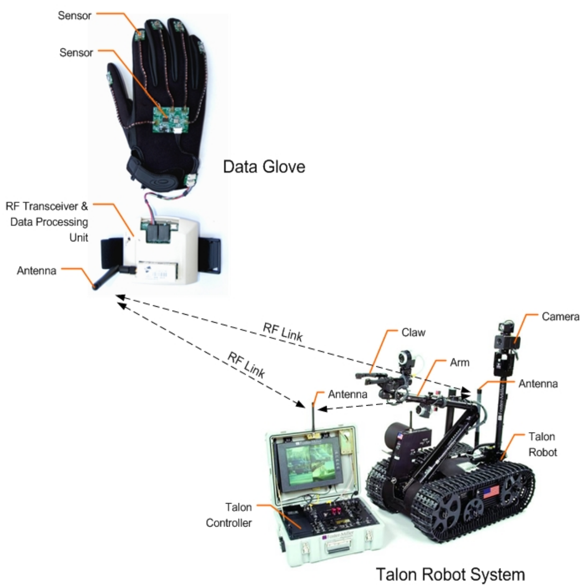


**Fig. 1.** Data glove (Patent pending NCN 99084; SN 12/325,046)

other sources into a package and sends them to the robot for execution. This architecture has the advantage of allowing traditional control of the robot as well as conforming to the robot's existing interface.

For some applications the data glove can control the Talon directly without using the controller. For other applications, data-glove information can be translated into data to a PC via an RF-receiving station where the data-glove information is translated into data compatible with devices such as a mouse or game pad and transferred to the PC’s USB input device. The receiving station can interface to software for the Multiple-Operational Control Unit (MOCU), which is used to control the Talon and other robots.

## 4 Human Factors

Translating glove data into robot control commands based on gross motor skill and fine motor skill human hand provides granularity not possible with uniform control mechanisms, such as a joystick. For example, gross hand motion is translated into commands controlling coarse motions of the robot, whereas fine motion of fingers is translated into more precise motion control. Orientation and motion sensors on the back of the data glove, shown in Figures 1 and 2, provide gross motion information of hand postures and dynamic gestures used to control characteristics such as speed and direction, operation of the arm, and rotation of the camera mount. Bend sensors mounted on the glove’s fingertips measure the fine motion of the fingers. That information is used as a reference to control the precision of the Talon claw’s aperture. The fine motion of the fingers also can be used to control other high-resolution operations such as the focus-and-zoom lens of the robot’s camera.

The data glove gives users an intuitive sense of control, which facilitates learning the robotic operation. The glove also frees users to observe video and audio data feedback and the environment rather than focusing on the control mechanism, resulting in a more effective overall operation. The data glove does not need pivot-reference station points such as mechanical joysticks. Moreover, the data glove does not require the user to stay in contact with the Talon controller module. The user may move during control operation, and therefore, can operate the robot in various situations and positions. For example, the user can lie prone to maintain covertness, which offers a low-profile advantage on the battlefield.

Figure 1 also depicts the sensor circuit board that is mounted on the back of the glove, the wires that connect it to the sensors on the fingertips, as well as the RF transceiver and data-processing unit that the user wears on the forearm. The glove and processing unit are light and flexible enough so that they do not cause physical fatigue. The apparatus is not difficult to hold and it does not impede the user’s motion. This aspect of the apparatus enables the user to concentrate on the control aspects of the robot and that task that the robot is performing.

The user can interact with the robot in a manner that requires either line-of-sight proximity to the robot, or a screen display of the output from the camera mounted on the robot, as shown in Figure 1. This method of interaction is different from eye-gaze based interaction [12], because the computer system does not track the user’s eye motion. However, the wireless-glove interaction is similar to eye-gaze-based interaction because neither method of computer interaction requires the use of a mouse.

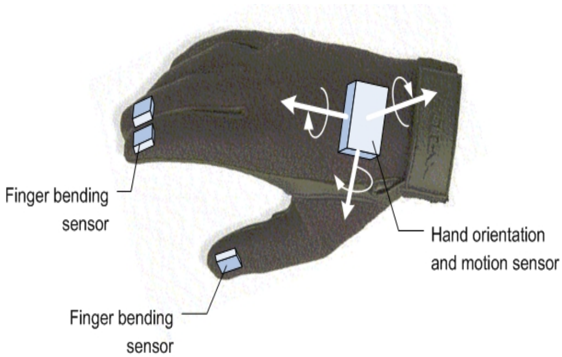


**Fig. 2.** Data glove sensor layout

Figure 2 shows an X-Y-Z axis of the whole hand, which is used as a reference for finger motions in general. The three types of sensors, listed above in section 3,detect relative finger motion and hand motion about this three-axis system. Three-axis micro-electromechanical systems (MEMS) accelerometers and gyroscopes have been used for wireless motion sensing to monitor physiological activity [3], [8], [11].

