

# Inertial Measurement Units in Gait and Sport Motion Analysis

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## INTRODUCTION

Inertial measurement units (IMUs) comprising accelerometers and gyroscopes have recently found use in a wide range of motion analysis applications after the invention of micro-electromechanical systems (MEMs). IMUs have been receiving an increasing interest because of their size, low power consumption, cost-effectiveness and portability. They have opened new avenues to human motion analysis, overcoming the limitations such as high cost, limited to closed environments, positioning of multiple cameras, alignment issues and occlusion in the traditional laboratory based motion analysis systems. In this article the usage of IMUs will be presented in two sections covering the two major branches of human motion analysis: 1) Walking gait and 2) Sports. The first section will demonstrate that the IMUs, along with advanced machine learning techniques, are able to differentiate walking patterns affected by sensorimotor disruptions. This will bring insight into abnormal or pathological walking patterns and may lead to ubiquitous gait monitoring applications. The second section will highlight applications in the sports domain, focusing on the variation between the body swing mechanics of low handicap and amateur golfers. Such type of technique analysis would contribute to performance enhancement as well as an understanding of injury mechanisms in golfers.

## BACKGROUND

On-field motion tracking is still a huge gap to identify the practical issues with human motion. It requires light weight, portable and wearable sensors to fill this gap. The advent of micro-electromechanical systems (MEMs) inertial sensors, as a technological evolution, has opened new avenues to measuring human movement analysis.

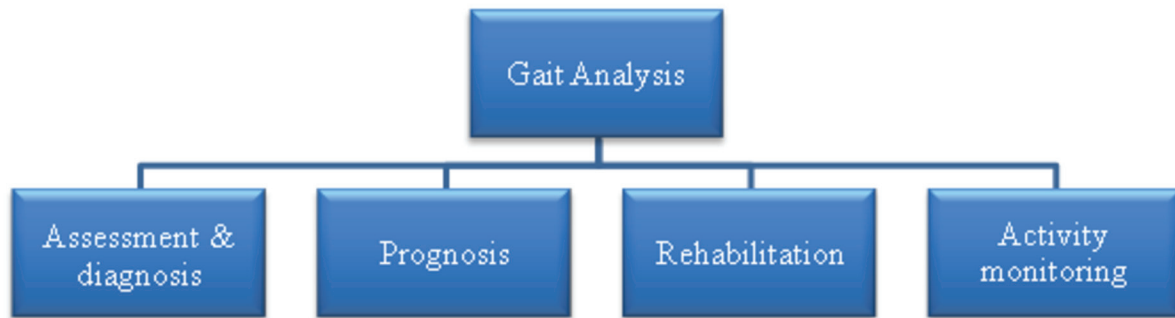
### Applications of IMUs in Human Gait Activities

Gait is the study of walking of an individual and is often related to the movement analysis of the lower limbs. IMUs are widely being deployed in gait applications after the invention of MEMs. The applications of IMUs in gait could be classified into four main areas as shown in Figure 1.

Studies have reported application of IMUs in assessing and diagnosing patients' gait function for Parkinson's disease (PD) (Djuric et al., 2010; Tien, Glaser, & Aminoff, 2010), diabetes (Petrofsky, Lee, & Bweir, 2005) and drop foot syndrome (Lau & Tong, 2008). Inertial sensors could also be used to monitor the recovery of patients after severe falls or surgeries (Cooper et al., 2008). Researchers also have demonstrated the applicability of IMU sensors for early detection of certain pathologies such as PD and risk of falls (Najafi, Aminian, Loew, Blanc, & Robert, 2002).

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Figure 1. IMU application areas in Gait related studies



In STUDY 1, we present an intelligent automatic gait classification system for identifying different walking conditions (walking normally with preferred walking speed (PWS), walking while carrying a glass of water, and walking blind folded) using foot kinematics data.

### Applications of IMU in Sport Activities

The application of MEMs inertial sensors are self-contained and allow measurement of recording and analyzing parameters outside of a constrained laboratory. The measurement mechanism of IMU could provide precise measurements in biomechanics (Berkson, Aylward, Zachazewski, Paradiso, & Gill, 2006). Therefore, it has been applied in sports for different purposes. As Figure 2 shows, MEMs inertial sensors could deliver practical and clinical applications ranging from player assessment and performance, to injury prevention and rehabilitation.

Sport-related injury occurs mostly in the ankle, knee, wrist joint and thigh for players. In sports, if the player's movement is continuously monitored and analyzed for possible injuries, coaches could develop strategies to avoid or minimize risky movements. Using the feedback system, players can change their ways of reacting to certain conditions or condition their training regimes. Therefore, IMU stays at the intersection of all these purposes.

In STUDY 2 we examine golf swing motion measured by inertial sensors. We compare the measured peak angular velocities of four body segments to determine differences between beginners and skilled golfers.

### STUDY 1: IMUs IN HUMAN ACTIVITY MONITORING

In this study we demonstrate an automatic detection of a novel set of walking tasks which challenge the balance of the subject, using multiclass SVMs based on portable sensors. Several studies have been carried out to differentiate walking patterns of subjects walking on a flat surface, on ascending and descending stairs, ascending and descending walk ways (Meng, Jingyu, & Yangsheng, 2009; Nyan, Tay, Seah, & Sitoh, 2006). However they have not incorporated dual-tasks which are likely to challenge the balance of the subjects. This type of analysis is very important as the ability to balance while multitasking degrades with aging (Mallau & Simoneau, 2009). In this study we investigate normal walking and two other dual-task walking conditions designed to simulate challenges to the balance control system and our reliance on visual feedback from the environment to assist with locomotion. The hypothesis is that these everyday activities could be detected using advanced classifying techniques, as the differences in walking conditions would require varying level of effort, attention, and feedback from the environment.

### Methodology

A group of 8 healthy young subjects consisting of 5 males and 3 females with no known gait disorders were recruited for this study. The experiment was carried out in the Biomechanics Laboratory of Victoria University, Melbourne, Australia. Two wireless foot sensors, each equipped with a Sparkfun IMU digital

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