

Using L_AT_EX to produce multi-media clinical reports

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1 Introduction

Gait analysis is a standardized clinical examination that arose from biomechanical research. The aim of this examination is to identify the dysfunctions in pathological gaits in order to propose an optimized therapeutic treatment.

The clinical interest of gait analysis is well established [5]. De Luca [2] demonstrated that this examination influences the surgical decisions. [3] showed the critical role of gait analysis in the treatment of gait problems in cerebral palsy. This examination allows the correction of all gait alteration in one operation session, reducing the number of operations and their psychological impacts. However, the clinical interpretation remains a difficult task. Some authors ([6], [4]) have noted the variability of interpretation between clinicians. Therapeutic conclusions may be different because the multidisplinary team involved in the interpretation process has to deal with a large amount of inter-related multimodal information concerning a complex task: walking. A user-friendly data presentation interface is critical to supporting this interpretation process. Commercial software applications sold with movement acquisition systems focus on multimedia and multimodal rendering. The 3-D animation of the movement and the graphic interactivity with the videos were favored. A CD is the main information medium. It contains different multimedia files (*.c3d, *.avi, *.pdf). Therefore, it appears difficult to use network software, such as *Clinicom* (Siemens), supplied by the hospital to collect and share medical information amongst its staff.

In this context, L_AT_EX seems to be an interesting alternative. The information flow inherited from the clinical gait examination can be merged into a unique document: a

portable document file (*PDF*). Using this method, data access is improved and clinical interpretation is facilitated.

Since April 2006, technical reports of gait analysis have been produced through L^AT_EX at our hospital, St Jacques Hospital, Nantes, France. The positive feedback of the hospital staff, combined with Thompsons articles ([7] and [8]) about the application of L^AT_EX for clinical trials, have motivated us to write this article. Our goal is to demonstrate that L^AT_EX is suitable for clinical examination which includes large amounts of information, such as a gait analysis. Simple L^AT_EX codes will be proposed for common usage, and specific packages will be highlighted, that produce a high-quality technical gait report with embedded multimedia features.

2 Measurement and progress of a clinical gait analysis

Normal gait is a cyclic movement. Stance phases alternate with swing phases which result in a forward progression of the center of mass. Biomechanical data is commonly normalized and represented as a percentage of the gait cycle.

Two levels of analysis are investigated during the examination. The first, a *qualitative* analysis, is carried out with high-frequency cameras to record spontaneous gait videos. They are essential in assessing the functional ability of the patient.

The second, a *quantitative* analysis, is performed with a 3-D acquisition system. Most laboratories use infra-red cameras to locate external markers placed on anatomical points. In conjunction with cameras, force plates and electromyographic devices are used to respectively measure the reaction forces during stance phases and muscular activity. All measurements become the input data of a model from which biomechanical parameters are computed. For clinical gait analysis, the main biomechanical parameters are the following:

- *Spatio-Temporal Parameters* (STP) provide global indications (for example: gait speed, stride length, duration of each gait phases, . . .)
- *Kinematic parameters* represent the 3-D joint rotations.
- *Kinetic parameters* represent the joint forces involved in producing the movement. Their computation is achieved on the condition that stance phases are performed on the force plates.
- *Muscular parameters* represent the on-off activity of each muscle.

