STUDY ON REMOTE CONTROL FOR FIELD ROBOT AND AUGMENTED REALITY VISION USING HEAD TRACKER SYSTEM

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ABSTRACT
Operating excavator on the risk surroundings is not safe for human to control on site. Consequently, automatic excavator called Field Robot has been researched to protect the workers from the hazardous environments. The remote excavation system is required to perform in such environments. This paper presents the study on remote control system for the Field Robot and augmented reality vision for user using head tracker system. The design of the remote control system that consist Remote Station and Filed Robot. In Remote Station, user can send the control commands through wireless communication. Besides, the Inertial Measurement Unit (IMU) sensor is integrated in a head mounted display (HMD) to track the motion of human’s head. These signals are transferred to the pan/tilt motor controller and to operate the motion of the CCD camera following the movement of operator’s head. The Field Robot is also contributed and some experiments are carried out to prove the feasibility of the proposed system.

KEY WORDS
Remote Control, IMU, Head Tracking, Field Robot, Vision

NOMENCLATURE

\begin{align*}
a \text{ (m/s}^2) & : \text{acceleration of object} \\
F \text{ (N)} & : \text{interaction force} \\
I \text{ (kg.m}^2) & : \text{moment of inertia} \\
k \text{ (N/m)} & : \text{stiffness of spring} \\
m \text{ (kg)} & : \text{mass of object} \\
L \text{ (Nm)} & : \text{angular momentum} \\
x \text{ (m)} & : \text{displacement} \\
\alpha \text{ (rad/s}^2) & : \text{angular acceleration} \\
\tau \text{ (Nm)} & : \text{torque on the gyroscope} \\
\omega \text{ (rad/s)} & : \text{angular velocity}
\end{align*}

INTRODUCTION
An excavator is used in general versatile construction operations. However, operating excavator on the risk surroundings is not safe for human to control on site [1]. Consequently, automatic excavator called Field Robot has been researched to protect the workers from the hazardous environments. The remote excavation system is required to perform in such environments. Besides, in this application, the pan/tilt camera is often used to help the operator to monitor the operating of the Field Robot and its working space. Normally, to control the pan/tilt
camera, user interacts the command interface by hand. However, other tasks often require a combination of complex manipulations such as excavator movement, attachment operation and swing. Therefore, a method to control the movement of pan/tilt CCD camera without hand should be considered and developed. This paper presents the study on remote control system for the Field Robot and augmented reality vision for user using head tracker system. The design of the remote control system that consist Remote Station and Field Robot is described in Figure 1. User is able to operate the robot via the joysticks and observe the working area by wearing a Head Mounted Display (HMD). An Inertial Measurement Unit (IMU) sensor is integrated in this HMD and detect the head’s movement of the worker. Then, these signal are received via the controller of Remote Station. The controller analyzes and transfer the information of Pitch/Yaw rotation angle to the control signal receiver of the Field Robot. The controller of the Field Robot analysis these data and drive the servo motors of pan/tilt CCD camera base via the desired rotation angle. The Field Robot is also contributed and some experiments are carried out to prove the feasibility of the proposed system.

![Figure 1 Design of the remote control system and augmented reality vision for Field Robot](image)

**MOTION TRACKING BASE ON IMU SENSOR**

An Inertial Measurement Unit (IMU) contains the Accelerometer sensor and Gyroscope sensor which are placed on three perpendicular axes to keep track of the position and orientation.

A single axis accelerometer consists of a mass, suspended by a spring in a housing. Springs are governed by a physical principle known as Hooke’s Law (1). This states that a spring will exhibit a restoring force which is proportional to the expansion or compression amount.

\[ F = kx \quad (1) \]

The other important physical principle is that of Newton’s second law of motion which states that a force operating on a mass which is accelerated will exhibit a force with a magnitude as:

\[ F = ma \quad (2) \]

This force causes the mass to either compress or expand the spring under the constraint that:

\[ F = ma = kx \quad (3) \]

Hence an acceleration a will cause the mass to be displace by:

\[ x = \frac{ma}{k} \quad (4) \]

If we observe a displacement of x, we know the mass has undergone an acceleration as:

\[ a = \frac{kx}{m} \quad (5) \]

In this way, the problem of measuring acceleration has been turned into one of measuring the displacement of a mass connected to a spring. In order to measure multiple axes of acceleration, this system needs to be duplicated along each of the required axes.

