L'evolved: Autonomous and Ubiquitous Utilities as Smart Agents

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Abstract
Ubiquitous computing has been focusing on creating smart agents that are submerged into everyday environments, however, recent development on physical computing is demanding a shift from calm computing to a physically engaging form. Computing is no more limited to increasing our comfort through passive and pervasive deployment, they can now be created as being more actively intermeshed into our physical tasks. We present *L'evolved*, autonomous ubiquitous utilities that assist in user tasks through active physical participation. They not only dynamically adapt to individual user needs, but also work in close tandem with the users. By harnessing drone technology, we realize the design and implementation of a flying lamp and a desk that affords free motions and computational controls. Through specific use scenarios of those exemplary utilities, we show how this new form of smart agents promises various new ways of interacting with our physical environments.

Author Keywords
Flying Furniture; Actuated Environments.

ACM Classification Keywords
H.5.2 User Interfaces: Input devices and strategies (e.g., mouse, touchscreen)

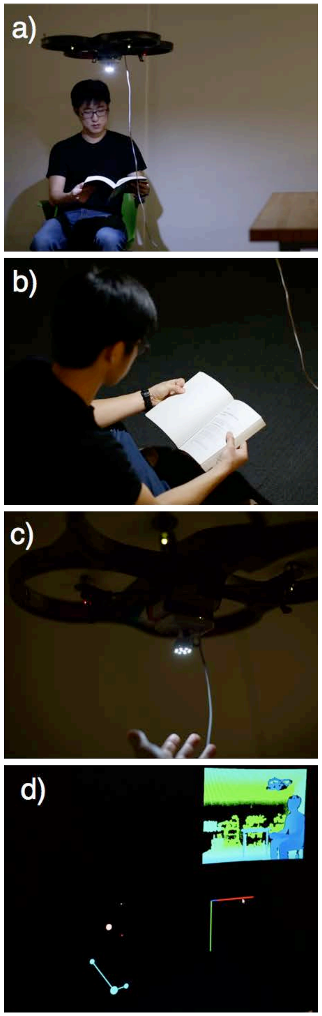

Figure 2: L'evolved lamp system. a,b) The lamp follows a user. c) Drone technology allows free 3D motion. d) User's activity is tracked using a depth camera

Introduction

We are surrounded by physical utilities that provide us opportunities for accomplishing different tasks. These utilities are, however, often standardized and physically constrained in terms of how they are used and the capabilities they offer. Therefore, the assistances provided by the machines are yet largely in a digital format, disconnected from physical spaces and environments.

Recent developments on physical computing touch upon the plausibility of moving 'engaging UbiComp' into physical spaces. Particularly, robotics technologies are migrating into everyday objects and environments, for example, moving and shape-changing furniture [2, 6]. These works show promising potential in augmenting present day utilities beyond their physical limits, and how autonomous smart agents can actively engage in our physical tasks in a more direct collaborative manner [4, 5].

In this demo, we present *L'evolved*, autonomous ubiquitous agents that transcend the notion of conventional static utilities. By leveraging the capabilities of drones to freely move around in 3D space, we can make products that dynamically adapts to users' need without restrictions in physical motion. More interestingly, they can play a more active role by enhancing and extending our capabilities to perform activities otherwise not possible. We present these ideas through example applications of a lamp and a desk.

Lighting

Traditional lighting systems, being fixed in a single position, have a lot of constraints in how we have to interact with them to achieve desired results.

Context and Spatially-aware Lighting

Using the smart lamp utility we built, one is essentially disengaged from the issue of controlling light to match one's need. The lamp flies to the position of a user and turns on its light. It follows the movements of the user, allowing for free movements or posture changes while reading in the dark. (Figure 1 (a,b))

Guide and Navigation

Our lamp also has the capability to direct a user's attention to a certain spatial position and thereby assist in navigation or a search for something. For example, the lamp remembers the last location where the user stopped reading a book and switched off the lamp. Later on, the lamp can light up above the book. (Figure 2)

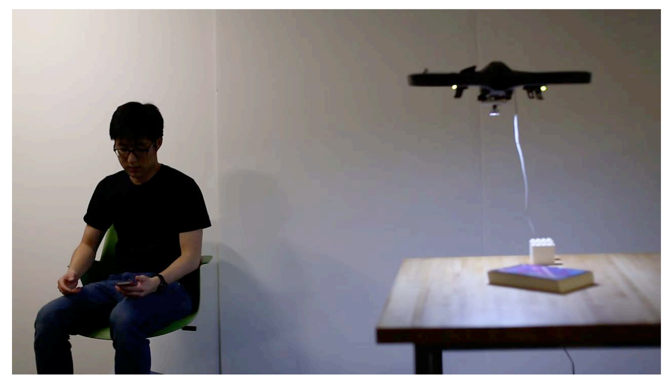

Figure 1: A lamp can direct a user's attention to a location or an object of interest. It can memorize the last location of a book the user was reading, and shed light on it upon the user's request

