Internet based bilateral Teleoperation System for Quad-rotor Flying Vehicles

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Abstract: **In this work, we propose haptic-based bilateral tele-operation for quad-rotor vehicles by using Internet communication infrastructure. The idea is to introduce shared autonomy to increase remote operation and manipulation capacity of the vehicle in uncertain flying environments. The design couples ground and remote sites by position and velocity signals of the master haptic and slave quad-rotor vehicle. Force reflection using haptic feedback provides human operator with a certain kinesthetic feeling of the interaction between vehicle and environment increasing the autonomy of the vehicle. The result will be an innovative human machine interface where the force feedback will complement the visual information during tele-operation surveillance tasks, enabling safe maneuvers. The experiments will be performed for indoor operation where this technique will achieve major impact.**

Keywords: Tele-operation, Human-Machine Interfaces, Haptic Shared Control, Lyapunov Control Methods.

I. INTRODUCTION

The popularity of small quad-rotor vehicles increased recently. This popularity arise due to the fact that quad-rotor's is easy to build and operate and have many potential uses in various applications, such as, surveillance for civilian and law enforcement infrastructure facilities, inspection and monitoring of borders, power grid lines, oil/gas pipelines and highways. An important feature of quad-rotor is that it can perform autonomous navigation tasks in dangerous and awkward environments that are inaccessible for human intervention. Recently, there is also a growing interest in developing advanced quad-rotor flying vehicles beyond simple locomotion and observation to physical interaction with various remote objects and environments. This, in fact, may extend quad-rotor's operation and manipulation in remote location to grasp, manipulate, retrieve and carry external payloads or physically interacting with the objects in the presence of the rough remote environment. An outline of this proposal is as follows. Section II describes the problem statement. Section III presents the related work. In section VI, we illustrate the methodological approach. Section V presents the expected contribution.

II. PROBLEM STATMENT

The current available autonomous tracking systems for quad-rotor [1 and 2] need human inspectors that are highly trained and specialized for inspection, search, and rescue or surveillance tasks. However, visual evaluation of the distance between quad-rotor and the target/obstacle may not be accurate because of the limited field of view resulting poor tracking performance and unstable control operation. Moreover, experience autopilot may even fail to achieve remote piloting due to the presence of complex aerodynamic effects either from uncertain environment or the interaction between the vehicle and the target object. Therefore, it is very important to develop new types of robotic interfaces for these devices. In this article we propose to integrate human operator with the flying vehicles through haptic device as shown in the Fig1. This setup allows the use of operated quad-rotor remotely from ground in order to perform surveillance tasks precisely and safely.

III. RELATED WORK

Algorithm design for haptic based tele-operation of unmanned flying robot can be traced from literature [3-8]. The existing designs can be classified into two categories as visual feedback and haptic feedback based tele-operator design. Authors in [3,8] proposed visual feedback based tele-operation strategies for miniature rotorcraft and quad-rotor helicopter for indoor environment. These designs have not been used haptic feedback to maneuver the flying vehicles. Well known artificial force fields from mobile robot research area were used to map the environment force for haptic feedback for tele-operation of the aerial vehicles in [4, 5, 6]. In [7], authors used optical flow from on board camera to generate force feedback to the human operator in order to avoid collision of the tele-operated flying vehicle. The method uses

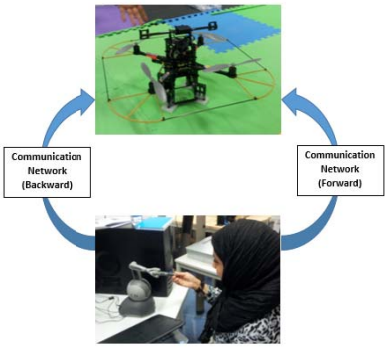

Figure 1: Tele-operation of quadrotor vehicle with visual and haptic feedback

optical impedance mapping approach to generate force feedback from the optical flow field. In view of the existing results, we can see that current tele-operation technology uses either direct or dedicated transmission lines to exchange information between local and remote sites to ensure the reliability of the telecommunications lines and low latency. In reality, however, such a dedicated telecommunications lines are very expensive which varies with the distance of the local and remote sites. In this work, we investigate tele-operation of quad-rotor via using widely available commercial telecommunication such as Internet. Then, the existence of the data transmission delay in commercial network plays a significant role in achieving stability, transparency and remote manipulation task.

IV. METHODOLOGICAL APPROACH

In this work, we develop dynamical model for the tele-operation systems including human, master manipulator, quad-rotor vehicle, remote environment and apply algorithm introduced in [9-10] to operate quad-rotor device when local human and remote quad-rotor are connected by Internet based communication network. The design can stabilizes and tracks the quad-rotor vehicle remotely by human operator through haptic interface in the presence of networks delay in uncertain environment. The proposed design could be used to grasp, manipulate, retrieve and carry external payloads or physically interacting with the remote objects perfectly and safely in the presence of uncertain indoor and outdoor environment. The environment forces that are acting on the flying vehicles are estimated and reflected back to the human hand through haptic device as well as feeding back into the control of the vehicle. The position-velocity/command from grounded master haptic device is sent to the remote slave via communication channel. Haptic force reflection from remote vehicle can bring the human operator with a certain kinesthetic feeling of the interaction between the vehicle and environment such as complex aerodynamic effects induced from uncertain environment forces. The force feedback through the haptic device can complement the visual information which increases the performance and safety making the vehicle more intelligent. Using energy function, we can establish asymptotic stability conditions of the closed loop tele-operators under time delay.

V. EXPECTED OUTCOMES

The research effort will be divided into three parts. First, we will develop dynamical model for master-slave tele-operation systems. Second, we will design a haptic based tele-operation strategy for quad-rotor flying vehicle. Finally, the proposed methods will be simulated in virtual environment and tested experimentally on quad-rotor vehicle at Khalifa University of Science, Technology and Research.

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