Processing, Converting, and Visualizing C3D File: A Free Web-based services

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Abstract:

The C3D format is a standard and pervasive file format in biomechanics to store and share motion data like the markers' trajectory and analog data like ground reaction force and electromyography data, etc. Also, most of the companies that design and manufacture biomechanical laboratory equipment export data as a C3D file, for instance, motion capture companies like Vicon, Qualisys, etc. Thus, the software to read and manipulate the C3D file could have a crucial effect on facilitating biomechanical research as a tool. Generally, there are two main methods to work with c3d files, First using developed APIs like Biomechanical Toolkit(BTK) and EZc3d, which users need to have basic programming knowledge. Second, there are some desktop applications to process and visualize C3D files like Visual3D, C3Deditor, and Mokka. Although, most of the motion capture systems have their processing software to obtain the kinematic and kinetic of motion. However, researchers according to their purposes, use other software as third-party software like Visual3D, MATLAB, and Opensim to process data and compute kinematics and kinetics of motion. OpenSim as open-source software is highly popular in biomechanical research, but the c3d files must be converted to another file that is compatible with the Opensim. So, our objective was to develop a free web-based service to read, process, and convert C3D files to other formats such as TRC and MOT files that are compatible with Opensim as input files.

Introduction

Usually in biomechanics, we want to acquire and process the kinematic and kinetic of a motion, there are several parameters that usually measure by laboratory equipment for instance motion capture system, force plate, EMG, EEG etc[1], [2], [3]. also, these data should be synchronize to process and evaluate kinematic and kinetic of motion. for instance, most of the biomechanical laboratories are equipped with a video-based motion capture system and one or more force plate and EMG device which are grab the data synchronously by motion capture software as a master device. The collected data could be stored in different file formats such as ANB, BSF, EMG, CSV, DAT and TXT. Beside the other file format, the C3D file format, was developed by Dr. Andrew Dainis and has been continuous use since 1987 and updated during

the years by some companies[4]. The C3D file format can store many types of information about data and system setup specifications that are important for interpreting the data[4]. Moreover, the large time series of 3D data and 1D data could be store. So, a C3D file could store the parameters to describe the systems configuration, trial and subject information and a large amount of time series data. For instance, number and labels of markers, global frame system coordination, video and analog frame rate, force plat's local frame coordination and also marker trajectory, angular speed etc., and analog time series data. regards to these features C3D file format is a proper choice for storing and sharing data. The C3D file format became a standard file format to satisfy biomechanics needs and most of the companies support the C3D file format and export data in a C3D file[5].

Alongside, the motion capture systems' software that have their own processing application like Vicon Procalc[6] or Qualisys calculus[], there are several commercial, freeware and open-source application which use to process and manipulate the motion capture data to compute kinematic and kinetics of motion like Visual3D[7],BOB[8], Anybody[9], OpenSim[10], Mokka[11] and etc.

Visual3D is a commercial software developed by C-Motion Company, it supports C3D format and solves different kinds of biomechanical problems such as inverse kinematics and inverse dynamics. Also, AnyBody is another commercial modeling and simulation software that supports C3D files to process and analyze different biomechanical aspects.

At the other hand, there are some free and open-source software to process or facilitate processing such as Opensim. Opensim is a freely available and open-source software to build and simulate musculoskeletal models to solve inverse kinematic, inverse dynamic and forward dynamic problem. Recently, the Opensim widely use in biomechanics filed and a lot of paper have been published that used OpenSim to process and analyze the musculoskeletal system. However, the Opensim desktop application (GUI) does not support the C3D file and the user needs to convert the C3D data to *.trc and *.mot files. The .trc files contains the markers trajectory data and *.mot contains the external forces – ground reaction forces(GRF) in the Opensim coordination frame. Also, the C3D file is not a human-readable format, so the users have to script in MATLAB, Python or another programming language and use APIs to read and process C3D data to convert them. Although, MOKKA is free and open-source desktop application to read and visualize the C3D file. It can convert C3D files to some other file format like *.TRC. Moreover, there are few python package and C++ API to read the C3D files but having basic programming knowledge is inevitable like EZC3D and BTK.

