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MIDS: GUI and TUI in Mid-Air Using MEMS Sensors

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Abstract **– Why the mouse and the keyboard are the necessary input devices for a normal computer? A mouse can handle the Graphic User Interface (GUI) very well and a keyboard can help users to input text as a Text User Interface (TUI). However, there is no fundamental reason that GUI and TUI must be performed by separate input devices. The objective of this paper is to propose a multi-functional micro input device, which can handle both graphical based and text based input interfaces. The first prototype of a micro-input-devices system (MIDS) has been built by our research group. The MIDS is composed of sensors and processors that are used to process fingertip motion information and can be packaged in rings wearable by fingers. The motion information from the fingers could then be passed on to a wristwatch containing signal analyzers and potentially wireless transmitters to communicate with mobile computing devices wirelessly. In this paper, the performance of our MIDS system in measuring fingertip motion is compared to measurements acquired using high cost and high performance acceleration sensors. Our experimental results proved that MIDS is a viable approach to replace the mouse and the keyboard.**

Index terms **— Micro input device, Multi-functional input device, Wearable computer input device, Micro sensors**

I. INTRODUCTION

In the evolution of computer user interfaces, mice and keyboards were the primary devices in computer inputs. Although we have many other input devices such as light pens, keypads, wands and joysticks, mice and keyboards are still the most common input devices. Mice can get the input for graphical user interfaces (GUI) while keyboards can get the input for text-based user interfaces (TUI). Users can control the computer by using these two input devices for most applications. However, the computer designers tend to make the computer and its components as small as possible so that the computer becomes wearable, smaller in size, more compact and powerful. For example, notebook computers, wearable computers, PDA and Palms are popular mobile computers in the world. Traditional design of mice and keyboards may not be suitable for those small computers. It is necessary to have a new design of the user input device.

Comparing to those small computers, the traditional desktop has larger compatibility and are much more powerful. The monitor, computer case, mouse and keyboard are the four main parts for desktop computer in the working environment. In order to keep the advantages but still want to improve the desktop computer, we try to reduce the size of the input devices such that we can reduce the size of the desktop as well as laptop computers.

Although there are thousands of computer input devices in the world, to the best of our knowledge, not much wearable multi-functional micro input devices exist. For instance, Prince proposed a concept to develop a finger mounted computer input device, most likely it is a virtual keyboard [1]. B. Thomas et al. have done an evaluation of the virtual keyboard, forearm keyboard, and Kordic keypad input devices for wearable computers [2]. J.K. Perng et al. have developed an acceleration sensing glove for input text by recognizing hand-gestures [3]. S. Mascaro et al. have investigated a fingernail sensor to measure the finger posture and forces, which can be used to develop a virtual mouse [4][5]. Recently, there are two companies have promoted their new products in the one of the largest high-tech shows Comdex Fall 2001. Samsung designed another novel virtual keyboard, called Scurry. Its intended is for PDAs and the wearable computer [6]. Senseboard Technologies AB developed a new type of virtual keyboard, which allows mobile computer users to type efficiently without a physical keyboard [7].

Our design, MIDS, is the combination of the virtual mouse, light pen and virtual keyboard such that it allows user to input text, move curser, control drag and drop motion, draw computer graphics (CG) on the desk or in mid-air. Therefore, this novel computer-human-interface allows user to use only one input device to handle both graphical based and text based input interfaces. In order to catch up with the development of the computer, a small size, wearable and multi-functional input device is needed. MIDS can fulfill the need of the market.

II. MIDS: MICRO INPUT DEVICES

The final goal of this project is to design a micro-input-devices system (MIDS) by applying MEMS technologies. It will serve the functions of the present day mouse, light pen and keyboard such that it allows user to input text, draw graphical image, move curser, and control drag and drop motion. MIDS allows users to select the mode such that user can select what kind of virtual input device they want to use at that moment. This project uses MEMS sensors to measure multi-dimension force, acceleration of each finger and hand, and wireless transmit these information to the

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computer for input information process. In this paper, the first prototype and the schematic of the MIDS have been shown. With the initial measurements for fingertip, the performance of the MIDS can be estimated. Finally, two tests for fingertip using MIDS are compared with the initial measurements.