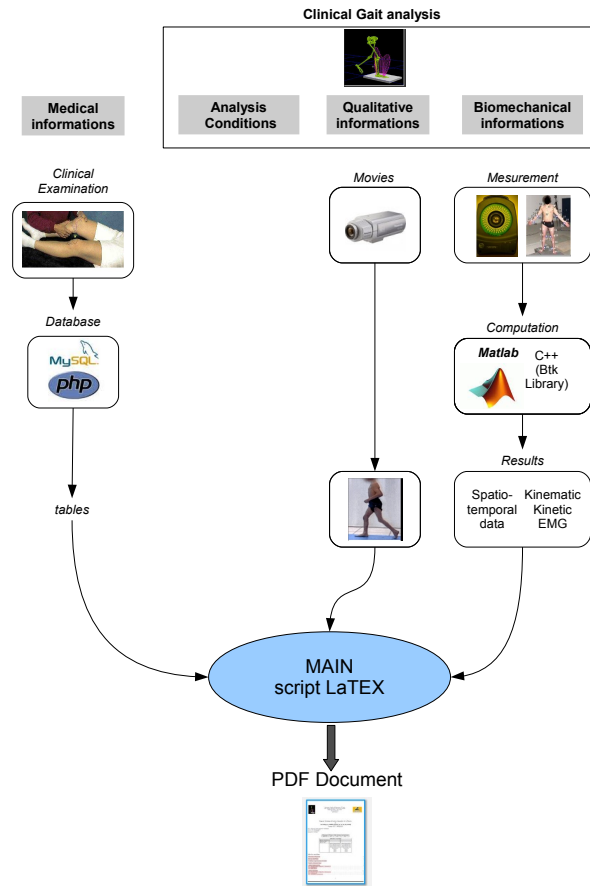


Figure 1: Representation of the information flow inherited in a clinical gait examination

An all-comprehensive gait analysis doesn't deal with biomechanical data solely. Clinicians have to relate them to their medical knowledge to answer the medical question. That is why a gait examination necessarily includes a standardized testing of lower-limb-range of motion [9]. This testing is especially important because it allows better communication between clinicians.

3 The information flow of a clinical gait examination

Figure 1 presents the information flow of a clinical gait examination.

Data set 1 - medical data

The use of $\text{L}^{\text{A}}\text{T}_{\text{E}}\text{X}$ for producing a technical gait report has initially been motivated by the need to provide medical information for a database. Software such as Access (Microsoft) or FileMaker (FileMaker Inc.) are perfectly suitable for database work. Nevertheless, we have chosen the programming languages PHP/SQL because $\text{L}^{\text{A}}\text{T}_{\text{E}}\text{X}$ can interface with it.

The solution consists in working with the PHP interface: PhpMyAdmin (see figure 3). The results of a SQL request can be exported as a tabular table. This solution is useful for specific SQL requests.

