

Tracker Video Modeling with Spreadsheets

The Tracker Video Modeling Tool can overlay computational models on a video clip to compare theoretical predictions with real experiments. Three types of models are available: (1) kinematic models, (2) dynamic models, and (3) external models. This tutorial shows how to create an external model that accesses spreadsheet data using the operating system's clipboard as shown in Figure 1.

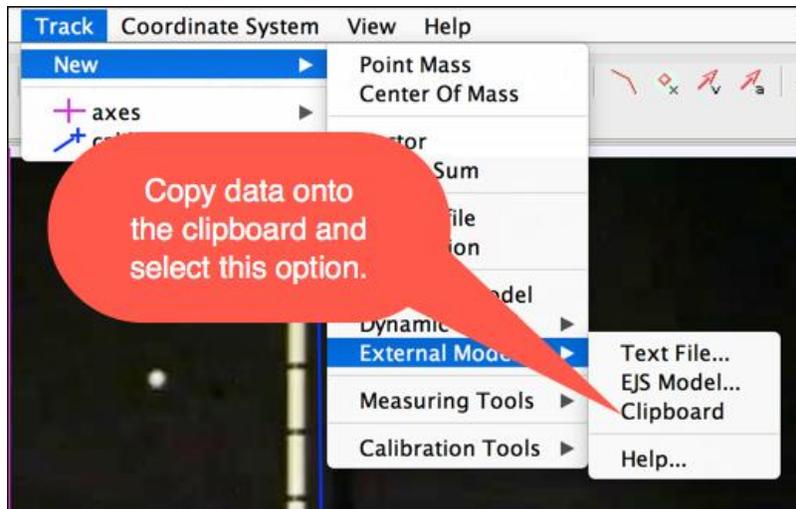


Figure 1: Importing data from an external computational model using the clipboard.

The complete Tracker Video Modeling with Spreadsheets tutorial, including video and spreadsheet, is packaged in a single Tracker zip file (balltoss-spreadsheet.trz) available on the AAPT-ComPADRE [Open Source Physics](#) website. Download the Tracker zip file to any computer that has Tracker (and Java) installed and double click the file to open it. This will load the video into Tracker and open the associated Excel spreadsheet so that you can follow the instructions in this tutorial. Note that you can change the TRZ extension to ZIP to view the resources without using Tracker.

Spreadsheet Models

Tracker can import (x, y) data from almost any program if the data can be copied to the clipboard or saved as a text file. The only requirement is that x and y values are separated by whitespace, commas, or semicolons and that coordinate pairs are on separate lines.

A good choice for simple modeling is a spreadsheet because spreadsheet programming is easy to learn and because the spreadsheet is easy to document using text cells and graphics as shown in Figure 2.