The MIDS includes four main parts. They are MIDS rings with MEMS sensors, wireless transmission watch, wireless transmission interface board for PC and the display interface program. The MIDS rings will be worn on the fingers with a wireless transmission watch on a wrist to act as a communication link between the sensors and the CPU. Inside the watch, a microprocessor is used to analyze the sensor signal and encode the signal for wireless transmission. Another microprocessor is placed in the wireless transmission interface board to decode the receiving data and convert the command signals to the PC. An illustration below in Figure 1 shows the comparison between traditional input devices and wireless MIDS.

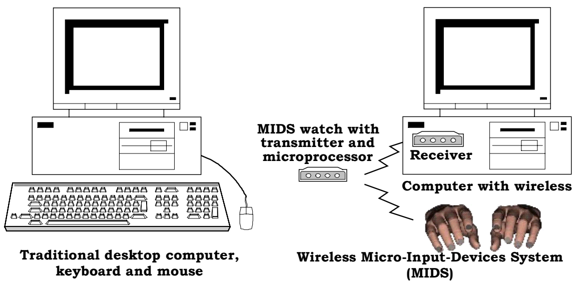

Figure 1: Configuration comparison between traditional input devices and wireless MIDS

There are many potential applications for this invention. Piano player can use the MIDS to play a virtual piano so that they need not to learn typing. Their piano keyboard input patterns can be transferred to the computer, which could translate and record the song or play it on the speakers directly. Another application is that users can use the MIDS to communicate through the Internet using conventional sign-language gestures, i.e., a users can just use sign-language motions and the computer can translate the motions into sentences without any typing form the fingers. One of the more meaningful applications for the MIDS will be its usefulness to help the blind. MIDS can help them make brail-based typing by using different finger motion patterns. When the finger motion patterns are transferred to the computer, the computer can translate those patterns to words and then save them as a document. Other applications for the MIDS will include emulation of a laser-pointer, and as a light pen for languages such as the Chinese.

With the MIDS, not only a revolution will take place for input devices, but also computer development may enter another generation. It is foreseeable that virtual reality glasses will replace the monitors for mobile computers, and the MIDS can be used as input devices. Imagine this: carrying a sunglasses and a very compact CPU box, and wearing a wireless-linkage watch and two gloves embedded with the MIDS sensors and batteries – one can work conveniently in many places not possible today. Our invention will make this possible in the near future.

A. MEMS Sensors for Multi-axes Force Sensing

In the MIDS, one of the most important parts is the MIDS ring. Figure 2 shows the schematic of the MIDS ring. There are two dual-axis MEMS accelerometers manufactured by Analog Devices Inc., two printed circuit boards and one ring-shape housing. In the Figure 2, sensor A is placed at the top of the MIDS ring horizontally. It is used to measure the fingertip acceleration in x and y direction. Sensor B is placed at the side vertically to measure the acceleration in y and z direction. Therefore, sensor A can detect the plane motion of the fingertip and sensor can detect the fingertip angle and the vertical movement.

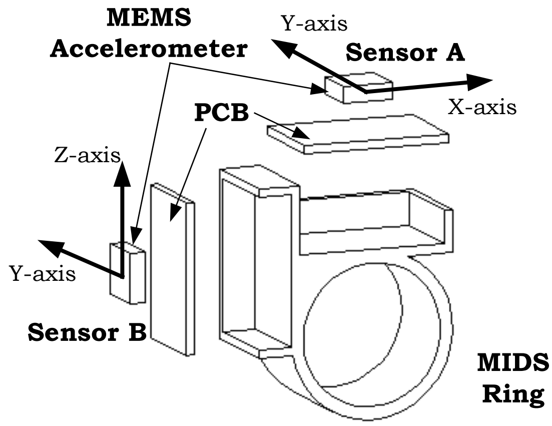

Figure 2: Schematic of MIDS Ring

B. Wearable Wireless MIDS

The first generation prototype of our MIDS has been built. Figure 3 shows the prototype of MIDS ring. The ring-shape housing has been made by rapid prototyping machine. Two MEMS accelerometers are placed on the PCBs and connected to same battery cell from the watch.

