An Optical-Tracking Calibration Method for MEMS-Based Digital Writing Instrument

A Ubiquitous Digital Writing Instrument (UDWI) has been developed by our group to capture and record human handwriting or drawing motions in real-time based on a MEMS Inertial Measurement Unit (μIMU). Although both the hardware and software of the UDWI have been steadily improved over the past year, noise signal can still exist to affect the UDWI system output. The noise may include the intrinsic drift of the sensors, misalignment of the sensors during PCB integration, and random noise, which are impossible to totally eliminate. Hence, in reality, we have to compensate the sensor drift after a hand-writing stroke is completed, which would lead to a delay during real-time hand-writing recognition. However, if a model is available for real-time errors in advance, a more effective compensation algorithm could be developed to overcome the drift. Therefore, we propose a novel idea of optical tracking technique to complete this calibration job.

This technique mainly consists of two components: one is the matching algorithm, which is operated in Microsoft Visual C++ environment; the other is the calculation of motion vector, which runs in MATLAB to convert the position into velocity and acceleration. After combining the two parts, it is possible to obtain the right data to carry out the comparison with the sensor output from the hand-writing video record. The matching algorithm is used to find out a block which has the most similar sum grey value of all pixels included to the template defined in advance. The found block has the same area as the template does and we use the left-upper corner point to display the location of each block. The criterion here is correlation coefficient. Usually, a template is defined as the position of pen tip as in camera view. After similar blocks are found, motion vectors in pixel can be obtained. Then they can be converted into practical units, such as millimeter. Next, according to a mathematical model we assume based on very tiny time interval between, the velocities are derived first. Then accelerations are obtained.

The camera used in this job is a special one which has a maximum sampling rate at 1,000 Hz. Since our Micro Controller Unit (MCU) has been set at 200Hz, which is fast enough to trace human hand-writing motion, the exposure time of out high speed camera is 0.005 second. Thus, a sequence of pictures is available to describe an entire hand-writing motion pin by pin. In addition, as introduced above, the matching algorithm helps us analyze motion vectors between two neighbor pins by calculating the sum of grey values of each block. Eventually, groups of information, including position, velocity and acceleration, are guaranteed and regarded as a reference to what we have from the μIMU. Actually, the accelerometers are working very well to provide us with accelerations. However, after integral of acceleration twice to have position information to reconstruct what people write, terrible drift happens. After setting up this optical tracking system, we are able to find out accurate velocity and position information for integral.

Finally, they become expectable and revisable, which means to reconstruct characters written by UDWI from direct integral of accelerometers output becomes feasible.

In the future, some tools may be developed to carry out this calibration job instead of this optical tracking system. For example, researchers can design and manufacture a robot arm holding UDWI, which can be controlled precisely to finish various 2-D or 3-D motions. At the same time, if this robot arm has enough Degree of Freedom (DOF), we believe it will simulate human hand-writing motion better and more accurate, and, of course, that will be repeatable, all of which can benefit us a lot to build reference to calibrate those sensors.