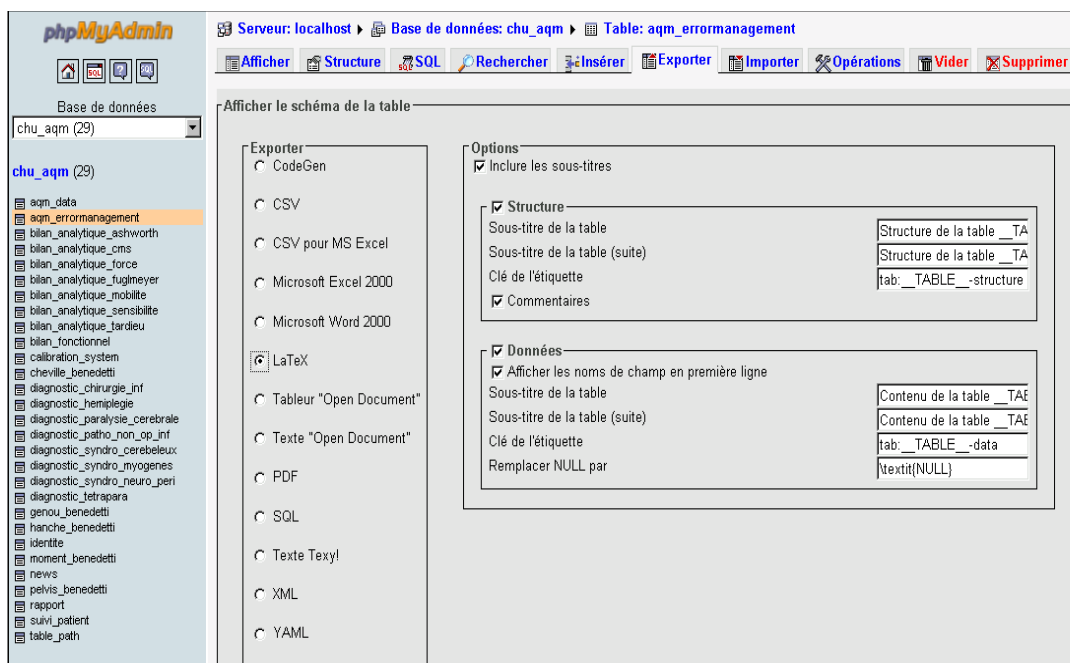


Figure 2: PhpMyAdmin interface for transferring data into a $\text{L}^{\text{A}}\text{T}_{\text{E}}\text{X}$ file

When SQL requests are frequent, an automatic process consisting of generating a (*.tex) file from PHP code is used. For example, consider the following SQL table which includes:

- INP: Identification Number of the Patient (INP) (primary Key of the SQL table)

- Date: Examination date
- Field1: (example: passive flexion of the left knee)
- Field2: (example: Ashworth scale of the muscle: tibialis anterior)

The code block 1 shows how to transfer into a L^AT_EX table all fields corresponding to a particular patient (in this case INP=14):

```

1  $sqlrequest = mysql_query("SELECT Date, Field1 ,Field2,
2                                FROM table WHERE INP=14");
3
4  $i=0;
5  $texFile = fopen('file.tex', 'w+');
6  fputs($texFile, "\begin{supertabular}{|c| *{3}{|p{2cm}}|}." "\n");
7  fputs($texFile, "\hline"." "\n");
8  fputs($texFile, "Date & Field1 & Field2 \\\ \hline"." "\n" );
9  fputs($texFile, " & G & D & G & D \\\ \hline"." "\n" );
10 while ($d=mysql_fetch_object($sqlrequest))
11     {
12         $i++;
13         fputs($texFile,$i." & ". $d->Date." & ". $d->Field1." & ". $d->Field2." \\\ \hline"." "\n" );
14     }
15 fputs($texFile, "\end{supertabular}");
    fclose($texFile);

```

Code Block 1: PHP code to export SQL request in a L^AT_EX table

The L^AT_EX package `supertabular` was chosen because it can accommodate the large amount of data which may be returned by the SQL request.

We have implemented this PHP code to collect medical information. Clinicians fill in medical forms using a web page that contains this PHP code. When the form is completed, an SQL database archives the information. Just before doing the L^AT_EX formatting, we create two **.tex* files from the database:

DiagnosisElement.tex, a table recalling the patient diagnosis and his therapeutic treatments.

ClinicalTesting.tex, a table listing values of the clinical testing.

The result is a comprehensive PDF report of the examination. This way, clinicians can easily access medical information useful to the clinical interpretation of biomechanical data. The report is complete and no browsing of online file folders for graphical data is required.

Data set 2 - biomechanical data

Biomechanical data come from the computational analysis of the 3-D measurements, using specific libraries or numerical software (*Scilab*, *Matlab (The MathWorks, Inc.)*, *Btk ([1])*). Data presentation consists of plotting curves and histograms. Their clarity is essential for accurate interpretation by clinicians. To that end, numerical software, like *Matlab (The MathWorks, Inc.)*, allows exporting plots to PDF files. The package `pdfpages` is then used to insert the PDF pages into the final report.

Even though the package `pdfpages` provides a workable solution, we would like to highlight the use of the package `pgfplot`. Indeed, it is a recent package that allows drawing of high quality plots directly in $\text{L}^{\text{A}}\text{T}_{\text{E}}\text{X}$ scripts. For our technical gait report, this package was used for plotting kinematic, kinetic, and muscular curves and the STP histograms (see figure 3).

