

## STATFREE – A SOFTWARE TOOL FOR BIOMECHANICS

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Traditionally, a major part of the time invested into a study in biomechanics is devoted to the measuring process. The following data analysis is often statistics with its standard procedures as t-, F- and Chi<sup>2</sup>-testing. The strive for the analysis increases along with the expansion of theoretical background and/or model building. StatFree is a software for the post-measuring process. It performs statistical analysis, provides comprehensive graphic options and has a build-in programming utility to calculate the numeric efficiently and flexibly.

**KEY WORDS:** software, analysis, visualization, calculation, testing.

**INTRODUCTION:** Traditionally, empirical research in biomechanics (and other sciences) consists of the measurement process, rearrangement of the data, statistical analysis, result presentation and ends with discussion and conclusion of the consequences. A major part of the time spent in a study is the measuring process. The following steps in the research process as filtering and doing the statistics with its procedures as t-, F- and Chi<sup>2</sup>-testing is regarded as standard, which normally does not consume much time. However, the effort and time taken for the data processing increases with a stronger theoretical background and/or a more sophisticated model building. An example is the “dynamical systems approach”, which was a portrait in Joseph Hamill’s (Hamill, Haddad et al. 2005) Beijing keynote lecture, in which interactions within a (biomechanical) system are analyzed. Another method (well known in physics) is the description of a physical state in phase space representation. Phase space consists of all possible combinations of coordinates and momentums of a physical system. For a system in biomechanics such as the human body, the phase space can be regarded as the key coordinates of the body (the joints of neck, shoulders, elbows and hip etc. as well as some distal endpoints) and their respective velocity. This is possible because the segment masses do not change significantly during most actions and hence momentum and velocity are proportional to each other. For a description of a body with  $n$  coordinates the phase space is a vector space of  $2n$  dimensions. To keep the time and effort in the post data processing at bay, flexible software is indispensable. The purpose of this paper is to demonstrate the advantages of the software StatFree within a research process especially when more complicated theoretical approaches are involved. Under the following headings an overview of StatFree’s features is given and further its functionality is demonstrated with the example of the cyclic motion of running on a treadmill. The software was first created to give students a tool to pursue their course tasks. Later on it became clear that after modifications it turned into a valuable instrument for research as well.

**METHOD:** Software for the post measuring process needs to have various attributes: A common data format to be able to receive data from measuring systems; Tools to rearrange the data structure; Digital filters; a flexible programming unit; graphic options for two and three dimensional graphs; a facility to document the analyzed process. StatFree can serve for all these needs. StatFree is a Windows based statistics, analysis, graphics and mathematics programming package. It uses ANSI text format. Within StatFree two data sets with up to thousand variables each and thousands of cases (the maximum depends on the computer hardware) are active. It is designed to perform its major tasks by only a few clicks. For example visualizing the mean and the standard deviation and/or error of data sets can be done by two key strikes only.