Thus, according to the Opensim pervasive, an application that could read and convert C3D files to *.TRC and *.MOT files that are compatible with the OpenSim input files are very useful and practical for Opensim users without having any programming knowledge. Our objective was to develop a web-based application that everyone can upload C3D files through a web browser to convert them to the files that they need as Opensim's input files and also visualize and process the C3D data.

Method

C3D Reader and Processing Force plate data

According to the C3D file format documents[4], procedures were developed in JavaScript to read different sections of the C3D file for instance header, groups, and parameters that include system configuration for instance capturing frame coordination, video and analog frame rate, number of markers and analog channels etc., and the face plate configuration like corners and origin position. Also, based on the header information (C3D File Format, C3D File Integer Type) the markers' position and analog data read as time series data. In the next step, the ground reaction forces, moments and center of pressure(COP) based on the force plate configuration are computed for each plate.

C3D Visualizer

Data visualization has an impact role in studying the data and C3Dtools display the data such as analog data, markers' position, GRF, and COP using the chart.js[12] (Figure 3) and visualize the markers' position and GRF vector in 3D space using three.js[13] (Figure 1-2) Also, the distance between the 2 markers and the markers' path could be shown by selecting the desired markers.

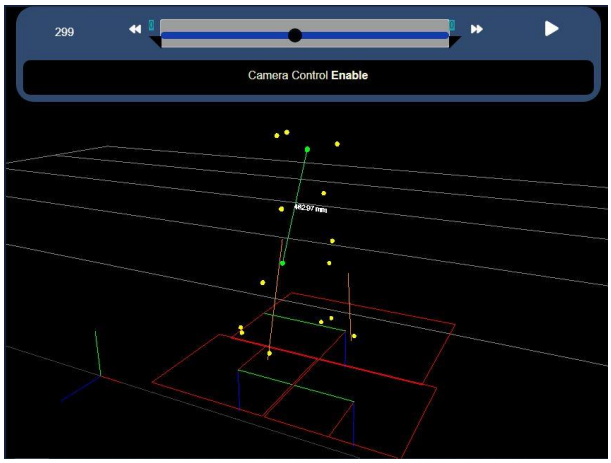

Figure 1- 3D Visualizer

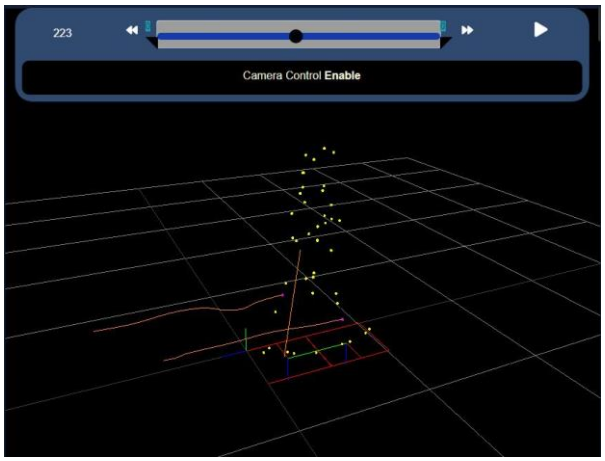

Figure 2- Display markers' path

Figure 3- Display data via chart.js

C3D files Converter

The users can upload their C3D files to convert them to a trc, mot, and txt file. In the first step C3D file is read to obtain markers' trajectory and analog data such as force plate data. Then users have several options to export the files that they need (Figure 4). Opensim needs markers' trajectory in the Y-Up coordination system and external forces like GRF, as input files. Regards to usually the motion capture system frame set to Z-Up, there is an option for exporting a trc file to transform data to the Opensim coordination system (Y-Up).