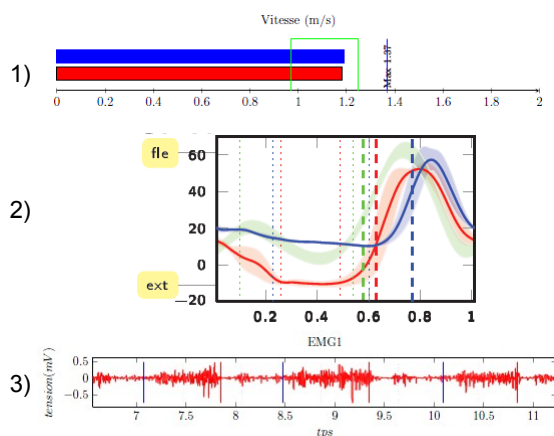


Figure 3: Pgfplot examples. 1) SPT: Gait speed, 2) Kinematic: Knee Flexion, 3) Muscular activity

The external library `clickable` associated with the package `pgfplot` activates the plots. The point coordinates can be displayed. Thanks to the `clickable` library, clinicians can, for example, display the maximal knee flexion value.

The code block [2] contains the commands to plot the gait speed histogram (see figure 3-1). Values of the left- and right-cycle gait speed are inserted at lines 3-4; 7-8.

```
1 % Gait speeds of our patient
2 %-----
3 \newcommand{\Rspeed}{1.39} % right gait cycle
4 \newcommand{\Lspeed}{1.36} % left gait cycle
```

```

5 % Gait speed bounds of our healthy database
6 %-----
7 \newcommand{\NormalSpeedMax}{1.25}
8 \newcommand{\NormalSpeedMin}{0.97}
9
10 \pgfplotsset{width=15cm, height=3cm, compat=newest}
11 \begin{tikzpicture}
12   \begin{axis}[cycle list={{blue,fill=blue},{black,fill=red},{green},{red},{blue}},
13     ymin=0.5,ymax=2,xmin=0,xmax=2,
14     hide y axis,axis x line=bottom,
15     title=Vitesse (m/s)]
16     \addplot+[xbar] coordinates
17       {(\Rspeed, 1.5)};
18     \addplot+[xbar] coordinates
19       {(\Lspeed, 1)};
20     \addplot coordinates
21       {(\NormalSpeedMax, 0) (\NormalSpeedMax,2)
22        (\NormalSpeedMax, 2) (\NormalSpeedMin,2)
23        (\NormalSpeedMin, 2) (\NormalSpeedMin,0) };
24   \end{axis}
25 \end{tikzpicture}

```

Code Block 2: Code for producing a gait speed histogram as figure 3-1

The `pgfplot` manual shows a rich set of plotting techniques. Reading coordinates provided by an external file is useful. For gait analysis, kinematic and kinetic data have to be compared to normal gait. Data dispersion is typically quantified by the standard deviation. As an example, table 1 explains the organization of the external file (*datafile.dat*) associated with the knee flexion-extension.

Columns 6 and 7 are devoted to our healthy gait database.

Table 1: Organization of the external file (datafile.dat) for the knee flexion-extension

Column 1	Cycle percentage
Column 2	Left flexion-extension <i>mean subtracted from its standard Deviation</i>
Column 3	The double of the left flexion-extension <i>standard deviation</i>
Column 4	Right flexion-extension <i>mean subtracted from its standard Deviation</i>
Column 5	The double of the right flexion-extension <i>standard deviation</i>
Column 6	Healthy flexion-extension <i>mean subtracted from its standard Deviation</i>
Column 7	The double of the healthy flexion-extension <i>standard deviation</i>
Column 8	Left <i>mean</i> flexion-extension
Column 9	Right <i>mean</i> flexion-extension

In spite of a large panel of plots, `pgfplot` cannot fill the surface bounded by two curves. A solution explained in the code block [3] consists in handling the area plot mode.