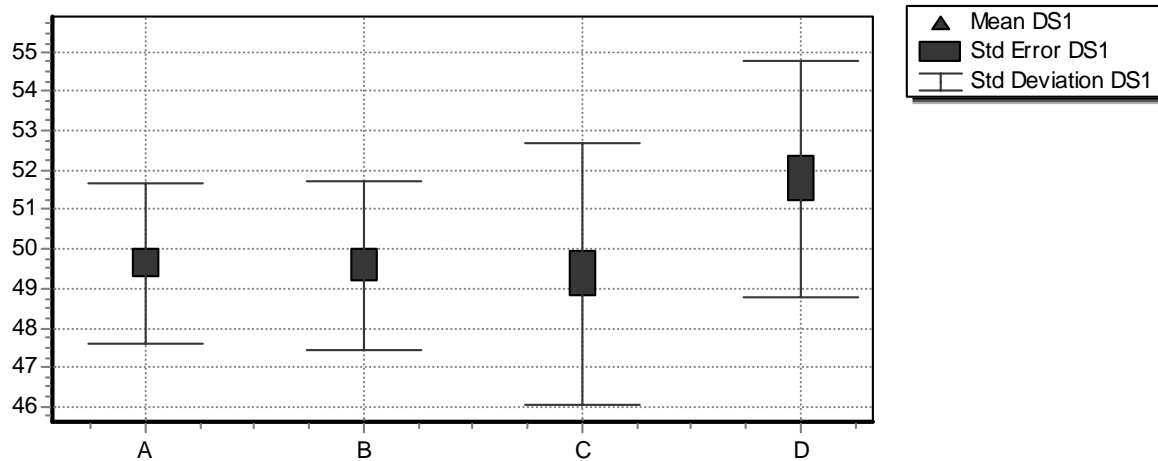


Figure 1: Example for the visualization of data sets

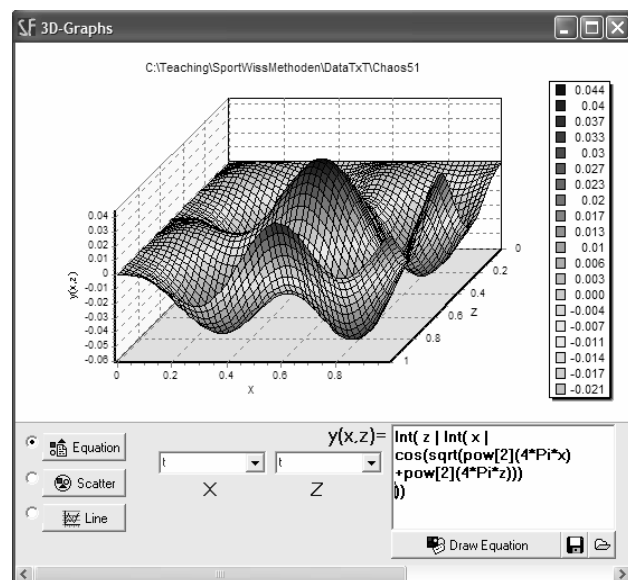
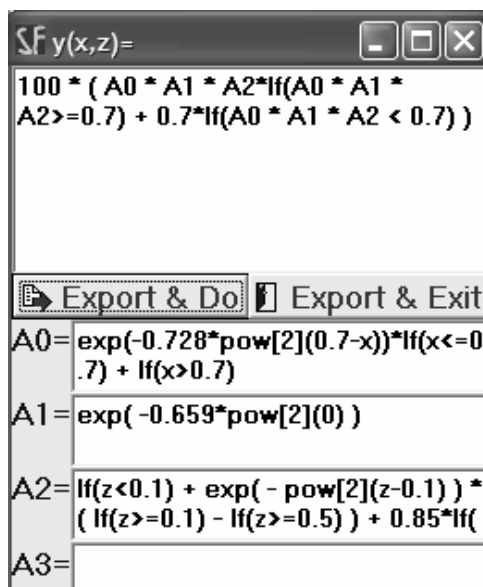


Figure 2: Equation builder with substitution fields      Figure 3: Surface plot of a double integral

A further key strike saves the calculated numbers for further use. When a t-test for independent samples is performed, automatically a Chi<sup>2</sup>-test and a F-test are performed as well. The Chi<sup>2</sup> result tests if the samples are distributed normally (a prerequisite for the t-test). The F-test checks if the variances are significantly different or not. This ensures that the appropriate t-test (equal or non-equal variances) is automatically used. One major item within StatFree is a facility to program complex algorithms for data analysis or graphic display. All variables can be included and combined with and within 21 algebraic functions; four continues densities (normal, t, F and Chi<sup>2</sup>) and four operators. The operators perform numerical differentiation, numerical integration, iteration and an If-operator allows piecewise definition of functions. With these operators differential equations can be solved numerically and deterministic chaos can be explored. Regarding the graphic potential, StatFree has three different graphic windows. The windows called 2D and 3D offer various options from pie charts to line charts (2D) and line graphs to surface plots (3D). Those two graphic windows are of use for a quick analysis within the research process. The graphs are created with few clicks for fast information. The third graphic window called "Extended Graphs" offers all sorts of graphs, those which can be found in 2D and 3D and many more. In addition, all attributes can be changed.

To see StatFree's capabilities we use an example from biomechanics for illustration. In the following example a subject is running on a treadmill for about 20 minutes. The question is

does the movement pattern change during the run or not? Clemens Müller, one of my students supplied the row data. Two dimensional coordinates were calculated with the help of an APAS system at 50 Hz. 1500 frames at the beginning of the taping (after acclimatization of about one minute) and 1500 frames just before the end of the run were taken. The test parameter is the distance from hip to toe as it changes during the run. Therefore, in this example only the vertical and horizontal coordinates of the hip marker and of the toe marker are of interest. The first step in the analyzing process is writing an equation in StatFree's equation generator. The simple expression is given in equation (1). In the first line the expression appears in the usual way where the variables  $v_2, v_3, v_8, v_9$  are combined to calculate the distance. Line two displays how the formula is written in StatFree.

$$l = \sqrt{(v_2 - v_8)^2 + (v_3 - v_4)^2} \quad (1)$$

$$\text{sqrt}(\text{pow}[2](v2-v8) + \text{pow}[2](v3-v9))$$

Step 2 filtering is done using a F<sup>3</sup> filter (Vietsen and Riehle 2004). The result is the filtered length as a function of time. The numerical differentiation (step 3) creates the second parameter needed for the phase space diagram. For the following explanations data set one contains the 1500 frames of the beginning of the run and data set two hosts the 1500 frames at the end of the run.

