

Inertial MEMS, from Life Enhancing to Life Saving

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IDEA IN BRIEF

Use of Inertial sensors to meet emerging needs in the medical/health fields will help bring about significant quality of life enhancements.

Motion is both integral and essential to life. Those of us who are mobile are in seemingly perpetual motion, and for those that are immobile, mechanical aids of some form may be required to assist in providing motion. It is not difficult to imagine then how an inertial sensor capable of measuring this motion could become as valuable in delivering useful information about ourselves as an audio (microphone) or optical (camera) sensor is today.

When it comes to quality of life discussions related to MEMS, it may be useful to define varying degrees or stages, from measuring, to enhancing, to ensuring. As with audio and optical sensing, it is easy to identify applications where inertial sensors can measure, capture, or gauge an individual's output/health. For instance, a pedometer uses an accelerometer to detect steps and provide a measurement of fitness activity. It is also readily apparent that motion detectors embedded in a prosthesis for better balance/control can enhance the mobility of the disabled and that accelerometers detecting upright vs. prostrate positioning can be used for life-saving patient monitoring. In this article, we explore the technical challenges and range of complexity in motion

sensors, across the quality of life opportunities for measuring vs. enhancing vs. ensuring.

SENSOR PERFORMANCE

While the success of inertial MEMS sensors within the automotive and consumer markets has brought about rapid advances in sensor performance along some metrics, there is still a substantial difference in performance requirements between those existing applications and the still emerging needs of medical quality of life. To examine the broad level needs across applications, we can compare requirements in power, size, reliability, environmental robustness, performance, and performance drift. Power and size are possibly the only of these specifications that have already been pushed to extreme levels by consumer applications. Sensors developed for automotive also have typically required high levels of reliability and environmental robustness.

SINGLE SENSOR APPLICATIONS

Quality of life measurement applications, such as activity monitors, can benefit from low power, small size sensors but also require a high level of environmental robustness to be able to distinguish actual desired movement from other random influences. Quality of life enhancement tools can be separated into body-worn devices, such as prostheses, and surgical or diagnostic devices, such as a robotic surgery tool or portable ultrasound device. In either case, due to the increased level of active control vs. the passive monitoring of measurement devices, the performance and reliability demands are increased. To address quality of life ensurance, including micro remote surgery and other life critical monitors, not only is high performance required but also very low drift over time is needed, as well as minimal sensitivity to environmental influences.

Table 1. Relative Specification Comparison Across the Quality of Life Application Spectrum

Sensor Parameter	Impact on Quality of Life ¹			
	Measuring	Enhancing		Ensuring
		Body Worn	Surgical or Diagnostic	
Power	H	H	M	H
Size	M	H	M	H
Reliability	L	M	H	H
Environmental Robustness	M	M	H	H
Performance	L	H	H	H
Performance Drift	L	H	M	H

¹ Level of complexity, performance challenge: L = low-end; M = midrange; H = high-end, most challenging.

Table 1 establishes some relative figures of merit to compare the complexity of various types of quality of life applications across broad specification factors. Even for the relatively lower level requirement found in measurement devices, the combination of very low power and small size, along with the ability to reject temperature/shock/vibration influences, sets the needs of these applications apart from the simplest of consumer driven sensor needs.

MULTIPLE SENSOR APPLICATIONS

The discussion so far has been centered on the characteristics of an individual sensor, perhaps measuring linear motion (single axis accelerometer) or angular motion (single axis gyroscope). In reality, there are relatively few real life scenarios where motion is limited to (or discernible by) a single sensor type or single axis. To capture the most precise representation of motion, or to allow use under unrestricted conditions (mounting position or range-of-motion), it is typically required to intelligently merge multiple sensors and accurately align the sensors to the application reference

frame. So, beyond the basic transducer element, the mechanical and sensor/signal-processing requirements also vary widely, and increase in complexity as we move from measurement to enhancement to insurance.

An interesting example can be found in the use of inertial sensors in the operating room for more accurate alignment of artificial joints (knee or hip) to a patient's unique anatomical structure. This quality of life enhancing application aims to improve joint alignment to less than one-degree error from the patient's natural alignment axis, vs. what is often a three-degree or larger error today with purely mechanical alignment approaches. This has the potential of offering less invasive and shorter surgery time, as well as substantially more postoperative comfort and longer lasting joint replacements.