Development of an Immersive Teleoperating System for Unmanned Helicopter

Masanao Koeda†‡, Yoshio Matsumoto†‡, Tsukasa Ogasawara†
Graduate School of Information Science
†Nara Institute of Science and Technology
‡CREST, JST(Japan Science and Technology)
8916-5 Takayama, Ikoma, Nara, Japan
Phone: +81-743-72-5376, FAX: +81-743-72-5379
E-mail: {masana-k, yoshio, ogasawar}@is.aist-nara.ac.jp
URL: http://robotics.aist-nara.ac.jp

August 11, 2004

Abstract

To collect the information on devastated districts, it is effective to use helicopters. However, the operation using manned helicopters costs a lot. It is expected that the use of unmanned helicopters can reduce the cost of these tasks. It is known to be more difficult to operate unmanned helicopters remotely than to operate manned helicopters. The reason is that an operator cannot know the attitude of the helicopter when the operator is far apart from it, and the coordination system between them varies drastically depending on the attitude of the helicopter.

In this paper, we propose an immersive teleoperating method of unmanned helicopters which allows an operator to control unmanned helicopters easily and intuitively as if the operator is on board. In this method, an operator controls a helicopter remotely while watching the surrounding views of the helicopter through a head mounted display(HMD). To verify the feasibility of the proposed method, we first developed a flight simulator and conducted comparative experiments. Then we developed an immersive teleoperating system of unmanned helicopters which consists of an omnidirectional vision sensor and a HMD with an angle sensor. The experimental results indicate our proposed method has an advantage over the conventional operating method.

1 Introduction

Recently unmanned helicopters are used for various purposes, such as crop-dusting and remote sensing. However, it is difficult for an operator to control unmanned helicopters remotely. One reason is that an operator cannot be aware of its attitude when the operator is far apart from the helicopter. Another is that the coordination system between the helicopter and the operator changes drastically depending on the attitude of the helicopter. To solve these problems, several studies have been made on autonomous helicopters [1, 2, 3]. Since autonomous helicopters need to have landmarks or flight paths in order to fly, they are not suitable for flight tasks where the situation changes every minute such as a disaster relief. Additionally, many sensors and computers for controlling are needed to mount on a helicopter. Since the payload of a helicopter is sharply small, autonomous helicopters tend to become large-sized, heavy, and expensive.

There has been a research area in which an efficient
operation of a remote vehicle is investigated, called teleoperation or telexistence[4]. Telexistence enables a human being to have a sensation of existence in a remote environment where a surrogate robot exists.

For instance, Tachi et al.[5] designed and developed telexistence master slave system TELESAR for remote manipulation experiments, and preliminary evaluation experiments of telexistence were conducted for the first time. By comparing the telexistence master-slave system with a conventional system such as observing through a CRT display, the efficacy of the telexistence master-slave system and the superiority of the telexistence method were demonstrated experimentally.

Hightower et al. developed the Remote Presence Demonstration System Greenman[6]. It had an exoskeletal master controller with kinematic equivalence and spatial correspondence of the torso, arms, and head. Its vision system consisted of two video cameras and eyepiece monitors mounted in an aviator’s helmet. Even with its simple claw hands and no force or tactile feedback, novice operators were able to perform manipulative tasks without training.

However, there has been few studies that tried to teleoperate unmanned helicopters. We consider the advantages of teleoperating unmanned helicopters, and the importance of an immersive teleoperating. Consequently we propose an immersive teleoperating system for unmanned helicopters.

2 Immersive Teleoperation of a Helicopter

Figure 1 shows the conceptual diagram of an immersive teleoperating system of a helicopter. In this system, a camera and a wireless video transmitter are mounted on a helicopter. The captured video image around the helicopter is sent to the operator during the flight. On the ground, a wireless video receiver picks up the transmitted image which is displayed to an operator through an immersive display. The operator controls the helicopter remotely by watching the surrounding views of the helicopter through the immersive display and operating a controller. The advantage of this system is that only a camera and a transmitter is necessary to be installed on a helicopter. Therefore it is possible to use a compact helicopter with a small payload, and make it light weight and cheap. Additionally, it becomes easy to control an unmanned helicopter because a coordination system between a helicopter and an operator doesn’t change even when the attitude of a helicopter changes. Furthermore, an operator can keep controlling even when a helicopter is out of the operator’s sight as long as the video image can reach the operator and the helicopter can receive the control signal.