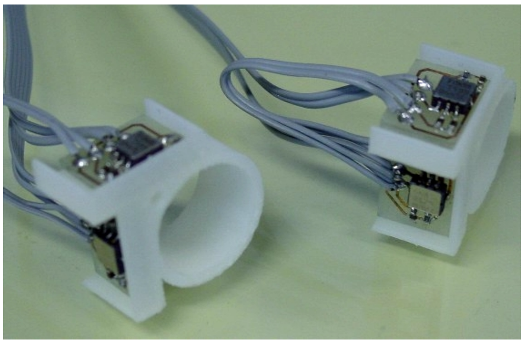

Figure 3: Prototype of MIDS rings

The data acquirement has been shown in Figure 4 and Figure 5 shows the whole wearable MIDS prototype. The microprocessor at90s8515 is used to count the duty cycles of the sensing signals and convert the signals to acceleration information. Then the Radiometrix TX2 transmitter is used to transmit the packed signal one by one. One the other side the RX2 receiver passes the received data to another microprocessor and the data will be unpacked and the command define function will base on the data to define and pass the suitable commands to the PC from the serial port.

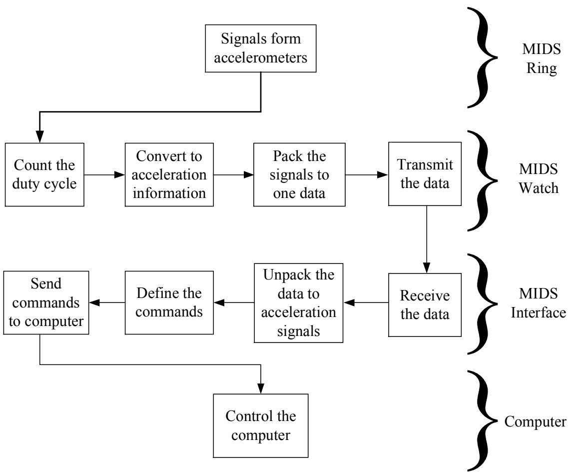

Figure 4: Data acquirement for MIDS

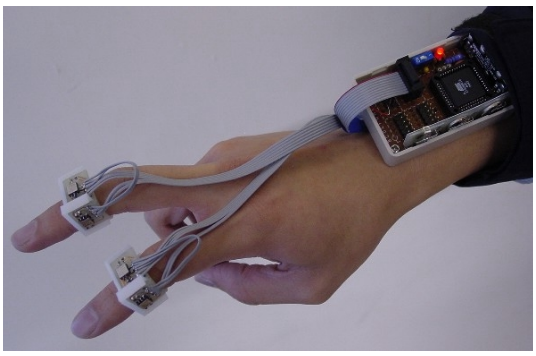

Figure 5: Wearable wireless MIDS prototype

III. Experimental Results

Experiments were performed to calibrate our MIDS using high-sensitivity commercial non-MEMS-based accelerometers. This will determine the upper bound sensing sensitivity for human fingertip motions, as the commercial non-MEMS based accelerometer has more than 10 times the sensitivity of the MEMS-based sensors used to build our MIDS rings. Two calibration experiments were performed: 1) measurement of the fingertip motion in z-axis for click motion detection; 2) measurement of the fingertip movement on x-y plane to determine the trajectories of the movement as sensed by the motion sensors. The results are compared below.

A. Measurement of Finger Tip Motion Using Non-MEMS-Based Sensors

The experimental setup for fingertip motion measurement is shown in Figure 6. Two Bruel & Kjaer accelerometers are placed on a fingertip and connected to a charge amplifier. The signals are then passed to the computer through dSPACE DSP board with Matlab real-time-workshop toolbox.

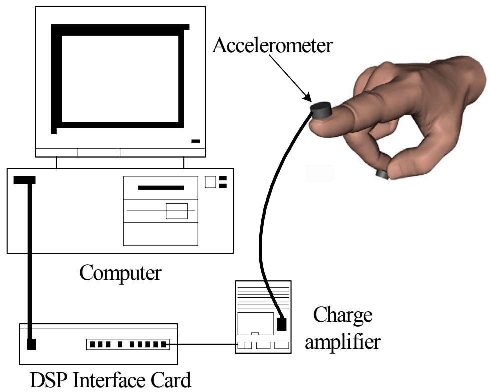

Figure 6: Experimental setup for fingertip motion testing

1) Fingertip motion test 1: click motion in z-direction

Measurement for click motions in z-direction is shown in Figure 7, which basically shows the up and down motions of the fingertip. Three cases are distinctive in the data plot: one peak (a), two peaks (b), and three peaks (c). As indicated in the figure, the time duration for each of the sampled motion is about 1 second. Regions (a), (b) and (c) shown in the figure correspond to single-click, double-click and triple-click, respectively. These results show that the accelerometer could detect the click motions (even for triple-click) within a short time (about 1 second). The sampling frequency used for this experiment is 100data/sec (0.01sec/datum). The response time of the sensors are fast enough to measure the fingertip motions based on our experimental observations.