First, a white area plot corresponds to the mean value subtracted from its standard deviation (see table 1 [Columns 2;4;6]).The double of standard deviation is then stacked to represent the area dispersion (see table 1 [Columns 3;5;7]).

```

1 \pgfplotstableread{datafile.dat}
2 \begin{tikzpicture}
3   \tikzset{
4     every pin/.style={fill=yellow!50!white,rectangle,rounded corners=3pt,font=\tiny},
5     small dot/.style={fill=black,circle,scale=0.01}
6   }
7 \pgfplotsset{every axis/.append style={font=\tiny, xmin=0.01, xmax=1.01}}
8 %--standard deviation area plot of the Left knee flexion-extension--%
9 %-----%
10 \begin{axis}[enlarge x limits=false,stack plots=y,area style,
11   height=0.4\paperheight,
12   width=0.4\paperwidth,
13   ymin=-20.00,
14   ymax= 70.00,
15   clip=false]
16   \node[small dot,pin=180:{fle}] at (axis description cs:0,0.9){};
17   \node[small dot,pin=180:{ext}] at (axis description cs:0,0.1){};
18   \addplot[color=red!10!white,ultra thin, fill=white, fill opacity=0.2]
19     table[x index=0, y index=1] {datafile.dat};
20   \addplot[color=red!10!white, ultra thin, fill=red, fill opacity=0.2]
21     table[x index=0, y index=2] {datafile.dat} \closedcycle;
22 \end{axis}
23 %--standard deviation area plot of the Right knee flexion-extension--%
24 %-----%
25 \begin{axis}[enlarge x limits=false,stack plots=y,area style,
26   height=0.4\paperheight,
27   width=0.4\paperwidth,
28   ymin=-20.00,
29   ymax= 70.00 ]
30   \addplot[color=blue!10!white,ultra thin, fill=white, fill opacity=0.2]
31     table[x index=0, y index=3] {datafile.dat};
32   \addplot[color=blue!10!white, ultra thin, fill=blue, fill opacity=0.2]
33     table[x index=0, y index=4] {datafile.dat} \closedcycle;
34 \end{axis}
35 %--standard deviation area plot of the healthy knee flexion-extension --%
36 %-----%
37 \begin{axis}[enlarge x limits=false,stack plots=y,area style,
38   height=0.4\paperheight,
39   width=0.4\paperwidth,
40   ymin=-20.00,
41   ymax= 70.00]
42   \addplot[color=green!10!white, ultra thin, fill=white, fill opacity=0.2]
43     table[x index=0, y index=5] {datafile.dat};;
44   \addplot[color=green!10!white,ultra thin, fill=green, fill opacity=0.2]
45     table[x index=0, y index=6] {datafile.dat} \closedcycle;
46 \end{axis}
47 %--Mean curve of the Left knee flexion-extension--%
48 %-----%
49 \begin{axis}[enlarge x limits=false, thick,
50   height=0.4\paperheight,
51   width=0.4\paperwidth,
52   ymin=-20.00,
53   ymax= 70.00]
54   \addplot[red] table[x index=0, y index=7] {datafile.dat};
55 \end{axis}
56 %--Mean curve of the Right knee flexion-extension--%
57 %-----%
58 \begin{axis}[enlarge x limits=false, thick,
59   height=0.4\paperheight,
60   width=0.4\paperwidth,
61   ymin=-20.00,
62   ymax= 70.00]
63   \addplot[blue] table[x index=0, y index=5] {datafile.dat};
64 \end{axis}
65 \end{tikzpicture}

```


Code Block 3: Code for producing area plots of the kinematic (or kinetic) data.

Data set 3 - videos

Videos are essentials for gait analysis. They are the first media interpreted by clinicians. Videos are part of a qualitative analysis, and allow observation of the body type and pathological dysfunctions (e.g. patella dysfunction) which a 3-D system cannot measure.

L^AT_EX is well-suited to media inclusion thanks to the package `movie15`. This package, restricted to Adobe Reader, embeds videos. Videos are played either with the Adobe built-in player or with an external application.

