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Validation of RoboGuide to Support the Emulation of Sporting Movements using an Industrial Robot

J. A. Jones*, P.G. Leaney, A.R. Harland, S.E. Forrester

Sports Technolgy Institute, Loughborough University, Loughborough, LEICS, LE11 3QF, UK

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Abstract

Mechanical testing plays an important role in the development of athletic footwear. Typically, these tests do not accurately represent the forces and motions the footwear experiences during human use and there is substantial scope to improve this situation. The purpose of this study was to assess the extent to which RoboGuide software can be used as a virtual environment to support the emulation of the ground contact phase of human locomotion on a FANUC™ six degrees of freedom industrial robot. A series of simple (linear and corner) and complex (sagittal plan heelstrike running) movements were completed on both the robot and RoboGuide using the same input kinematics. The effect of movement velocity, level of robotic smoothing and number of co-ordinate points defining the trajectory were also investigated. The resulting movement and timings on the robot and Roboguide were compared to the input kinematics as well as to each other. The results indicated small differences in the robot and RoboGuide trajectories for simple linear motions (< 30 mm), that became much greater for the complex footstrike motion (~ 100 mm). These differences were affected by levels of smoothing and movement velocity and, notably, only with no smoothing did the robot and Roboguide approach the input trajectory. To conclude, RoboGuide does not accurately represent the motion of the FANUC™ robot and therefore only has limited use in supporting the physical emulation of complex sporting movements.

Keywords: Athletic footwear; mechanical testing; 6 DoF industrial robot

1. Introduction

The modern running shoe industry began in the 1970's and has grown to be worth $13 billion per annum globally [1]. Leading running shoe companies currently invest large amounts of money into

* Corresponding author. Tel.: +44 (0)1509 564822; fax: +44 (0)1509 564820.
E-mail address: j.a.jones@lboro.ac.uk.

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product research and development, with mechanical testing remaining a focus. Mechanical wear testing aims to evaluate the performance of a shoe under realistic use conditions [2]. Examples of such devices include the Wheel Wear Machine (WWM) developed by adidas to replicate walking and running gaits [3], the Pedatron STM528 test machine [4] designed by SATRA as a walking footwear-surface abrasion tester and the Stewart Platform, intended to replicate force application [5]. These devices have a number of advantages over human testing, such as the ability to complete large numbers of ground contacts in short timeframes. However, their ability to generate ground contacts similar to that of human locomotion remains a major issue, e.g. the WWM has a running ground contact time over three times longer than a human (~0.6 s versus ~0.2 s) [3].

Challenges remain in the development of a biofidelic mechanical test devices for athletic footwear. More recently, the potential of an established multi-dimensional kinematically-controlled robot with recognised control systems was investigated as an alternative method to emulate the ground contact phase of human locomotion [6]. The Japanese FANUC^{TM} R-*2000i*-B 6 Degrees-of-Freedom (6 DoF) industrial robot was used to emulate heelstrike and forefoot running gaits over 500 ground contacts. The robot kinematics were found to be highly repeatable (<1.5mm average SD in trajectories) however issues were reported regarding the timescale of ground contact and trajectories compared to the original human data. Three variables were identified as influencing how well the actual robot movement matched the original human movement: level of robotic smoothing (higher levels ensured a "natural" smooth movement); movement velocity; and the number of data points used in the footstrike programme.

One of the accompanying tools provided with the FANUC^{TM} robot, is the computer software RoboGuide, which simulates the robot in a virtual environment. The robot's environment, layout and motion scan be simulated giving the advantage of not having to alter real world parameters until potential benefits are assessed. Results from a more traditional industrial setting (Jin and Yang 2009) have shown that fast-track programming using RoboGuide can help to reduce robot downtime and make the manufacturing process more efficient [7] & [8]. RoboGuide can be used to manipulate the virtual robot as in the real world and these kinematics can be evaluated using a number of analysis features, trajectories can be monitored and measured, the built in timers and collision detect feature can also be used for further analysis as well as the ability of recording movements to a video file. As such, this software also has the potential to support research into the development of human emulations on the FANUC^{TM} robot.

The robot has a number of programmable and embedded features within its control system that affect its resultant motion; it remains unknown whether these features have also been built into RoboGuide. Some literature has compared a 90º rotation on the robot and RoboGuide and found the finishing position to be the same in both cases [9], no study has attempted to compare the complete trajectories of RoboGuide versus the robot based on the same input programme. For applications in emulating the ground contact phase of human locomotion a detailed comparison of RoboGuide kinematics versus the robot is necessary in order to assess the degree to which RoboGuide can be used to support the development of the emulation of complex sporting motions on the FANUC^{TM} robot. Hence, this study aimed to compare the kinematics (trajectories and movement timings) of RoboGuide versus the robot using initially a number of simple one and two dimensional movements followed by the more complex movement of human heelstrike running.

2. Methodology

Two sets of trials were conducted: (1) simple vertical, horizontal and 90° corner movements (the first two involving a 400 mm displacement from the start point to the turnaround point, the corner involving a 400 mm displacement from the start point to the corner and a further 400 mm to the turnaround point); and (2) sagittal plane heelstrike running based on human kinematic and ground reaction force data