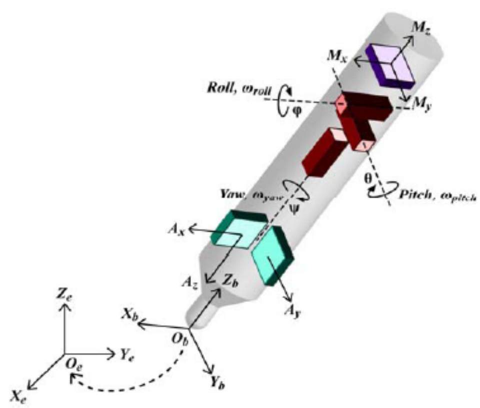


Figure 1. Coordinate frames of the UDWI

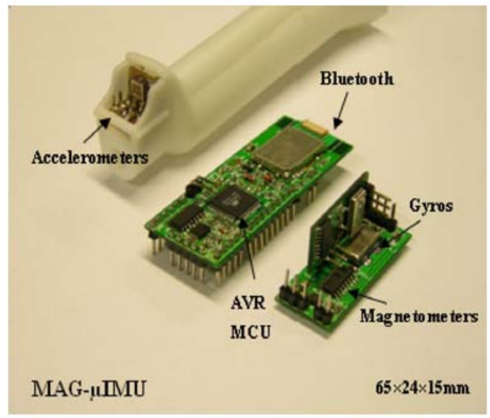
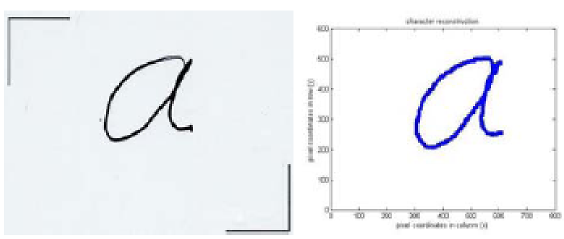


Figure 2. Major components of the UDWI: MAG- μIMU with Bluetooth Module



(a) (b)

Figure 3. Character comparison: a) the written one; b) the reconstructed one.

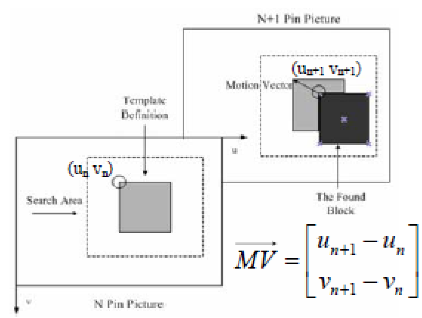


Figure 4. Estimation of motion vector

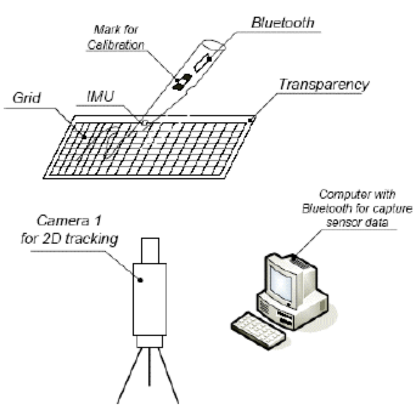


Figure 5. Schematic of writing and data collection

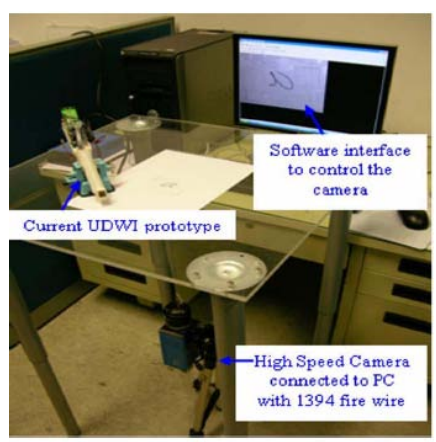


Figure 6. Experimental platform of 2D motion calibration

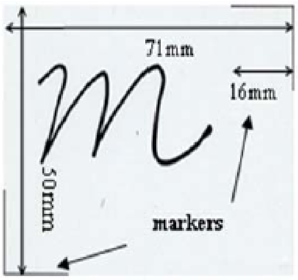


Figure 7 Transparency with paper as the background for writing

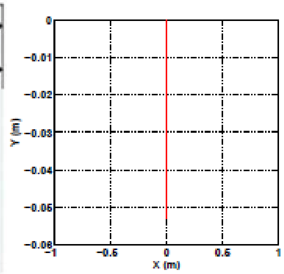
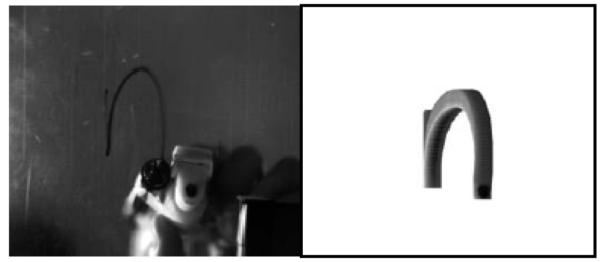


Figure 8. The reconstructed line by the matching algorithm



(a) (b)

Figure 9. Letter *n* from the experiment: a) the written one b) the reconstructed one consisting of each found block.