Gyrosopes are instruments that are used to measure angular motion. Mechanical gyroscopes operate on the basis of conservation of angular momentum by sensing the change in direction of an angular momentum. According to Newton’s second law, the angular momentum of a body will remain unchanged unless it is acted upon by a torque. The fundamental equation describing the behavior of the gyroscope is:

\[ \tau = \frac{dL}{dt} = \frac{d(I\omega)}{dt} = I\alpha \quad (6) \]

The IMU combines all the advantages of the two single systems described above, e.g., low latency, high frequency, self-contained, small, light and robust. A basic algorithm to derive the pose of an object is shown in Figure 2. At first the orientation is calculated by integrating the angular rates provided by the gyroscopes. Using roll, pitch and yaw from this step, the accelerations are rotated from the body into the world frame. The position is then derived by a simple double integration of the world frame acceleration values. [2]-[5]
**SYSTEM CONFIGURATION**

**Hardware setup**

The system consists of two modules:
- Remote station for the operator
- Field Robot

Remote station concludes the Joysticks for operating the attachment, swing, travelling of Field Robot. These control signals are inputs of the embedded controller and will be transferred via wireless transmitter. Field Robot includes the receiver to get the control signal from the remote station and input to embedded controller to operate the Field Robot valve system. The diagrams of Remote Station and Field Robot are presented in Figure 3 and Figure 4.

**Remote Station**

The Remote Station of the system is shown in Figure 5. It is designed with three modules which are wireless communication, user control interface and HMD integrated IMU sensor. Two above joysticks are used to control Field Robot’s attachment and upper-base swing and the below joysticks are used for left/right travelling of the lower-base. An IMU sensor is mounted to the HMD so that they are forced to move accordingly to the human head.

**Field Robot**

In our system, the Field Robot was used is Solar 105 manufactured by D company. To apply the remote control system some components consist sensors; embedded computer, wireless router, Electro...
Proportional Pressure Reducing (EPPR) valves were installed. The Field Robot side components are demonstrated in Figure 6.

Controller box

EPPR valves

Field Robot

Figure 6: Field Robot

Pan/Tilt Camera system

The CCD camera of vision system is placed on the top of driver seat and facing the ahead working area. This setup is carried out a first person view inside the cabin for the operator when control the Field Robot with the Remote Station. The vision system of the Field Robot is composed by CCD camera, pan/tilt base and wireless communication module that shown in figure 7.

Figure 7 Placement of Pan/Tilt CCD Camera system in Field Robot

EXPERIMENT AND RESULT

Experiment

In this application, the remote control combined with the head tracker system for Field Robot is proposed and some experiments are carried out and analysis the feasibility of the system. Two types of experiments are required to verify are remote control signal and the feeling of the user when using the head tracker system.

Figure 8: Head tracker system experiment.

The process of head tracker system experiment can be shown in Figure 8. User wears the HMD and move their head to observe the surrounding environment taken via the CCD camera.

The remote control with head tracking system experiment is described in Figure 9. User operated the Field Robot by using Remote Station. The task is to control the boom, arm, bucket and swing to complete the desired demanded working. This experiment verified the effective and the ability of the proposed system for remote control of the Field Robot.

Figure 9 Work task of Remote control experiment

The work task of this experiment shown in figure 10 can be separated in four steps that described below:

Step 1: Digging the soil in front of the Field Robot
Step 2: Lifting the soil and rotate the Field Robot upper-base 90 degrees clockwise (right).
Step 3: Empty the load from the bucket to a defined area.
Step 4: Rotating the Field Robot 90 degrees counterclockwise (left).
To ensure the effectiveness of the system, the task was implemented by five operators and the average operation time was measured for each person.

**Result**

The experiments for the work task were performed by five operators to verify the efficient of the proposed system. Each person repeated four steps of work task for 3 times. Two observation methods are applied to these tests as: vision with monitor (method 1) and vision with head tracking system (method 2).

- **Vision with monitor:** The user operates the Field Robot and watching directly the monitor from a safe distance with Field Robot as usual.
- **Vision with head tracking system:** the operator manipulates the Field Robot and using head tracking system to observe the surrounding environment and working area as well as control the pan/tilt camera. The result shown in figure 11 elucidates the consumed times of method 2 are smaller than the consumed times of method 1 for all five operators. Thus, the operated time is reduced via using our proposed system.

![Average operation time of five operators](image)

**REFERENCES**