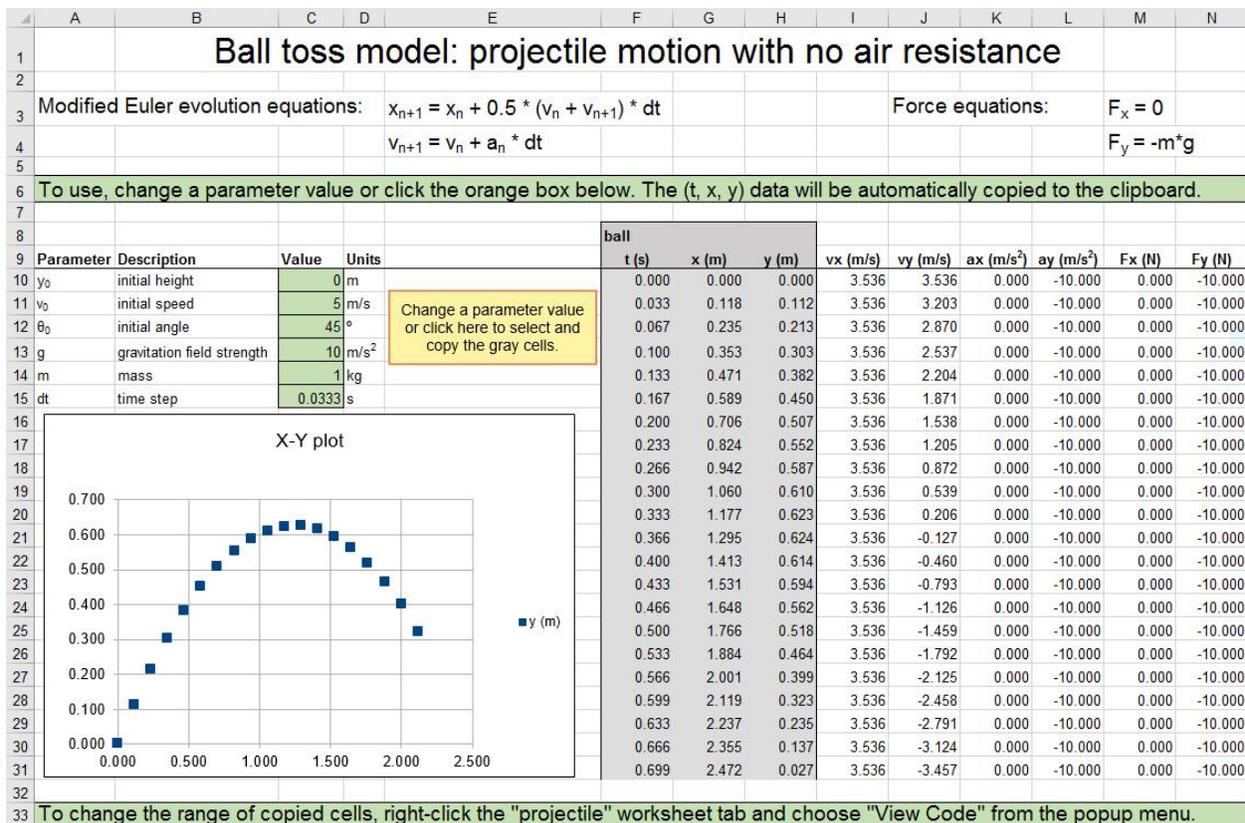


Figure 2: A spreadsheet model for the Ball Toss video clip.

The Ball Toss spreadsheet computes a table of (t, x, y, vx, vy, ax, ay) data using an algorithm for a point mass with an initial speed and angle. The first row of the position, velocity, and acceleration components in the table starting in cell F10 is computed using the parameter values highlighted in the green Value cells below cell C9. Subsequent data table rows are computed using the modified Euler algorithm. For example, the y-position and y-velocity values y^1 and v_y^1 in the next row are computed using the initial position y^0 , the initial y-velocity v_y^0 , and the new y-velocity v_y^1 :

$$v_y^1 = v_y^0 - g * dt,$$

$$y^1 = y^0 + 0.5 * (v_y^0 + v_y^1) * dt.$$

The x-velocity is constant because there is no x-acceleration. This algorithm is repeated for as many rows as desired. Click on a cell in the spreadsheet to see how the modified Euler algorithm is implemented using spreadsheet syntax.

The gray cells in Figure 2 show the data to be imported into Tracker: t, x and y columns plus two optional header rows that identify the data. Row 8 provides a name for the object ("ball") and row 9 identifies the columns and their units ("t (s)", "x (m)", and "y (m)"). When Tracker imports the data it reads the header rows, if any, to determine what is being imported (characters in parentheses are ignored). Since the first row contains the single string "ball" Tracker uses it to name the external model track. Since the second row includes strings that

begin with “x” and “y” and are otherwise identical (after stripping the units), Tracker interprets the corresponding data columns G and H as (x, y) coordinates. In this example this header row also includes the string “t” so Tracker interprets data column F as time.

Thus, it is easy to prepare data for importing into Tracker: the numerical data is organized in columns preceded by optional header rows with identifying information. If no header rows are provided the first 2 data columns are assumed to be (x, y) coordinates and additional columns, if any, are ignored.

Importing Spreadsheet Data into Tracker

In the spreadsheet model, copy the gray cells (track name, column identifiers, and numerical data) to the clipboard either with the mouse and keyboard or by clicking the orange box. In Tracker, select the Clipboard item in the Track|New|External Model menu as shown in Figure 1 to create the external model track. The track points are drawn on the video when it is played.

Model Builder

The Model Builder (Figure 3) is displayed when an external model track is first created or by choosing Model Builder from the track’s menu. The builder allows the user to synchronize the external data with the video clip by setting properties such as the start frame, data stride and time basis.

