A MATLAB GENERIC TOOL TO EFFICIENTLY PROCESS C3D DATA FILES FOR APPLICATIONS IN OPENSIM

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SUMMARY

A new tool has been developed in Matlab - the most widespread instrument for data processing among biomechanists - to process kinematic and kinetic data from different laboratories. With a simple setup, it prepares data from any motion capture system in inputs for OpenSim. The software's main characteristics are: i) import of motion capture data from C3D files in Matlab structures, ii) highly configurable in parameters selection through xml files and user-friendly interfaces, iii) availability of data filtering algorithms iv) computation of centers of pressure and torques v) transformation of motion capture data between different coordinate systems vi) exporting output in .trc and .mot files, and vii) processing of EMG data.

INTRODUCTION

The several commercially available motion capture and force plate systems produce and present similar data in quite different formats. A standard file format - Coordinate 3D (C3D) - has been proposed to facilitate data sharing among research groups and to provide biomechanics and gait analysis communities with a common language. However, the common practice of gait laboratories is still to process the data in the each system proprietary format. This results in the proliferation of tools and codes that perform the same processes but differ just for the format of input data, thus preventing their sharing among laboratories. In line with the proposal of a unique data format, the aim of this contribution is to supply a common instrument for processing data which is complete, highly configurable and well-structured.

METHODS

Data collected with a motion capture and force plate system are labeled and then exported as a C3D file, which is the input for our application.
The developed tool is divided in three main parts: (1) C3DtoMAT, (2) Data Processing, and (3) Static pose Elaboration for scaling OpenSim [1] models (Figure 1).
The first part retrieves all the required information from the C3D file and store them in organized Matlab structures (.mat files). This avoid to have continuous accesses to C3D files, which are computationally expensive and redundant.
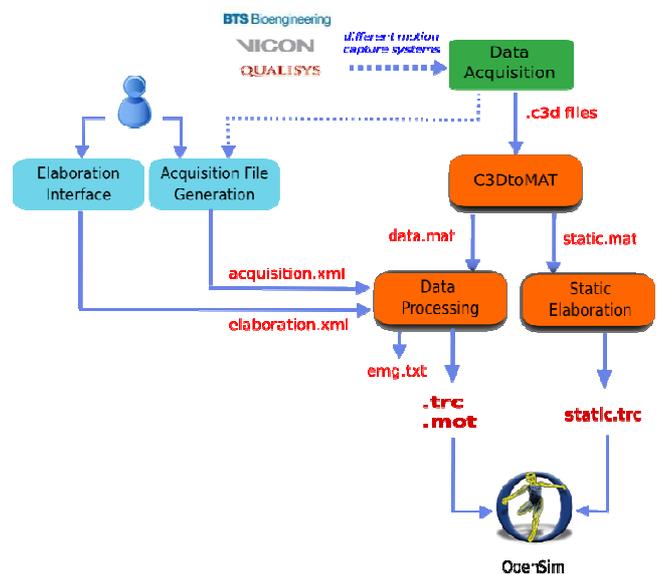

Figure 1: General scheme of the proposed Matlab Tool.

Starting from these structures, the second part produces .trc and .mot files for OpenSim, storing markers and forces information respectively. The flowchart of the implemented steps is depicted in Figure 2.
After data loading from .mat files, markers trajectories are piecewise interpolated if markers are missing for short intervals, and filtered with a zero-lag second order low pass butterworth filter. EMG signals are also filtered and processed for further applications.
Different methods for gait events detection are available. If events are stored in C3D files, they may be selected as start and end frames of the analysis, or they can be inserted manually. An automatic detection is even possible: a thresholding algorithm based on force plate data is implemented [2].
The third part uses the static trials to extract the information required by the OpenSim scaling procedure. Its main objective is to calculate hip (HJC), knee, and ankle joint centers. HJC is assessed exploiting Harrington [3] and Capozzo [4] methods, while knee and ankle joint centers are

defined as the mid points between knee epicondyles and malleoli, respectively. However, the structure of the software allows an easy integration of other algorithms. Finally the resulting trajectories are then rotated into OpenSim reference system and are stored in a .trc file, the OpenSim format for markers coordinates.
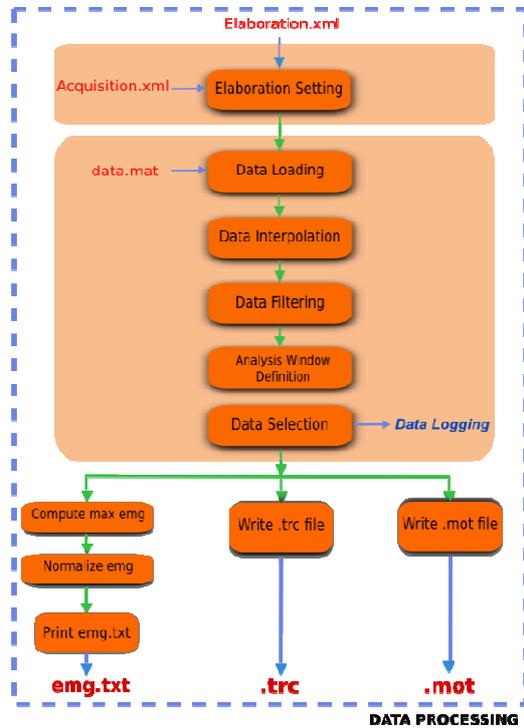

Figure 2: Flowchart of steps in the Data Processing part.

System configuration is performed by means of two different user-friendly Matlab interfaces, which produce and store two xml files required as input by the main code.

The first must be fill in for each data set and gathers all information describing the acquisition session (Acquisition.xml), such as the number of force plates, coordinate system orientations, marker sets, and EMG setups. The second one contains all the parameters defined by the users and which characterize each elaboration (Elaboration.xml). Examples of these parameters are the identifiers of the trial to be processed, the cut off frequencies for filtering the different input data, the list of markers to be written in the .trc files, and the method for gait event detection.

The xml language has been chosen for its suitability in the encoding of information, and an xml scheme (xsd) has been defined to validate data stored in the corresponding xml file. The graphical user-friendly interfaces has been developed to facilitate the user in compiling the configuration files according to the xml language semantic.

RESULTS AND DISCUSSION

Matlab tools to manage and prepare biomechanical data for applications in OpenSim have been already proposed in literature [5]. On SimTK.org website, several utilities are freely available: a package to extract raw gait data from a C3D file (https://simtk.org/home/c3dtoolbox), as well as a toolbox that converts VICON motion capture data into OpenSim inputs (https://simtk.org/home/lee-son).

Nevertheless, a main advantage of our software is that it is not limited to a specific motion capture system, but it has a general applicability. Furthermore, our intent was to realize a complete tool, which includes several steps of a whole procedure, not only a specific task as the single extraction of data from C3D files.

Finally, the clear separation among the configuration step and data processing facilitate the users, enabling to compile the graphical interfaces which generate the configuration files, thus avoiding any direct access to the main code. Future development includes implementation of Besier method for joint centers calculation [6] starting from different markers protocols and extending its use to different motion capture systems.

CONCLUSIONS

Manage data from different laboratories and research groups is becoming essential.

Despite the already available tools, a well-structured instrument to process data in a complete and flexible way is still highly desirable. Besides the tool developed herein has the potential to positively influence data management, since the way they are organized and stored need to be uniquely defined.

Currently, the proposed tool is successfully used in the three institutions of the authors to share and process data. The software will be soon released as an open-source project on SimTK.org website.

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