## 5 Data-Translation Methods

The data-glove processing unit reads and processes sensor data. Before data are sent to the robot, they are converted into machine language for robot control. Three basic methods are applied to convert hand motion and positions of the hand and fingers into computer-machine language inputs. These three different methods are depicted in Figures 3, 4, and 5.

Figure 3 shows how the thumb is used as an OFF/ON switch. Even though the sensor on the thumb provides fine resolution of position, translation software defines the sensor data range as two values, OFF or ON, depending on the angle between the thumb and the wrist. This operation of thumb provides the digital logic value "0" or "1" as input to controller. Electrical OFF/ON switches are used for critical robotic operations, such as such as shooting triggers, selecting buttons, and activating emergency switches.

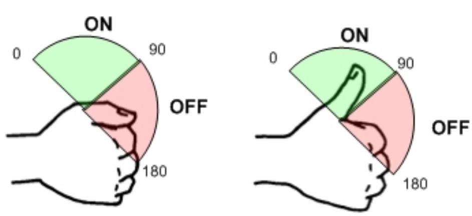


**Fig. 3.** Thumb operated as OFF/ON switch

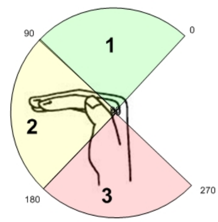


**Fig. 4.** Three regions of fingers positions

For some applications, the motion and positions of hand and fingers, needs to be divided into more than two regions. Figure 4 shows finger positions divided into three regions: region 1 from 0-90 degrees, region 2 from 90-180 degrees, and region 3 from 180-270 degrees. The wide range required for each region acts as a noise filter, filtering out natural hand and finger shaking of different users. This operation is coded into the numeric values of "1," "2," and "3." The code values provide an effective method to define hand and fingers positions, and therefore, define hand postures.

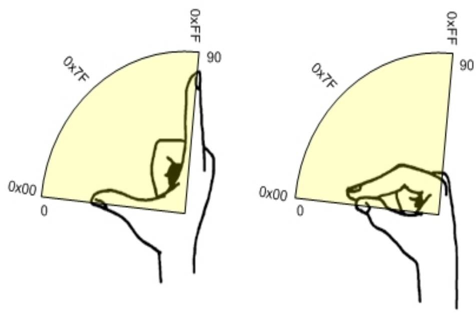


**Fig. 5.** Index finger operated as a potentiometer

For applications requiring precision control, the full resolution of the sensor is used. In Figure 5 above, the motion of index finger provides an 8-bit data range of values from 0 to 255 (0x00-0xFF). This operation is analogous to operation of a potentiometer. This angular vibrational motion can be used to control the gap of the robot's claw or zoom as well as the focus of the camera, etc.

## 6 Command Gestures for Talon Robot

Given the sensor arrangement and data- translation methods, the authors devised the following control language specifically for Talon Robot operation, which incorporates all of the most frequently used Talon commands.

Hand Relax-Neutral

Robot in Hold-on state

**Fig. 6.** Command 1 - Hold-on

Command 1 (Figure 6) - Hold-On: Opening the hand in a neutral-relax position is interpreted as hold-on state. This command will cause the Talon to retain current commands and stop receiving new commands. This also allows the hand time to relax or can be used as an intermediate state between commands.

Command 2 (Figure 7) - Mobility: The palm forms a vertically oriented fist as though it were holding a joystick. Rotating the hand left or right causes the robot to turn left or turn right. Higher degrees of rotation result in faster robot turning rates. Bending the hand forward or backward at the wrist controls the speed of the robot. A higher degree of bending results in a faster speed of the robot. A thumb pointing-up gesture acts as a brake, immediately bringing the robot's speed to zero as soon as possible. Thus, the motion of the glove is modeled after the joystick in which a potentiometer controls the robot's actions.

Previously, wireless teleoperation of an exoskeleton device was used to control a mobile robot's kinematics [4]. The robot in this study had two arms was designed to follow human motion [4]. The data glove described in the present work not only controls the robot's translational kinematics and a robotic arm but it also controls a camera mounted on the robot.

Command 3 (Figure 8) - Camera control: The hand forms the symbol for "VIEW" or "EYE" in American Sign Language. Gross hand panning left or right, i.e. a rotation about the Z-axis is translated into a panning-motion command to the robot's camera.

Bending the hand around the X-axis translates into a tilting motion command. The fine-grained angle of the index and middle fingers control the zoom of the camera's lens. For example, a gesture to open the hand, i.e. straightening the index and middle finger, makes the lens zoom out whereas the retraction of the index and middle finger towards a fist-like posture causes the lens to zoom in.

Command 4 (Figure 9) - Arm and claw control: This command is similar to command 3. The gross motion of hand around the X, Y, and Z axes is translated into commands to control the tilt, rotation, and pan of robot's arm respectively. The Bending the thumb and the index finger on the glove controls precisely the gap of the claw. As one might expect, widening the gap between the thumb and the index finger of the glove also widens the gap of the robot's claw. To grasp an object remotely, the glove allows the user to close the hand of the glove, thus narrowing the gap of the claw after the arm has been moved into the appropriate position near the object.