Figure 3: L'evolved desk system. a) Implemented using a drone attached to desk surface. b,c) The desk adapts to user's posture or walking position. d) Auto-eject capability adds preventing or alarming functionality to table

Furniture

We look at a basic furniture element, the desk, which is another essential utility that enables a lot of tasks that we carry out everyday. However, the static and unresponsive nature of desks causes a lot of adaptation on a user's side. We show how such user's adaptation endeavor can be reduced through *L'evolved* desk, made as a cubic wireframe structure with Balsa wood covering over the drone.(Figure 3 (a))

Dynamic Pose Adaptation

Through the desk's capability of dynamically adjusting position according to the user's movements, the user can effortlessly shift between sitting and standing at work. It can also be programmed to keep changing height after a certain interval of time for healthier working habit. Also, the desk is able to move around with the user, enabling the user to walk and write simultaneously. (Figure 3 (b, c))

Auto-Eject

By tracking and identifying markers on pens, it is possible to exploit the user's context around the task with the pens on the desk. If the user puts away a pen, the desk automatically goes away. If the user picks out a wrong pen, the desk flies away, auto-ejecting. Therefore, the desk can work in a very close tandem with the user, realizing a seamless and tightly coupled interplay between users and utilities. (Figure 3 (d))

Auto-Completion

Computational motion control of the desk can open up further design possibilities like auto-completing by the desk moving on a computed path when a person holds a pen over it.

System Implementation

The system consists of two main parts - a ground control tower for tracking and fixing the position of drones in 3D space and a human skeleton tracking system. The communications between the drones and the computer is done through Wi-Fi. (Figure 4)

IR Motion Tracking

We tracked the drones in 3D space by attaching retro-reflective markers, and capturing them with an Optitrack motion capture system [3]. In the desk implementation, we use the presence and positioning of different pens with different marker IDs to activate different desk utility modes as described above.

PID Control

The coordinates of the drone in space are sent to a computer, the central processing hub running different applications and sending control commands to the drone accordingly. We used the Parrot Drone 2.0 [1] SDK through which we send (roll, pitch, yaw, propeller speed) input to move the drones towards a goal position in space. Current positions of the drones from the motion tracker are fed into a PID loop, and the control parameters for roll, pitch, and propeller speed are computed using final goal position and PID gain parameters. The gains for the PID were optimized for the desk and lamp scenario separately, as different attachments to the drone result in different weights and balances, requiring optimization accordingly. The software runs at 30 frames per second, with very low latency.

This PID control system also benefits direct physical interaction with the table, as it provides additional stability once it is pressed away from its lock-in position. As a user writes, he automatically pushes the desk down, resulting in the drone trying to recoil back up due to PID control. This makes the desk stay more stationary, allowing high dexterity tasks like writing to be comfortable.

Tracking Users
Human position is tracked using a Microsoft Kinect Xbox 360. The kinect tracks the skeleton of a user. From this, we extract the co-ordinates of the head and the arms of the user. This data is used to estimate the rough posture of a user and is fed to the PID control loop.

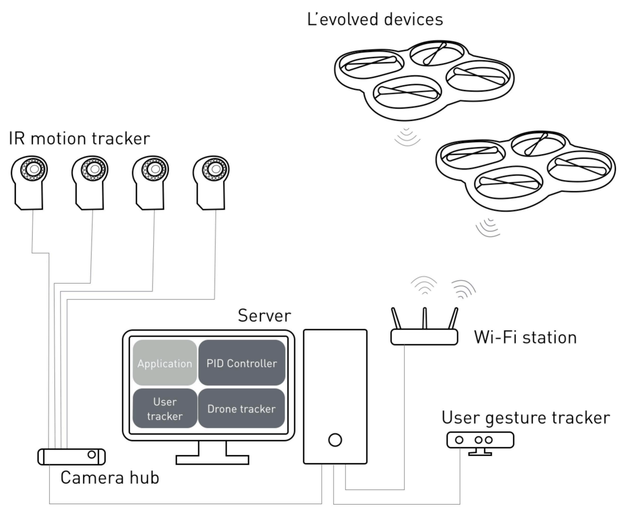

Figure 4: System Configuration

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