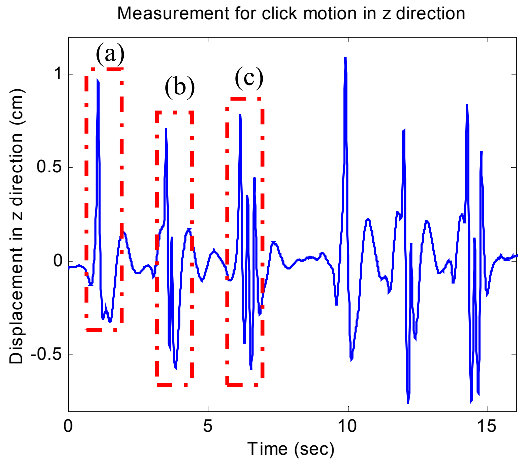

Figure 7: Measurement for click motion in z-direction

2) *Fingertip motion test 2: drawing a circle on the x-y plane*

The motion of a fingertip as it traverses around a circular path was also measured. (The circular path was imagined by the experimental subject; no reference circular path was placed on a table for the subject to follow.) The time-sequence data of the 2 sensors on the fingertip is shown in Figure 8, and the corresponding displace plot in the x-y plane is shown in Figure 9.

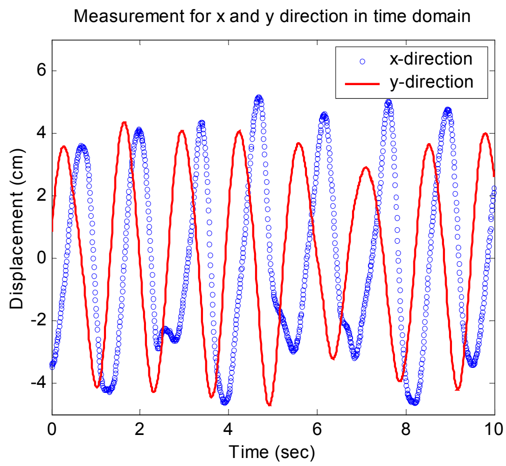

Figure 8: Fingertip motion in time domain from 2 different sensors

As shown in Figure 9, the commercial sensors could sense the fingertip motion quite well as indicated by the smooth pathlines.

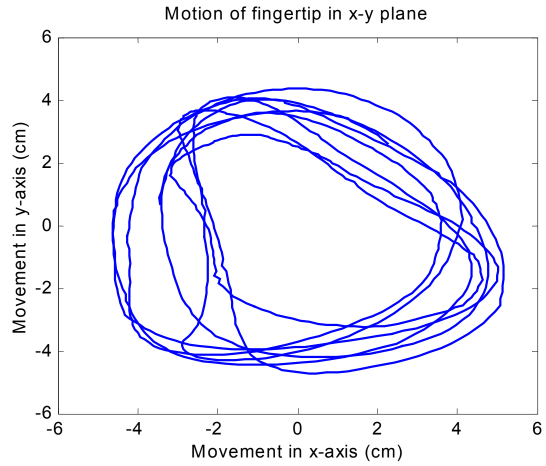

Figure 9: Fingertip pathlines on x-y plane

The experimental results above demonstrate that high-resolution commercial accelerometers could capture the fingertip motion quite well in both the z-direction and in the x-y plane with a fast response time. Therefore, we can conclude that an accelerometer is suitable for detecting the fingertip motion. However, the non-MEMS-based sensors used were bulky and expensive (~US$1000/each), have only one-axis sensing capability per sensor, and require a very expensive signal processor (a charge amplifier) to acquire data. On the contrary, the MEMS-based sensor has two-axes sensing capability and is packaged in volume 1/2 the size of the non-MEMS-based sensors, and only cost ~US$10 per sensor.

