Fingermouse: A Wearable Hand Tracking System

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ABSTRACT
In this paper, we describe a system that implements limited hand tracking and gesture recognition capabilities in a small low power module. A first application is a mouse replacement, worn on the body, that captures the hand movement and allows the user to control a mouse pointer. The hardware is based on 2 image sensors, a distance sensor and a low power DSP. The software consists of different tracking algorithms supported by stereo vision based background clutter removal. Our system proves that computer vision can be useful even for mobile systems with strictly limited computational and power resources.

Keywords
Stereo vision, real-time hand finger/tracking, wearable

INTRODUCTION
In many situations, in particular when referring to real world objects, gesture and hand tracking are an attractive input mode for wearable computers. Unfortunately, gesture recognition and hand tracking in a mobile environment are tough challenges. In particular varying lightning conditions and a moving, cluttered background make a reliable recognition difficult.

Research on mobile gesture recognition has so far focused on algorithmic improvements paying little attention to the computation resources needed for their implementation. As a consequence most recognition systems (e.g. [3,4]) have relied on high end, power hungry systems or even stationary workstations connected to the wearable over a wireless network. This greatly reduces the usefulness of such systems as an input device for wearable computer.

Our approach addresses the computational resources problem in three ways. First, we restrict the scope of the recognition problem by requiring the hand to be in a certain fixed distance from the camera and to start tracking in a predefined position. Secondly we use a distance sensor together with stereoscopic vision to get rid of the cluttered background. Finally we have implemented a special purpose hardware module that allows us to execute the necessary algorithms with a fraction of the power consumption of a general-purpose machine.

As a result we have a system that is small, low power but nevertheless able to acquire images and compute them independently, so that it acts as an autonomous peripheral to a wearable computer.

THE HARDWARE:
AN AUTONOMOUS, LOW POWER VISION PLATFORM

The hardware consists of the sensors, the computing unit and the interfaces, as shown in Figure 1.

The Sensors
The Fingermouse includes two low power CMOS cameras that capture black and white images with resolution of 256 by 256 pixels and 10-bit depth. The optics are small, light lenses with a very wide viewing angle of approximately 100 degrees, so that the hand can be close to the sensors.

Furthermore, a third sensor measures the distance of the hand from the Fingermouse. This can be used in the stereo algorithms or as a means to find out if a hand is present at all.

The Computing Unit
The main computing unit has been designed to execute computer vision algorithms efficiently. We chose the Texas Instruments TMS320VC33 low power DSP, running at 75MHz. It features a floating point unit and enough internal RAM to store an image. Both are needed for most computer vision applications. An additional flash RAM chip stores the boot code and could also be used to store images or any other data. The complete power supply for the Fingermouse is included in the system as well, so that it can run from a simple battery. Interfaces are RS-232, JTAG and a 32-bit bus.
THE SOFTWARE:
REAL-TIME TRACKING ON A LOW-POWER DSP

An important constraint in our system is that the background moves, since the device is worn on the body. In this special case, we want to determine the position of a hand/finger in the captured image. This position is to be determined absolutely (e.g. the coordinates of the fingertip) or relatively, which would mean only relative movements would be tracked. A standard PC mouse also tracks the relative movement only.

Some algorithms are also able to determine the orientation (angle) and the scale (relative size) of the recognized hand. We will now briefly describe two of the algorithms that we have implemented.

Tracking the Contour

The algorithm used here [1], knows the shape and initial position of the hand. Starting from that, a prediction is made for the position, orientation and scale of the hand in the next captured picture. A new measurement in the predicted area then has to update the actual parameters. These allow again the prediction for the next step.

The measurement is performed only at a few control points along the shape of the hand. This has the advantage that the algorithm needs less computation resources. Kalman Filtering [1] is used to make the tracking robust against false measurements (that arise), for example, from a cluttered background.

Stereo Vision: Seeing the Foreground

Since the Fingermouse features two identical sensors in a stereo configuration, the so-called disparity may be used for the hand segmentation. The optics of the sensors are designed so that a far background is projected identically on both image sensors. The hand is much closer to the cameras and projects differently (Figure 5a, 5b). Thus, the background vanishes in the difference image (Figure 6a).

Simple thresholding and morphology operations are used to remove eventual noise (Figure 6b). Having a segmented image, a number of parameters may be computed like centroid, extremal boundary, the most significant orientation and others.

DISCUSSION AND FUTURE WORK

We have shown a system that implements simple but useful computer vision algorithms in a compact low power module. Our primary application is a gesture-based mouse like input device for a wearable computer with limited power and computational resources. However our hardware platform is suitable for a variety of vision and signal processing algorithms found in wearable applications, which it can execute at a fraction of the cost (in terms of power consumption) of a conventional computer system.

In the next stages of the project the performance of the system as a wearable mouse will be evaluated quantitatively and the implementation of more complex gesture analysis will be investigated.

At a later point, an ASIC solution could reduce the system’s power consumption by an order of magnitude.

ACKNOWLEDGMENTS

The Fingermouse was co-designed by Pascal Flammant, as a diploma thesis at the Swiss Federal Institute of Technology.

REFERENCES

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Results
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The Software
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People
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Poster Diagram (2m x 1m):