

3D kinematic analysis by BodyMech

A Matlab based open source software package for research and education

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Abstract— BodyMech is MATLAB based software designed to be used for human movement analysis in a research laboratory environment. It offers a data-structure that can be used for well designed and maintainable application programs to run for a specific project in a particular laboratory. BodyMech offers also most of the functions that are generally needed for 3D human movement analysis based on marker registration. Finally BodyMech includes a graphical user interface that can be used to interactively analyze and visualize experiments of human movements. BodyMech runs in MATLAB. Users of BodyMech should at least have basic knowledge of structured programming and of the MATLAB programming software.

Keywords-kinematics; software; education;

I. INTRODUCTION

For the 3D kinematic analysis of human movement a number of markers based systems are currently available. Such wide spread availability and growing interest in human movement analysis results in an increasing number of research projects that are entertained by e.g. PhD students. Part of these projects are well served by commercially available analysis software. Commercial software is able to provide 3D kinematic analysis tools to its users that could never be met by programming efforts of a single researcher or a small research group.

However, a significant number of research projects will need a specific approach that can only be achieved if the kinematic analysis is done through custom written software. Such customized analysis could include both methodological issues of processing marker registrations into anatomical or functional meaningful data; as well as non-common models of the human skeletal system related to specific marker configurations, or another sensor setup.

The main problems that arise in custom analysis are: how to build your software, within the time limitations of the project; how to reuse tools that were developed in previous projects, (but ill documented); how to ensure the quality of programs that were written by a researcher who needed a tool, but never had the time to test it thoroughly. These problems are common to many groups where starting students need quite some time to discover the programming efforts of their predecessors. Moreover, commercial software will suit the need of many projects, but the algorithms used will remain proprietary, for

well respected reasons. However, this prevents quality assessment from independent sources.

Altogether, an open source software package that deals with 3D kinematic analysis of human motion would contribute to the advancement and quality of the work of the community of researchers into human motion analysis.



Figure 1. The BodyMech logo

II. BODYMECH

Since 1999 we started to maintain a number of well documented software functions in MATLAB to create a software library for general use in studying 3D kinematics of human movement. This was developed into a structured software package, called BodyMech (Fig. 1), that is based on several design considerations.

1. MATLAB

BodyMech is based on the MATLAB (from The MathWorks, Natick, Massachusetts, USA) programming environment. It runs from version 5.3 and higher.

2. Rigid Body mechanics

BodyMech uses models of the human movement system based on multiple rigid bodies, all with 6 degrees of freedom. These rigid bodies are called "segments" and each segment has a local coordinate system attached.

3. Data structure

All data is kept in a structured array that is structured in relation to the model as well as the workflow (see 4) of a project of analysis of human movement. The MATLAB data structure BODY is shown in the appendix. BODY contains fields that have obligatory names, but users may want to add fields of their own.

All segment kinematics are expressed using (4x4) transformation matrices.

4. Workflow

The workflow of a typical project contains 3 stages:

- definition of a model for the project (*projectmodel*)
- calibration the *projectmodel* towards each specific subject under study (*session model*)
- applying each *session model* to several measurements of tasks that are performed by the subject (*trial model*)

See also Fig. 2.

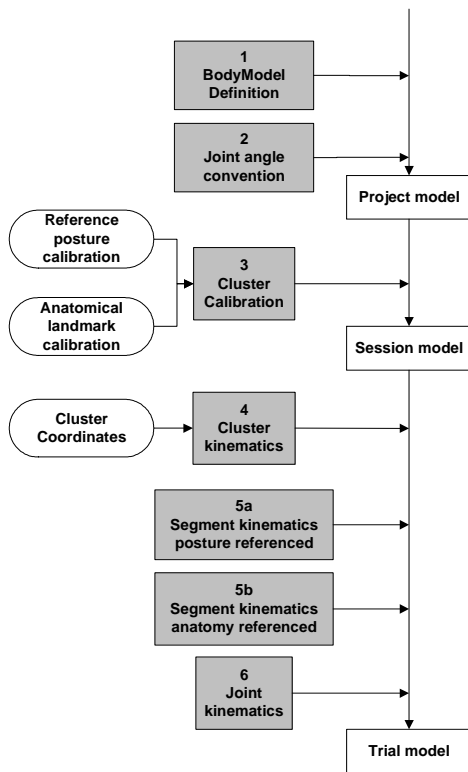


Figure 2. Workflow (1-6) of a project of human movement analysis
Ovals indicate marker measurements

5. Standard functions

For all standard operations related to the analysis of human movement, a function is defined that operates on the data structure. These functions may be straight forward implementations of well known algorithms from the scientific

literature e.g. [1,2]; or functions that have been made available on the internet; or functions that were shared to us by colleagues. All functions are well documented in the header.