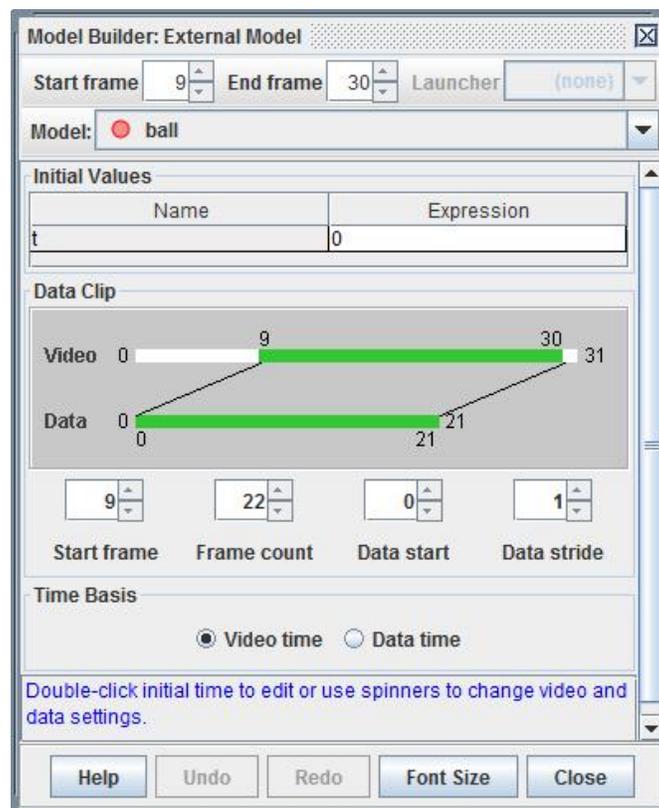


Figure 3: Model Builder for Ball Toss spreadsheet.

In the Ball Toss example, the data is correctly synchronized by default (Figure 3): the graphic shows that data point 0 is displayed on video frame 9 and the rest of the data follows. But we recommend you use the model builder to explore the data clip options before continuing. For example, change the data stride to 2 and note that (a) every other data point is skipped and (b) the remaining data points are displayed on video frames 9 to 19. Play the clip within Tracker and note the effect. This data stride feature can be used to synchronize an external model that uses a smaller time step than the video. Experiment with the other data clip settings to see what effect they have on the graphic (Figure 4) and video synchronization.

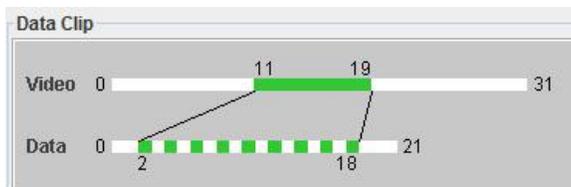


Figure 4: A data clip with start frame 11, frame count 9, data start 2 and data stride 2.

The time basis is what tracks use to determine velocity and acceleration. The model builder lets you choose that basis to be either the video time itself (default) or the imported data time (if any). It is usually best to use video time since it is determined by the recording camera. Choosing data time replaces the video frame times with the values in the imported time column. In most situations, data times and video times should use the same time step Δt .

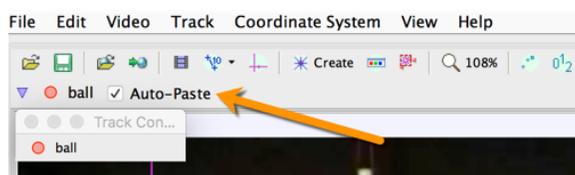
Reset all model builder settings to their original values (start frame 9, frame count 22, data start 0, data stride 1) before returning to the spreadsheet to fit the model to the video.

Fitting the Spreadsheet Model to a Video

Fitting your model to a video means adjusting the parameters until the model tracks the real object in the video as closely as possible. One starting strategy could be to create a Point Mass and track the ball with the mouse for several steps to estimate the initial speed and angle.