The code block 4 illustrates how to embed a video. All options are explained in the `movie15` manual. However, we underline the usefulness of the three buttons (lines 11 to 13) added to adjust the video rate. Such buttons are valuable for clinicians when an abnormal movement occurs at a specific time.

```
1 \begin{center}
2   \includemovie[text={Click to activate the video},
3     label=videol,autoplay,
4       palindrome=true, toolbar,
5         repeat,continue,
6           mouse,
7             mimetype=video/avi]
8           {.5\linewidth}{.375\linewidth}{videol.avi}\\
9   \vspace{0.3cm}
10  Choose the video rate :\\
11  \movieref[default]{videol}{Normal}
12  \movieref[rate=0.5]{videol}{Slow}
13  \movieref[rate=0.1]{videol}{Very slow}\\
14  \movieref[pause]{videol}{Play/Pause}
15 \end{center}
```

Code Block 4: Code for embedding video file

Data set 4 - examination context

A gait examination may be carried out in different contexts. A standard environment considers that gait analysis was performed barefoot and without external aids. However, crutches or other assistance may be required. All of these elements influence the clinical interpretation, and must be presented on the title page of the technical gait report. To this end, we used a simple process: a `*.tex` file is created that contains a set of L^AT_EX commands that explain the examination context.

The code block 5 presents a minimal `\newcommand` list for describing the examination context. These commands are included in the title page, for example

Gait examination report for: \Title{} \PatientLastName{},
\PatientFirstName.

```
1 \newcommand{\INP}{00} % identification number
2 \newcommand{\PatientLastName}{LEBOEUF}
3 \newcommand{\PatientFirstName}{Fabien}
4 \newcommand{\Gender}{M}
5 \newcommand{\Title}{Mr}
6 \newcommand{\BirthDate}{09/06/1997}
7 \newcommand{\Physician}{Dr ?} % Physician who called the gait examination
8 \newcommand{\ExaminationDate}{20/10/2010}
9 \newcommand{\GaitSpeed}{spontaneous gait}
10 \newcommand{\ClinicalContext}{post-operation}
11 \newcommand{\Shoes}{No}
12 \newcommand{\ProthesisOrthesis}{No}
13 \newcommand{\ExternalHelp}{No}
```

Code Block 5: minimal newcommand list for presenting the examination context

4 The main L^AT_EX script

The main L^AT_EX script (block code 6) includes block codes previously presented:

pst.tex: see code block 2

Kinematic.tex or *Kinetic.tex*: see code block 3

video.tex: see code block 4

title.tex: see code block 5

DiagnosticElement.tex: see section 3

ClinicalTesting.tex: see section 3

The report compilation is done with pdfL^AT_EX.

```
1 %-----Required Packages-----
2 \usepackage{pgfplots}
3 \usepgfplotslibrary{clickable}
4 \usepackage[francais]{babel}
5 \usepackage[latin1]{inputenc}
6 \usepackage{amsmath}
7 \usepackage{amsfonts}
8 \usepackage{amssymb}
9 \usepackage{graphicx}
10 \usepackage{movie15}
11 \usepackage[pdftex]{hyperref}
12 \usepackage[final]{pdfpages}
13 \usepackage{supertabular}
14 \usepackage{ifthen}
15 \usepackage{tabular}
16 %-----Newcommand -----
```

```

17 \input{title.tex}
18 %-- Kinetic choice
19 \def\Cinétique{0}
20 %-----Title page-----
21 \begin{document}
22 \parbox{3cm}{\includegraphics[scale=0.8]{logoLaM1ext.pdf}}
23 \parbox{13cm}
24 {
25   \centering
26   \noindent Laboratory Address
27 }
28
29 \begin{center}
30   \Large{ Technical gait report \ of \ }
31   \textbf{ \ PatientFirstName{} \ PatientLastName{} (nIf; le \ BirthDate)} \ \ } %
32   Identification: \IPP
33 \end{center}
34 \noindent \emph{Tif;che}: \tache \CommTache \ \
35 \emph{Clinical Context}: \ClinicalContext \ \
36 \emph{Examination Date}: \ExaminationDate \ \
37 \emph{Called by}: \Physician \ \
38 \begin{center}
39   Data acquisition context : \ \
40   \begin{tabular}{|c|c|c|}
41     \hline \textbf{Shoes} & \textbf{Orthesis-Prothesis} & \textbf{external help} \ \
42     \hline \Shoes & \ProthesisOrthesis & \Externalhelp \ \
43     \hline
44   \end{tabular}
45 \end{center}
46 \newpage
47 %-----Medical information-----
48 \section{Medical information}
49   \input{DiagnosticElement.tex}
50   \input{ClinicalTesting.tex}
51 \newpage
52 %-----Videos-----
53 \section{Videos}
54   \input{Movie.tex}
55 \newpage
56
57 %-----biomechanical data-----
58 \section{Biomechanical data}
59   \subsection{Spatio-temporal parameters}
60     \input{Pst.tex}
61   \subsection{Kinematic charts}
62     \input{Kinematic.tex}
63   \ifthenelse{\Cinétique=1}
64     {\subsection{Kinetic charts}
65       \input{Kinetic.tex}
66     }
67     {No Kinetic charts available}
68 \end{document}

