BUILDING AND TESTING OF A SIMPLE HIGH SPEED KINEMATICS MEASUREMENT SYSTEM

STANCIC, I[vo]; SUPUK, T[amara] & ZANCHI, V[lasta]

Abstract: Ability of precise measurement and analysis of human movements is an essential tool for biomechanical research used in sports or clinical applications. Ideally, the measurement system should be non-invasive, safe to use, customizable and relatively inexpensive. In this paper design and evaluation of a high speed optical motion tracking and analysis system is described. It is designed to work with low cost components (LED markers, industrial cameras and PC). Static accuracy of the system is tested and results are presented in a form of error histogram. System is intended to be used in biomechanical laboratories, where expensive commercial equipment is not available, but high precision 3D kinematics measurement is mandatory.

Key words: kinematics measurement, active markers, biomechanics

1. INTRODUCTION

Human motion analysis becomes even more interesting because of its interdisciplinary nature and a wide range of applications. Last few decades of technological development created many types of kinematics measurement systems; magnetic, acoustical, mechanical, inertial and today mostly used optoelectronic devices (Winter, 2004; Medved, 2001). Modern motion capture and analysis systems were created for the needs of entertainment (game and film industry) and biomechanical research. Commercial optoelectronic systems like Optotrak or Vicon (Winter, 2004; Medved, 2001; Stancic 2009) that were constantly developing for last decades, show astonishing results; linear accuracy below millimetre and angular accuracy of only tenth of degree (Maletsky et al., 2007). Drawback of the mentioned systems is their high cost, and as a consequence they are not available to all biomechanical laboratories or studios. Hence, our idea was to present a procedure for building and testing a simple high-speed kinematics measurement system with abilities comparable to commercial systems.

Our system was based on a white visible-light LED marker, rather on an Infra Red (IR) marker, allowing simpler operation and troubleshooting in the measurement setup (Stancic, 2009). Another idea was to allow integration with the other laboratory equipment, using hardware triggers and easily accessible code developed in MATLAB (MATLAB, 2010). As described, main application of our system is marker tracking and calculation of a human body kinematics during movement. Kinematics analysis software was also developed. Software was able to automatically calculate, analyse and visualise all relevant kinematics data. An advanced image processing and analysis algorithm was used to achieve higher precision. Several subpixel algorithms, based on analysing of uneven distribution of a pixel light intensity around the marker centre, were developed, tested, and integrated inside our system.

Backbone of our system was a hi-speed industrial camera paired with the PC and a number of small, light-weight 3 mm markers (Fig. 1). Better performance should be achieved using IR markers and IR camera with a higher pixel accuracy (16 bit), but as this system is aimed for biomechanics laboratories, where simplicity and low measurement cost is more important than a sub-millimetre precisions or measurement speed in hundreds of Hz, this system should be adequate.

2. EXPERIMENTAL RESULTS

Camera used for this work was a Basler 602fc fast industrial camera with Fujinon 12.5 mm lenses. Before actual measurement, we had to calibrate the system (cameras) to remove distortions and to obtain camera matrices (Shapiro & Stockman, 2001; Trucco & Verri, 1998). Physical camera calibration is commonly divided in to obtaining extrinsic and intrinsic parameters. Intrinsic parameters encompass focal length, image format, and principal point while extrinsic parameters are needed to transform object coordinates in to a camera coordinate frame, or in multi-camera system describe relationship between the cameras. Lenses distortion is decomposed in radial and decentring component, by knowing the distorted image coordinates corrected coordinates are recalculated. Camera model used by Heikkila et al allowed least square optimisation with distorted image coordinates, and in final achieved an accuracy of 1/50 of pixel size (Heikkila et al., 1997).

Fig. 1. Active Marker attached to fingertip (top), same marker with housing (bottom)

We have developed a method for testing the accuracy of markers in static conditions, where known position of a marker on rotating body was compared with the measured one (Lujan et al. 2005). Also, maximum density of markers in limited area which could be precisely tracked was benchmarked, showing that smaller body segments like fingers and foot could be successfully tracked.
The super-resolution technique was proposed to pre-process the captured image. In real conditions, when marker is not perfectly aligned with pixel centre, marker intensity distribution is not uniform on the edges. This property is used for creating Super resolution marker model, which was the core of our sub pixel accuracy resolution system.

3. CONCLUSIONS

The objective of this paper was to create and validate simple and cost effective kinematics measurement system with sub-pixel accuracy capabilities. LaBACS kinematics measurement system is a low cost system based on active visible light markers and fast industrial cameras. Algorithm incorporates components for camera lens distortion removal, system calibration, marker detection and tracking. High accuracy of marker 2D / 3D position reconstruction was achieved, and finally system is tested in working conditions for measuring human gait. Currently, the developed system is testing in Laboratory for Biomechanics Automation and Control System at University of Split

4. ACKNOWLEDGMENTS

This work is supported by Croatian Ministry of Science under the Project 023-0232006-1655 "Biomechanics of Human Motion, Control and Rehabilitation.

5. REFERENCES

Stanci ć I., Borojevi ć D., Supak T., (2009), Development and Testing of a Device for Human Kinematics Measurement. WSEAS transactions on systems, Vol 8, 1083-1092

****MATLAB on line Users Guide.