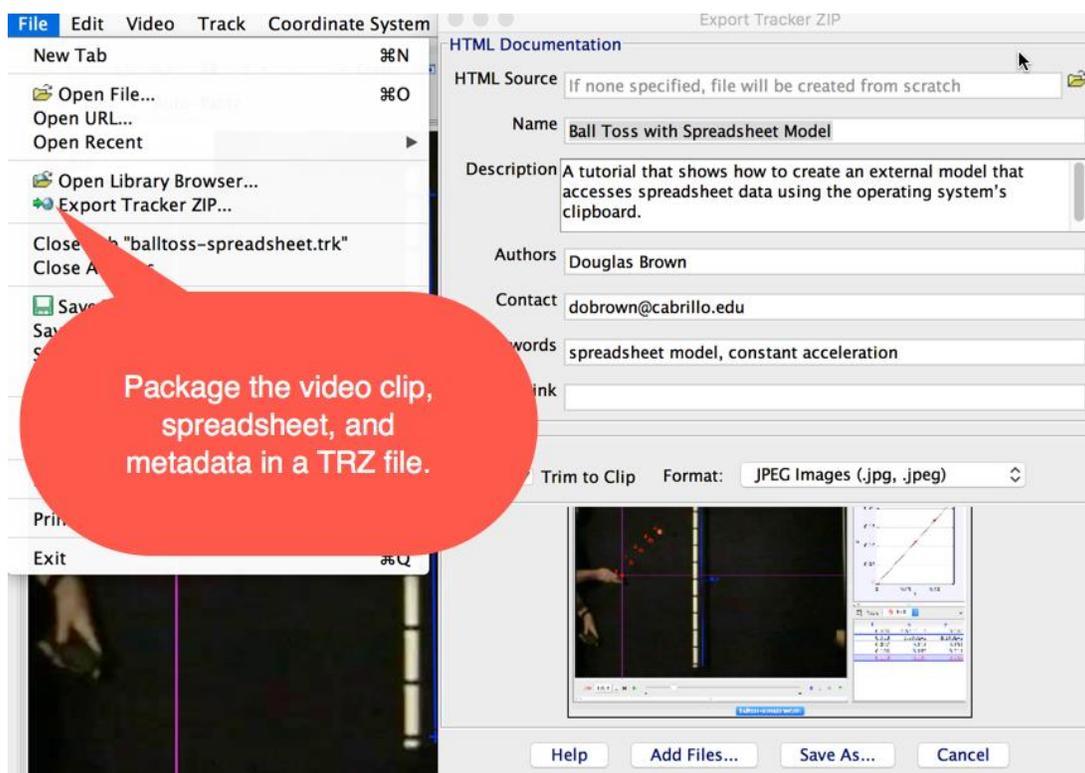
Follow these steps, repeating as needed, to adjust your model for the best fit:

- Play or step through the video and visually compare the model with the real ball.
- For each of the model parameters y_0 , v_0 , θ_0 , g , and m , use your knowledge of the model equations and your observations above to predict whether their value should be (a) increased, (b) decreased or (c) left unchanged for a better fit.
- Change one or more model parameters, copy the new data to the clipboard and return to the Tracker program. (Some, but not all, spreadsheets will automatically copy the data when a parameter changes.) Note that Tracker automatically updates the track if the auto-paste option is checked.



Creating a Tracker Zip File (TRZ)

A **Tracker ZIP file** is a zip file with extension “trz” that contains an entire Tracker experiment including the tracker data file (trk), video clip, support documentation (such as a spreadsheet model and pdf) and metadata. Since they are self-contained and self-documenting, TRZ files are the easiest and most convenient way to package and share Tracker experiments.



Online Tracker Resources

There are numerous ways to get additional Tracker examples and help. The Tracker program has extensive help available from the Help menu. Tracker Help is also available on the Tracker website at <www.physlets.org/tracker>.

The AAPT-CompADRE [Open Source Physics \(OSP\)](http://www.physlets.org/tracker) website distributes an extensive collection of Tracker experiments under the CC Attribution-NonCommercial-ShareAlike (CC BY-NC-SA) license. Visit the OSP site and search for “Tracker.” Then use the “Refine search” option to narrow your search to a specific topic. You can also start by searching for a topic and then narrow your results by selecting the Tracker Video Model type.

The OSP site hosts numerous bulletin boards where registered CompADRE users can ask questions and share information and one of the most popular is the Tracker Discussion Forum. Registration and participation in the Tracker Forum is free and we encourage all Tracker users to post their questions and suggestions to this bulletin board.

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Tips, bug reports, and suggestions for video analysis using Tracker.

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Happy Tracking,

Doug and Wolfgang