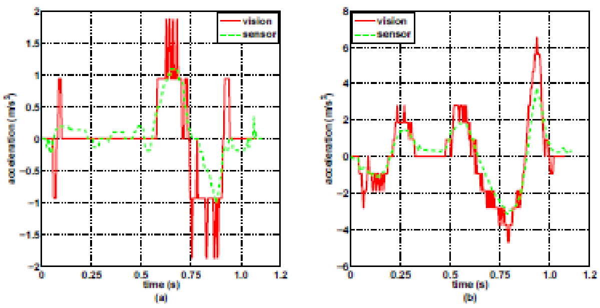


Figure 10. Comparisons of accelerations of letter *n*: a) in *x* axis b) in *y* axis

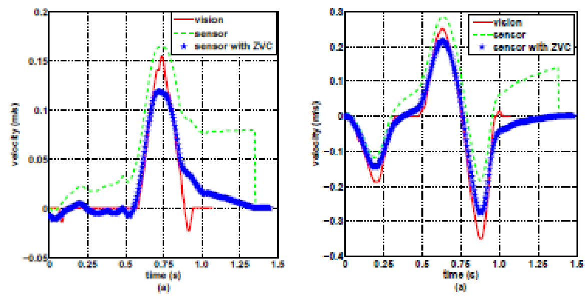


Figure 11. Comparisons of velocities of letter *n*: a) in *x* axis b) in *y* axis

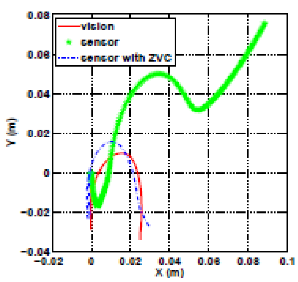


Figure 12. . Comparison of reconstructed with optical tracking, MEMS sensors, and MEMS sensors with ZVC correction of letter *n*

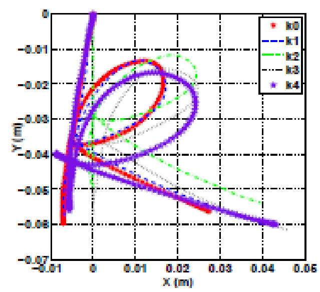


Figure 13. Letter *k* from optical tracking system and matching algorithm

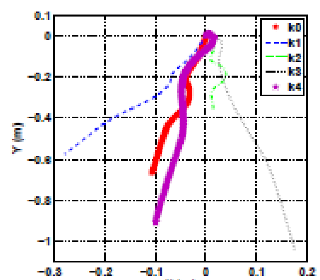


Figure 14. Tracks of letter *k* from sensors' raw data

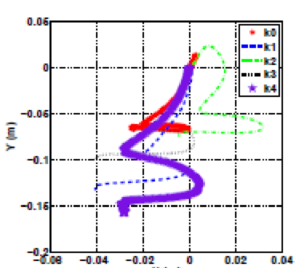


Figure 15. Tracks of letter *k* from sensors' raw data with ZVC

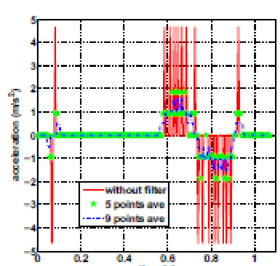


Figure 16. Curves of accelerations in *x* direction with different filters

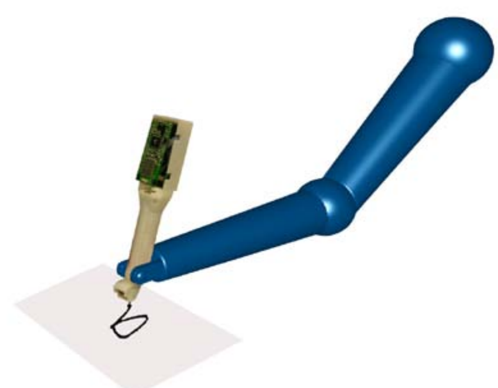


Figure 17. Future work: robot arm aid for calibration of MEMS sensor system