6. Laboratory interface

In order to import the measurements from a particular laboratory, an interface has been defined, to facilitate the definition of laboratory specific functions. For common situations (e.g. the import of C3D files) functions are available.

7. Users and user interface

BodyMech is intended to be used by users who have a basic knowledge of MATLAB as well as the principles of 3D kinematic analysis of human motion. Most BodyMech applications will consist of programs with a mixture of BodyMech standard routines, and custom function files. These custom routines may vary from dedicated graphing to advanced modeling. However, novice users, or students on a minor assignment, may want to use BodyMech through the menu items of the user interface.

Visualization is very helpful in inspection of data. Therefore the user interface also enables visualization of measurements: segment-coordinate systems (see Fig. 3.) as well as stick diagrams.

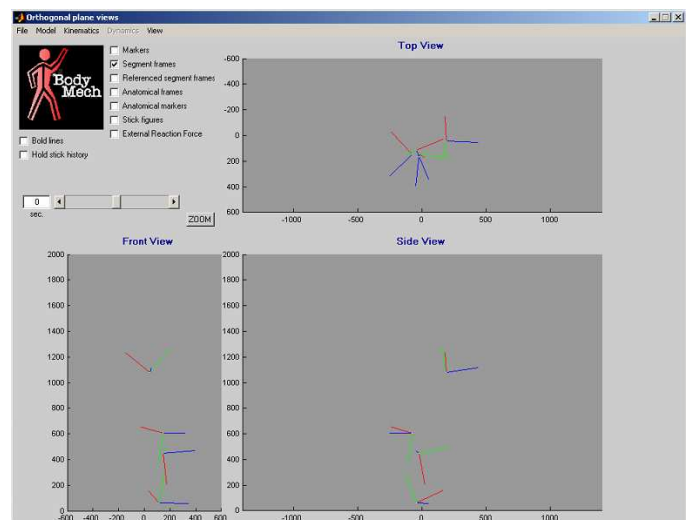


Figure 3. BodyMech Orthogonal Views of kinematic variables of a typical session (gait analysis with 4 segments); selected option: segment frames

8. Documentation

In order to maintain a good documentation, functions that could be included as a standard BodyMech function, are strictly tested and must adhere to certain type of layout. All functions as well as the over program design are included in a reference manual. Also, functions are theoretically documented in a textbook on human movement analysis. Finally, for novice users a tutorial is available, as well as a demo dataset.

III. RESULTS

The BodyMech software package & documentation will be available from the internet, see www.bodymech.nl (starting June 1, 2006)

IV. DISCUSSION

Our experiences over the last 5 years have shown that MATLAB as a platform means a low threshold, since many students do master MATLAB in some extend. Data-structures usually need some introduction. The use of data-structures has been proven as an effective way to enforce proper administration of data (something that non-experienced programmers usually lack), which is highly appreciated by students and their supervisors.

A drawback of MATLAB is the speed of processing. Large data sets will need some time for a complete 3D kinematic analysis. This might be solved by writing some functions using C++ and compile it to a DLL. However, in research applications flexibility is usually preferred.

The idea to define an open source tool to share the results of effort, is within the spirit of our scientific community. However, trying to maintain a tool that is useful for a lot of people, without resources, is not very easy. We developed BodyMech to facilitate the projects at our laboratory, and we put some additional effort in sharing it with others. We just expect that in the future people can use it to efficiently run research projects.

Another type of users are those who are involved in the development of kinematics analysis tools. We hope that bugs that inevitably must be present, will be found by some critical users. Others may want to replace function files with better ones, or to extend BodyMech with additional tools. Currently we are adding EMG processing. Inverse dynamics might be a next step.

Altogether we conclude that BodyMech can be a useful software platform, to serve the research into the 3D kinematics of human movement.

ACKNOWLEDGMENT

Many people have contributed to BodyMech. This project is really a team effort, specific contributions are acknowledged in the header of functions. We also like to thank the many students that contributed by trouble shooting and suggesting improvements.

REFERENCES

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- [2] Cappozzo A, Della Croce U, Leardini A, Chiari L. Human movement analysis using stereophotogrammetry. Part 1: theoretical background. Gait Posture. 2005 Feb;21(2):186-96. Review.

V. APPENDIX BODY STRUCTURE