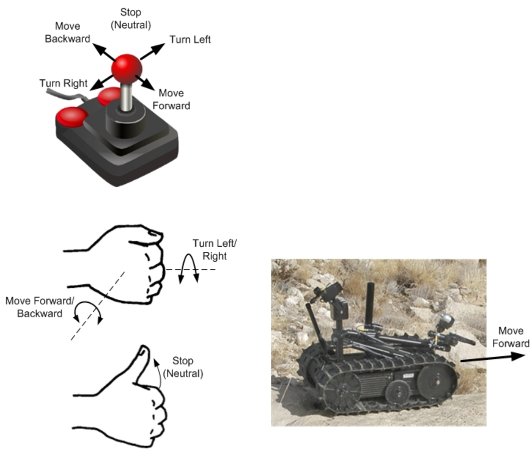


**Fig. 7.** Command 2 – Mobility

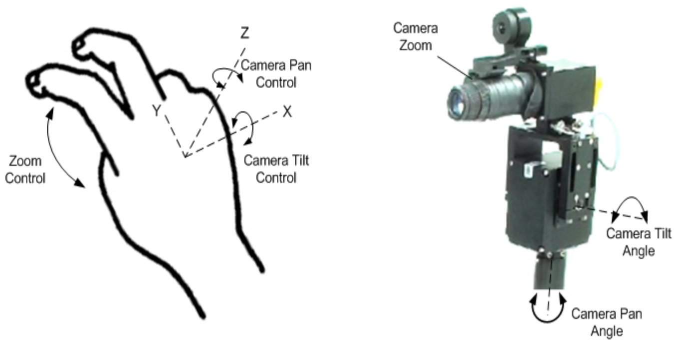


**Fig. 8.** Command 3 - Camera control

These commands were selected because the user's hand performs a motion very similar to the one the robot's camera and claw perform. Thus, the system of commands is more intuitive, easier to learn, and easier to remember than some arbitrary system in which the robot's motion does not track user's hand closely.

The following is an explanation of how the user tells the glove which mode of operations to use. When the user wants to widen the robot's claw, pick up an object, then focus the camera on that object, the following method is used to convey the command sequence to the robot. The user performs the posture-pause command that tells the robot to keep the current position of claw. Then the user performs the exit command to exit current claw control command state to hold-on state. When the robot is in the hold-on state, the user performs the posture-camera-control command to enter the camera-control state from the hold-on state. Thus, using one hand, the glove can control multiple robot operation commands at the same time. However, in case of ambiguity among hand postures that may cause robot perform undesired operation, the user must operate one command at a time. The software program defines the command states that require user to perform the hand posture to enter and exit a specific control-command state.

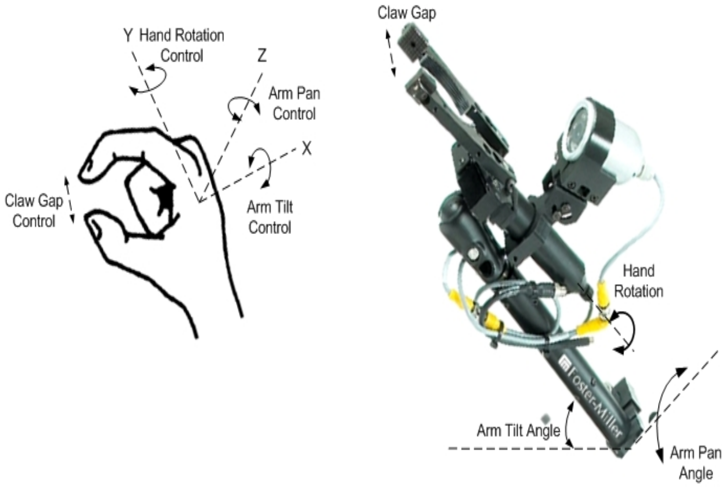


**Fig. 9.** Command 4 - Arm and claw control

## 7 Testing with Pacbot

The robot platform that was used for testing was a Pacbot, (Figure 10), which has capabilities that are similar to those of the Talon. The data glove interfaced with the MOCU software to control the Pacbot via PC wireless USB port. A configuration file was modified to map and scale the data-glove commands with the data that the MOCU sent to the Pacbot.

**Fig. 10.** Pacbot

## 8 Directions for Future Research

A future data glove will have an input-filtering algorithm to minimize unintended commands originating from noises that produce shock and vibration, which can perturb the natural motion of the hand and fingers. This upgrade also will make the glove more robust in the battlefield environment, which is characterized by loud noises, shock, and vibration from gunshots, bombs, and low-flying aircraft.

Another future modification will be for the robot to transmit haptic signals to the glove, thus creating a tactile image of an object as the robot's claw narrows its gap around the object, thus simulating the feel of the object in the user's hand. This could enable better handling of fragile items as well.

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