3 Simulation

To verify the feasibility of the proposed method, we firstly developed a flight simulator and conducted comparative experiments.

3.1 System Configuration of Flight Simulator

Figure 2 shows the overview of the flight simulator developed for this experiment. This simulator consists of a personal computer, a HMD, an angle sensor, and a controller. An operator wears a HMD with an angle sensor which can measure the orientation of the head. The image displayed on the HMD changes according to the orientation, thus the operator can look around freely. The controller to operate the helicopter in the
Figure 2: Overview of flight simulator system

Table 1: Result of experiment using flight simulator

<table>
<thead>
<tr>
<th>Subject</th>
<th>Time[s]</th>
<th>Distance[m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>I</td>
<td>N</td>
</tr>
<tr>
<td>A</td>
<td>169</td>
<td>56</td>
</tr>
<tr>
<td>B</td>
<td>84</td>
<td>54</td>
</tr>
<tr>
<td>C</td>
<td>161</td>
<td>41</td>
</tr>
<tr>
<td>D</td>
<td>67</td>
<td>54</td>
</tr>
<tr>
<td>E</td>
<td>96</td>
<td>55</td>
</tr>
</tbody>
</table>

N:Normal flight mode I:Immersive flight Mode

This simulator is the same device as that used for a real radio-controlled helicopter.

This simulator has two modes: normal flight mode and immersive flight mode.

- **Normal flight mode (Figure 3)**
  The operator controls a helicopter wearing an HMD with an angle sensor, and watches the image around him. The operator can look around him as if the operator is standing on the ground.

- **Immersive flight mode (Figure 4)**
  The operator controls a helicopter wearing a HMD with an angle sensor and watch the image of the camera mounted on helicopter. In this mode, the operator can see the circumference of the helicopter as if the operator is on board.

3.2 Experiments with Flight Simulator

A task was given to five subjects to control the helicopter from a takeoff point to a landing point with avoiding an obstacle in the simulator. Figure 5 shows the allocation of the standing point of the operator, the takeoff point, the landing point and the obstacle. Since all subjects had no experience in operating a radio-controlled helicopter, the experiments were conducted after making practice for 10 minutes in both modes.

Table 1 shows the experimental result comparing normal flight mode to immersive flight mode. The time to complete and the total flight distance from the takeoff point to the landing point are shown. Comparing by the time, all the subjects completed the task faster using immersive flight mode than using normal flight mode. Similarly compared by the total flight distance, three subjects (A, B and C) flew shortly using immersive flight mode. However all the other subjects (D and E) took almost the same
Figure 5: Allocation of takeoff point, landing point, and obstacle

Figure 6: Developed immersive teleoperating system

time. Since A, B, and C cannot know the attitude of the helicopter when the operator is far apart from it, they cannot operate well in normal flight mode. On the other hand, D and E get accustomed quickly to operate the helicopter, they can operate it in both modes.

Therefore it is clear that the operator must take long time to complete the task in normal flight mode.

4 Implementation

4.1 System Configuration

Figure 6 and 7 illustrate the overview of the developed immersive teleoperating system, and Table 2 shows the specification of this system. In this system, an omnidirectional camera[7] and a wireless video transmitter are mounted at the bottom of the helicopter. An omnidirectional image is sent by a transmitter(Figure 8). Using a hyperboloidal mirror, it is possible to convert an omnidirectional image to perspective images of a virtual camera. Since panning and tilting of the camera can be simulated by generating view-dependent images from omnidirectional images, there is no need to attach the mechanisms to rotate the camera on the helicopter.

The system on the ground consists of a portable personal computer, a wireless video receiver, a HMD and an angle sensor. A received omnidirectional image is captured by the PC and converted into perspective images(Figure 9). Then the converted image is displayed on the HMD which the operator wears. The angle sensor attached to the HMD is utilized to measure the head pose of the operator. The displayed image to the HMD changes depending on the head direction of the operator. As a result, the operator can control a helicopter with high immersion.

