

ezc3d: An easy C3D file I/O cross-platform solution for C++, Python and MATLAB

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DOI: [10.21105/joss.02911](https://doi.org/10.21105/joss.02911)

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Submitted: 09 October 2020

Published: 21 February 2021

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Summary

This work introduces the open source ezc3d library which provides a light and comprehensive API to easily read and write *c3d* files. The C++ core provides a fast file I/O library, and convenient MATLAB and Python3 interfaces are also provided so researchers can smoothly implement ezc3d in their current workflow. It supports *c3d* files from the main biomechanics software, namely: Vicon, Qualisys, Optotrak, BTS and XSens. In addition, since the *c3d* standard allows for multiple ways to store force platform data, a force platform analysis module is provided. The main feature of this module is to express forces and moments in more common reference frames—that is, expressed in the global reference frame calculated at either the origin or at the centre of pressure—so they can be directly interpreted by the user.

Statement of need

The *c3d* binary format ([Cramp, 2019](#)) is an open source standard extensively used in the field of biomechanics. Most of the software for biomechanical data collection and data analysis can read and export *c3d* files. Initially, this format was designed to store three-dimensional point and analog data (e.g., force platform or EMG). Nowadays, by stretching the standard, companies have managed to integrate new types of data, including for instance IMU data. To match the needs of the community, Motion Lab Systems—which created and maintains the *c3d* format—regularly updates the standard to match the biomechanical needs and to include new usages of the format.

Despite being extensively used by the biomechanics community, there are surprisingly few alternatives when it comes to manipulate *c3d* files outside analyses software. This has forced scientists to develop *ad hoc* solutions for each project which requires writing file I/O codes for each software file format. While it would make sense to develop a portable solution once and for all, the binary nature of the *c3d* format discourages biomechanists from digging into the trouble of developing such a solution. To our knowledge, BTK ([Barré, 2013/2020](#)) is the most mature (if not, the only) biomechanics library that provides an API to read and write *c3d* files. Unfortunately, despite its open sourced nature, the project has been mostly abandoned since~2016. It gets more and more out-of-date as it does not implement the changes in the standard of the format. Unfortunately, due to the intricate connections of its modules, it proved difficult to update BTK. The ezc3d toolbox is an up-to-date solution that will fill all your *c3d* management needs.

The dependencies

The ezc3d library was designed to be a dependency-free library such that the lay users could easily link ezc3d with their project. Thus, by default, no dependency is needed to compile

nor to use the API. Moreover, thanks to the absence of external library requirements that could change at any time, `ezc3d` will remain available on all major operating systems, namely Windows, Linux and Mac.

By nature, biomechanics data are matrix-based data. A linear algebra solution was therefore developed to store and manipulate such data. Our solution will, however, never be as effective as those from dedicated linear algebra libraries. Hence, thanks to the highly effective Eigen linear algebra library (Guennebaud et al., 2010), a fast accessor module is also available.

Current usage of `ezc3d`

The library got the attention of two major modeling frameworks in biomechanics, namely the Anybody Modeling System (Rasmussen, 2019) and Opensim (Seth et al., 2018). One of the employees of the former prepared and maintains the `conda-forge` recipe for `ezc3d`, so it can be easily installed and updated using Conda. Since version 4.0, Opensim embraced the `c3d` format file by providing the capability to read `c3d` files. The `ezc3d` library was chosen as the default `c3d` reader back end.

Acknowledgment

The authors would like to thank François Bailly for its help in the writing of the paper. Also, many thanks to Sahel Locher who designed the lovely `ezc3d` logo!

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