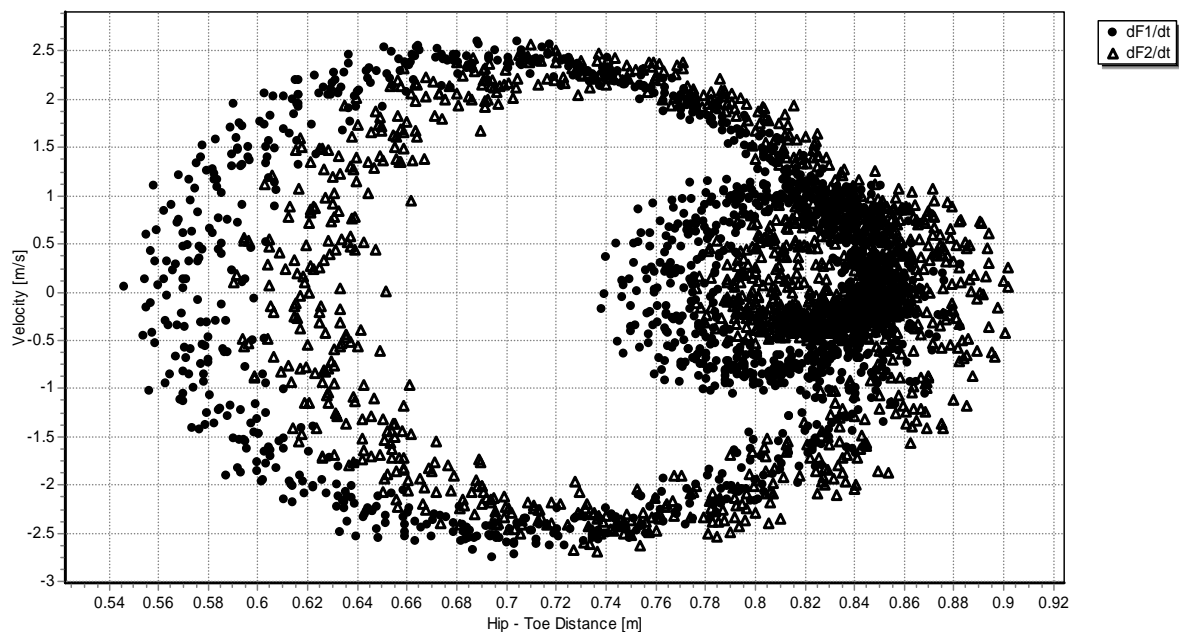


Figure 3: Phase space diagram

Step 4 is the creation of an average one cycle track for each of the two data sets. This is one of the StatFree's functions. One has to define where to start within the cycle. It helps to choose a common start for both of these circles. StatFree allows setting a vertical start line with three numbers. In the example of Figure 3 the choice is 0.75 m on the horizontal axis and the interval -3m/s to -1.5m/s on the vertical axis.

**RESULTS and DISCUSSION:** The outcome is the mean, the standard deviation and the standard error for the coordinate as well as the velocity. StatFree gives a graph that displays a phase space diagram with vertical and horizontal error margin. For this example however the graph is confined to a mere phase space diagram with means for coordinate as well as velocities (see Figure 4).