```

Code Block 6: Main tex code

It is worth noting the use of the package `ifthen` for automating the report. The command `\ifthenelse` will include kinetic data *Kinetic.tex* in the report only if it is available (line 19).

5 Conclusions and possible improvements

In this article, we have shown that \LaTeX is well-suited to producing technical gait analysis reports. \LaTeX differs from commercial software in its capacity to handle and centralize information flow. Indeed, a gait examination results in a large amount of information, and producing a single document containing everything improves data access and consequently facilitates the clinical interpretation.

An isolated presentation of biomechanical data is not sufficient for clinicians. We have shown the variety of techniques used to create a single clinical document. A \LaTeX database interface was used to include external information. We used web-based PHP solutions to collect data into a SQL database. Finally, we used a variety of \LaTeX packages and files to complete the single-document solution.

Improvements. Our SQL database records each gait analysis episode in order to recall the diagnosis and previous data (SPT and clinical testing) of the clinicians into the technical report. An improvement would be to eliminate the PHP script and instead use packages such as `sqltex` or `LaTeXdb`. The database access and SQL requests would be directly implemented within a *.tex* file. This would achieve two efficiencies: the report automation would be improved, and it would be faster to execute a specific SQL request.

In our opinion, the merger of biomechanical and medical information is a first solution to reduce the variability of clinical gait interpretations highlighted by some authors ([6], [4]).

Moreover, \LaTeX facilitates the spread of useful information, especially in a local hospital where hard copy is widely used. The \LaTeX PDF output allows printing of a high-quality document. The package `pgfplot` contributes by drawing high-quality vector graphics. The output quality is an element which is worth considering, because a high-quality document will be more readily used.

Nevertheless, currently the paper patient folder has been replaced by a medical e-folder. Our technical report is well-suitable for this framework since the PDF output can be viewed online. The use of the packages `movie15` and `pgfplot` associated with *javascript* plug-ins improve the PDF interactivity. `Movie15` embeds all types of multimedia files without the need to browse online file folders, and can play view videos simultaneously.

Furthermore, `Movie15` enables the inclusion of 3-D objects, such as graphics provided by medical imaging devices. As an example, figure 4 shows a 3-D view of an humerus. This kind of information is of great interest for clinical gait interpretation, and is used to analyze patients that have orthopaedic surgeries.

However, the multimedia performance of commercial software is not yet completely sufficient for clinical analysis. For example, our reports do not include 3-D animation of gait. A future enhancement might be performed with *javascript* plug-ins.

u3D model, Click to active mimetype

Figure 4: 3-D Humerus representation included with the package `movie15`

In our hospital environment, the technical gait reports received positive feedback. Clinicians appreciated getting information in one document, as did the IT department, because the PDF is suitable for data protection and medical e-folder development.

In conclusion, hospitals could benefit greatly from high-quality reports generated in part by \LaTeX . Solutions presented in this article show \LaTeX 's relevance to clinical gait examination reports. The use of \LaTeX to combine text, graphics, and 3-D visualization and animation would make it a promising tool for other medical examinations where data fusion is required.

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