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CHAPTER 2: REVIEW OF RELATED LITERATURE

This chapter discusses the related literature and studies involving Microelectromechanical Systems (MEMS) Technology, its usage and the processes involve in its data analysis. The researchers reviewed the most recent available literature and studies that were highly related and of essence for the device to be constructed. Most of the involved articles are highly technical.

2.1. Microelectromechanical Systems (MEMS) Technology

As the name implies, Microelectromechanical Systems or simply, MEMS, is a technological combination of micro or miniaturized mechanical and electro-mechanical elements. These are made using the techniques of microfabrication.

Dimension wise, MEMS devices can vary from well below one micron on the lower end of the dimensional spectrum, all the way to several millimeters. Likewise, the types of MEMS devices can vary from relatively simple structures having no moving elements, to extremely complex electromechanical systems with multiple moving elements under the control of integrated microelectronics. The one main criterion of MEMS is that there are at least some elements having some sort of mechanical functionality whether or not these elements can move.

In 2007, researchers Amita Gupta and Amir Ahmad stated in their journal entitled “Microsensors Based on MEMS Technology” that the emergence of MEMS in that decade is considered as a major technology breakthrough since the invention of transistors. It is a combination of traditional silicon integrated circuit (IC) electronics with micromechanical sensing and actuating components.

While the functional elements of MEMS are miniaturized structures, sensors, actuators, and microelectronics, the most notable (and perhaps most interesting) elements are the microsensors and microactuators. Microsensors and microactuators are appropriately categorized as “transducers”, which are defined as devices that convert energy from one form to another. In the case of microsensors, the device typically converts a measured mechanical signal into an electrical signal.

The development and application of microsensors have grown considerably over the past several decades with common uses across various industries, such as automotive, pharmaceutical, environmental and manufacturing, to name a few. Common applications in automotive and aeronautical industries include accelerometers, gyroscopes, and navigation systems.

Ultimately, an article entitled “A Review of Actuation and Sensing Mechanisms in MEMS-Based Sensor Devices” (2020) presented the recent developments in standard actuation and sensing mechanisms that can serve MEMS-based devices, which is expected to revolutionize almost many product categories in the current era. The performance of sensors has been evaluated by various characteristic parameters, such as sensitivity, resolution, and accuracy.

2.2 Application of MEMS Technology in Writing System

As MEMS technology established a major improvement in technological aspect, this paved way for various innovations that utilizes this to reconstruct or to reimagine digital writing.

On 2010, Dong, et al. developed a Ubiquitous Digital Writing Instrument (UDWI) that captures and records human handwriting or drawing motions in real-time based on a MEMS Inertial Measurement Unit. This IMU consists namely of MEMS accelerometers, gyroscopes and magnetometers. This writing instrument interfaces with PCs in real-time via Bluetooth wireless protocol

In 2015, GyroPen is introduced by researchers Deselaers, Thomas, Keysers, Daniel, Hosang, Jan, Rowley, Henry. It utilized a method to reconstruct the motion path for pen-like interaction from standard built-in sensors in modern smartphones.

Similarly, M. Annie Priyadarshini and B. Naresh produced their own concept of MEMS based digital pen (2015). In their paper entitled "An Accelerometer-Based Digital Pen with a Trajectory Recognition Algorithm for Handwritten Digit and Gesture Recognition". They described that the users can use the pen to write digits or make hand gestures, and the accelerations of hand motions measured are wirelessly transmitted to a computer through a module.

Likewise, other researchers namely, Kalamathi B., Praba A., and Vennila V. published "An Accelerometer Based Digital Pen". Their hardware solution consists of a tri-axial MEMS accelerometer, ATMEL microcontroller, power supply, and an RF wireless transmission module. This research however focuses mainly in eliminating the use of keyboard. Thus, limiting human interaction to the computer.

2.3 Inertial Sensors, MEMS Technology Data Processing

In a written tutorial entitled "Using Inertial Sensors for Position and Orientation Estimation" authored by Manon Kok, Heroen D. Hol and Thomas B Schon on 2017, they tackled how MEMS based inertial sensor measurements are obtained at high sampling rates and can be integrated to obtain position and orientation information. These estimates are accurate on a short time scale, but suffer from integration drift over longer time scales. To overcome this issue, inertial sensors are typically combined with additional sensors and models. In the mentioned tutorial, it focused on the signal processing aspects of position and orientation estimation using inertial sensors.

Different modeling choices and important algorithms were introduced. These include optimization-based smoothing and filtering as well as computationally cheaper extended Kalman filter and complementary filter implementations. The quality of the estimates is illustrated using both experimental and simulated data.

Kok, Hol and Schon first identified the quantities measured by the inertial sensors namely: coordinate frames, angular velocity, specific force and sensor errors. Elaborating the coordinate frames the following specific frames were introduced:

Body frame (b)

It is the coordinate frame of the moving IMU. Its origin is located in the center of the accelerometer triad and it is aligned to the casing. All the inertial measurements are resolved in this frame.

Navigation frame (n)

It is a local geographic frame in which we want to navigate. In other words, we are interested in the position and orientation of the b-frame with respect to this frame. For most applications it is defined stationary with respect to the earth. However, in cases when the sensor is expected to move over large distances, it is customary to move and rotate the n-frame along the surface of the earth.

Inertial frame (i)

It is a stationary frame. The IMU measures linear acceleration and angular velocity with respect to this frame. Its origin is located at the center of the earth and its axes are aligned with respect to the stars.

Earth frame (e)

It coincides with the i-frame, but rotates with the earth. That is, it has its origin at the center of the earth and axes which are fixed with respect to the earth.

In the latter part of the tutorial a thorough discussion of Probabilistic Models were discussed considering the parametrizing orientations using rotation matrices, rotation vector, Euler angles, and unit quaternions. Lastly, estimating position and orientation processes were presented. These involves various smoothing and filtering methods. Evaluation of the overall method was through experimental and simulated data.

2.4 Synthesis

The researchers will then use the various the aforementioned IMU sensors and utilize the estimation introduced by Manon Kok, et al. As such, similar to the accelerometer-based digital pen, microcontroller will be an essential component of data gathering and transmission. Likewise, the processing will happen mainly on computer devices.