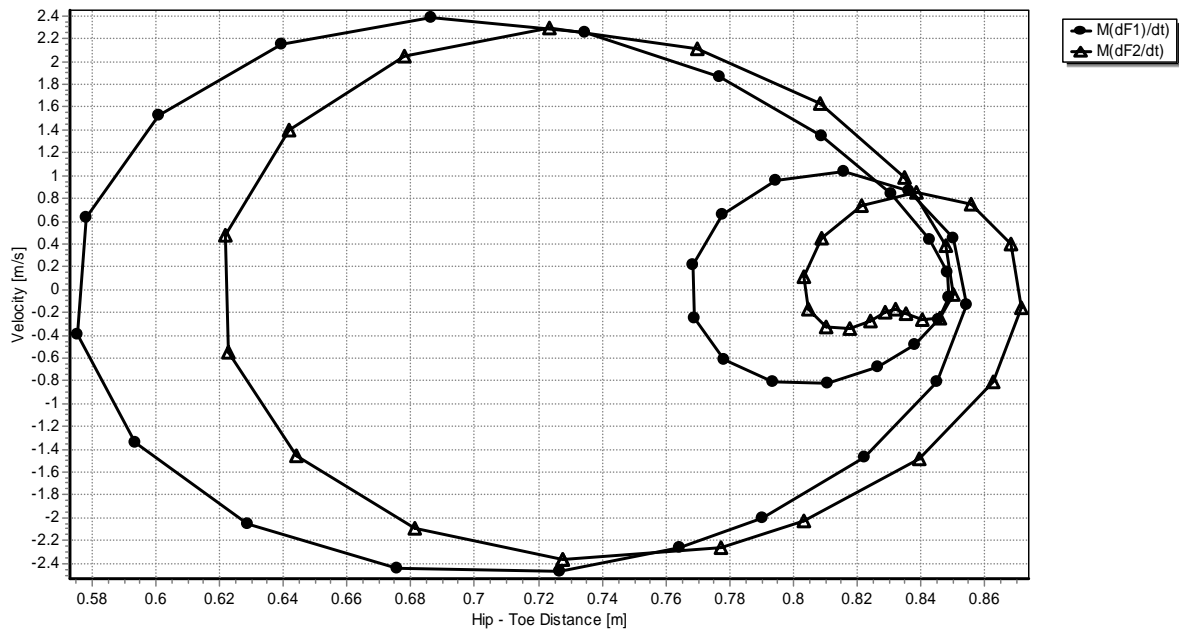


Figure 4: Averaged means of the data sets of Figure 3

The clear difference between the two curves is the decrease in stride length. But there is another interesting fact. The number of minima and maxima of the parameter velocity within one cycle changes between the beginning and the end of the run (Figure 5).

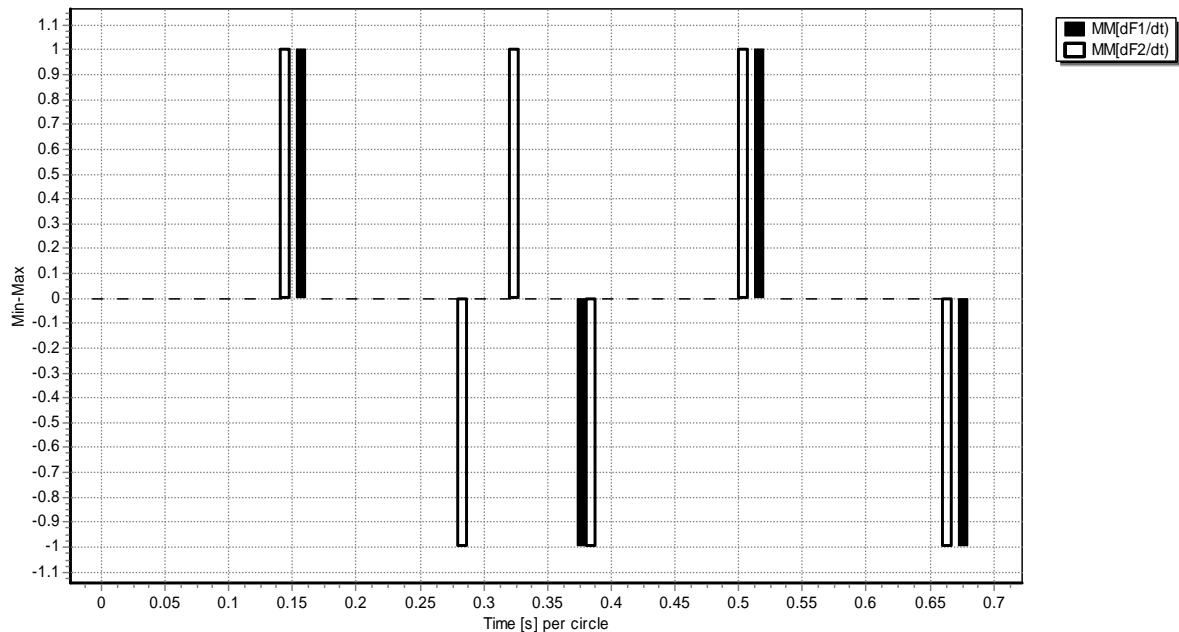


Figure 5: Minimum (horizontal value -1) and maximum (horizontal value 1) of  $dF/dt$

This might be regarded as the analogue to the famous period-doubling of chaos theory (for a references see for example (Strogatz 1994)).

**CONCLUSION:** StatFree can facilitate the whole post-measuring process from data rearrangement, intermediate results calculation, statistical analysis to the creation of the final graphs. StatFree is an alternative to pricey commercial software packages. With its flexible programming conveniences it can solve huge complex tasks, which go beyond the simple standard statistical analysis. A help file and two tutorials are of assistance to get acquainted

with the software. StatFree is free for educational and non-commercial use. It can be downloaded from <http://www.uni-konstanz.de/FuF/SportWiss/vieten/Software>.

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