<table>
<thead>
<tr>
<th>Table 2: Specification of developed system</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Helicopter</strong></td>
</tr>
<tr>
<td>HIROBO TURUGI XX</td>
</tr>
<tr>
<td>Length: 1.33[m]</td>
</tr>
<tr>
<td>Height: 0.64[m]</td>
</tr>
<tr>
<td>Payload: 1.2[kg]</td>
</tr>
<tr>
<td><strong>Camera</strong></td>
</tr>
<tr>
<td>ACCOWLE</td>
</tr>
<tr>
<td>Omnidirectional Vision Sensor</td>
</tr>
<tr>
<td>(Hyperboloidal Mirror)</td>
</tr>
<tr>
<td>Resolution: 512x492[pixel]</td>
</tr>
<tr>
<td><strong>Transmitter</strong></td>
</tr>
<tr>
<td>RF BS-550GTH</td>
</tr>
<tr>
<td>Weight: 0.25[kg]</td>
</tr>
<tr>
<td><strong>PC</strong></td>
</tr>
<tr>
<td>OS: Linux</td>
</tr>
<tr>
<td>CPU: PentiumIII 500[MHz]</td>
</tr>
<tr>
<td>Memory: 256[MB]</td>
</tr>
<tr>
<td><strong>Receiver</strong></td>
</tr>
<tr>
<td>RF BS-120GRH</td>
</tr>
<tr>
<td><strong>HMD</strong></td>
</tr>
<tr>
<td>i-O DisplaySystems i-glasses! LC</td>
</tr>
<tr>
<td>Resolution: 450x266[pixel]</td>
</tr>
<tr>
<td><strong>Angle Sensor</strong></td>
</tr>
<tr>
<td>DATATEC GU-3013</td>
</tr>
<tr>
<td>Measurable angle:</td>
</tr>
<tr>
<td>±60<a href="roll,pitch">deg</a>,±180<a href="yaw">deg</a></td>
</tr>
</tbody>
</table>

4.2 Generating Perspective Images

Figure 10 shows the geometry of HyperOmni Vision. The projection from the point $p(x, y)$ on the perspective plane to the point $P(X, Y, Z)$ in space is given
by

\[
\begin{align*}
x &= \frac{f(b^2 - c^2)X}{(b^2 + c^2)Z - 2bZ\sqrt{X^2 + Y^2 + Z^2}} \\
y &= \frac{f(b^2 - c^2)Y}{(b^2 + c^2)Z - 2bcZ\sqrt{X^2 + Y^2 + Z^2}}
\end{align*}
\]

where \( b, c \) are the parameter of the hyperboloidal mirror and \( f \) is the focal point of the camera. By computing above geometric transformation between \((x, y)\) and \((X, Y, Z)\), a perspective image viewing an arbitrary direction from the focal point can be generated. Real-time computation was achieved by making lookup tables every 2[deg] for the transformation.

4.3 Experiments with Developed System

In order to verify the feasibility of this system, we conduct an experiment to hover an unmanned helicopter using the developed system. The situation of an experiment is shown in Figure 11. The operator controlled the unmanned helicopter while looking at only the image displayed on the HMD. We confirmed that it is possible to control the helicopter in the situation that the operator can not see it directly.

5 Conclusions

In this paper, we proposed an immersive teleoperating method of an unmanned helicopter which allows
an operator to control it easily. To verify the feasibility of the proposed method, we developed a flight simulator and conducted comparative experiments. As a result, it turned out that the operation of an unmanned helicopter became easy by using this method. Then we developed an immersive teleoperating system of an unmanned helicopter which consists of an omnidirectional camera and a HMD with an angle sensor. The experimental results with flight simulator indicate our proposed method has an advantage over the conventional operating method.

**Acknowledgement**

This research is partly supported by Core Research for Evolutional Science and Technology(CREST) Program “Advanced Media Technology for Everyday Living” of Japan Science and Technology(JST)

**References**