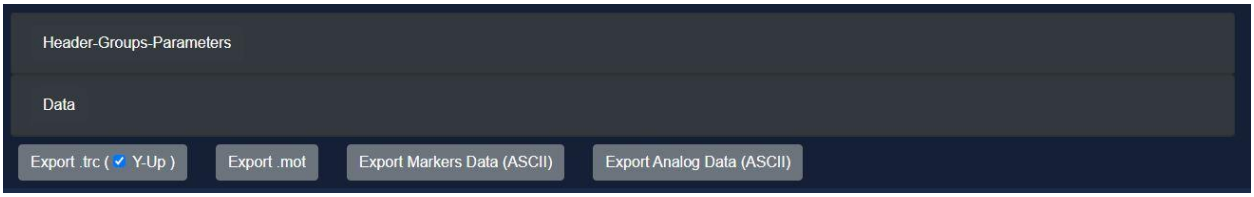

*Figure 4 - Export as *.trc, *.mot and ASCII file*

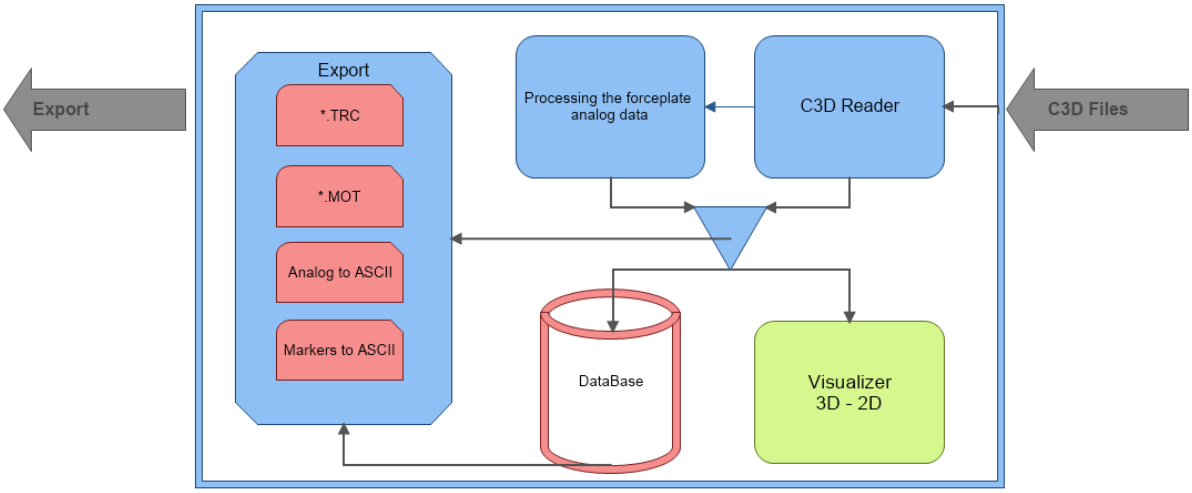

Figure 5 C3Dtools Converter Diagram

Discussion

At this moment, most motion capture system has their own kinetic and kinematic processing software but in some situations, these cannot satisfy the research needed and they have to use third-party software such as Opensim, Visual3D, etc. to process the collected data by motion capture system[12], [13], [14], [15]. And Opensim has had substantial growth in biomechanics recently, nonetheless, the Opensim users have to do data preparation to do that most of the time they need to script and have basic computer programming knowledge. The first option is using BTK, and EZC3D libraries to read C3D files and then process and write data to files as compatible with Opensim, obviously working with Python or C++ is inevitable. Second, using MOKKA, MOKKA is a very handy desktop application to read, Visualize, and process C3D files it just exports trc file which includes markers' trajectory, but the mot file as Opensim input is also needed.

C3Dtools is a free web-based service that users can access it everywhere just with a web browser and convert and process the C3D files. there are several tools on C3Dtools such as trimming, digital filtering, etc. Specifically, a section has been developed to convert C3D files to files that Opensim is needed.

Thus, C3Dtools could be useful and help researchers focus and consume much more energy on their scientific matter particularly researchers who do have not enough computer programming knowledge. At this moment, C3Dtools has 850 registered users and more than 3000 C3D files were processed via C3Dtools. Also, more than 11000 actions were done and 55% of these actions were related to Opensim software.

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