B. Experimental Results from MIDS\

Our MIDS (as shown in Figure 5) was tested using the same procedures from the above experiments. The result from fingertip clicking motion measurements is shown in Figure 10. As shown, the MIDS performed excellently as the single-click, double-click, and triple-click motions could be measured distinctively. The response time of the MIDS is fast enough to record a triple-click motion within a second as shown in the figure. Moreover, experimental results, as shown in Figure 11 and Figure 12, also indicate that the MIDS could also detect circular motion. Note, the circular paths are not as smooth as those shown in Figure 9, because the sensitivity of MEMS-based sensors are lower than the Bruel & Kjaer sensors. However, this problem can be solved by increasing the gain of the MIDS signal conditioning circuit, which is one of our ongoing efforts.

With the above results, we have shown that the MIDS could handle operations of existing common input devices. For the mouse, MIDS could detect the movement on x-y plane such that it could move a cursor and also handle the click motion; for the keyboard, MIDS could detect the finger movement (as a finger moves from one key to another) and the key-press action (as the finger types a key); for the light pen, MIDS could capture the trajectory of the finger such that it can draw a desired curve either in a fixed 2-D plane or in 3-D space.

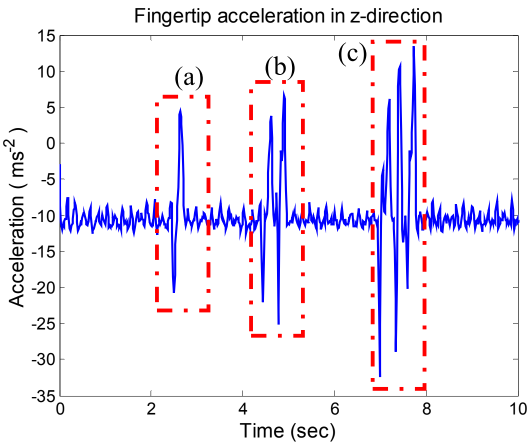

Figure 10:MIDS click motion test in mid-air

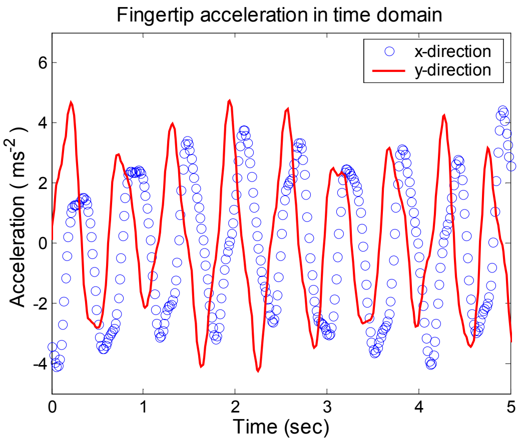

Figure 11: MIDS circular motion test on a desk (time sequence acceleration)

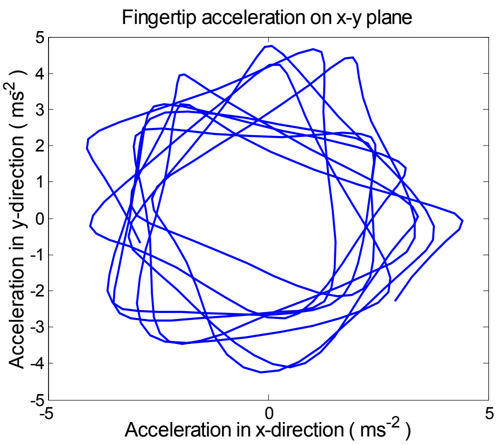

Figure 12: MIDS circular motion test on a desk

IV. Conclusion

A novel multi-functional wearable micro-input-device has been proposed. The schematic of the MIDS and the method of data acquirement have also been presented. The first prototype of MIDS has been made with click motion and circular motion tests. The performance of the MIDS is validated by commercial accelerometer. The results show that the MIDS can handle the operations of existing common input devices including mouse, keyboard and light pen. In the short future, the demonstration for virtual mouse, virtual keyboard and virtual light pen will be shown. With the MIDS Interface, the operations of MIDS can be displayed in the virtual environmental inside the computer.

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