Motion Termination

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Movement Termination Adjustment

Movement termination identification is an important preprocessing step in mouse-tracking and reach-tracking studies. The finalization of the arm movement relies not only on the experimental setup but also on the experimental condition. For example, two response criteria called the click and hover conditions, have been investigated in mouse-tracking experiments (see e.g. (Grage, Schoemann, Kieslich, & Scherbaum, 2019; Schoemann, Lüken, Grage, Kieslich, & Scherbaum, 2019)). In the first case, trials were terminated by clicking inside the target. In the second case, trials were terminated just after participants moved the cursor into the target. Therefore, the first condition allows for hesitation even when the cursor is inside the target, whereas the second condition stops the recording of the trajectories upon reaching the target. Therefore, the first one might require a method to decide the last point of the trajectory if a participant did not click immediately after the cursor enter the target. These two cases are important to consider in reach-tracking experiments in virtual reality. For instance, similar to the click condition, Kaiser and Bullinger (2020) performed a reaching precision study in virtual reality in which participants were asked to maintain the controller inside of the target. To identify the start and end of the movement, the authors divided the last phase of the arm movement into fine adjustment and holding by applying a kneedle algorithm and time-based condition. The most common method to identify movement termination relies on manually adjusting the trajectories or a speed-based criterion. For example, in a finger-tracking experiment, Gallivan and Chapman (2014) associated the last point of the trajectory with the frame set as "whichever of two events occurs first: the frame containing the maximum position value in the direction of the reach (i.e., the max reach extent) or the first frame in which the velocity drops below 20 mm/s" (p. 7).

Similar to the hover condition described above, the recording of the trajectories in the Simon Task in virtual reality was stopped at the last frame before the sphere attached to the controller entered the targets. As shown in Figure 1, the trajectories of some trials show a movement towards a target followed by a substantial movement back to the starting sphere and a subsequent movement again towards the same target. I developed a simple speed-based method to discard the segment of the movement trajectory that does not belong to the response in the case of these trials.

The first step is to identify if the trial is to be adjusted. Let $v_x(t)$, $v_y(t)$, and $v_z(t)$ be the velocities of the respective components of a trajectory and v_{th} be a velocity threshold. The speed of the x component of a trajectory is defined as $s_x(t) = \sqrt{v_x(t)^2}$, and the speed of the projection of the trajectory onto the YZ plane – that is, the plane parallel to the sagittal plane of the participants – is calculated as $s_{yz}(t) = \sqrt{v_y(t)^2 + v_z(t)^2}$. The point in time, t_{max}, of the trajectory associated to the maximum value of $s_x(t)$ is first found. The number of minima of $s_{yz}(t)$, such that $t > t_{max}$, are then calculated. If the number of minima is greater than 2 and any values of $v_y(t)$ and $v_z(t)$, for $t > t_{max}$, are lower than $v_{th} = -0.1$, the trajectory is to be adjusted. The existence of at least two

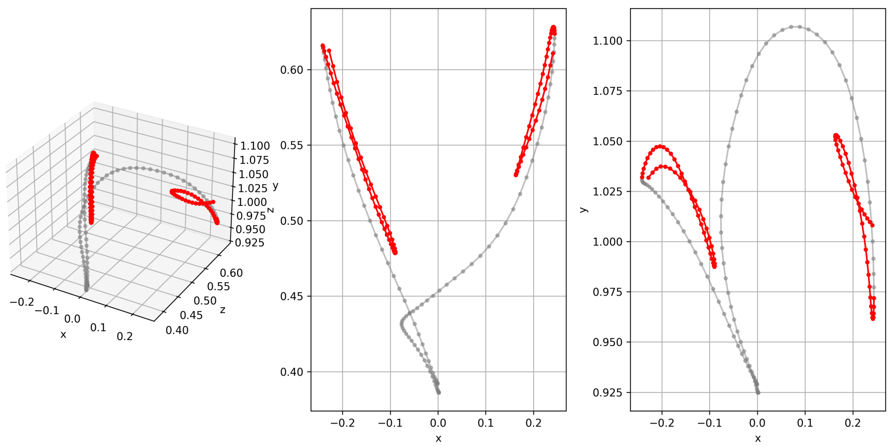

Figure 1: Examples of two trajectories that were adjusted. The trajectory segment that is to be removed is shown in red.

minima of s indicates that there were at least two discrete movements, whereas the threshold criteria ensures that this minima are associated with changes of direction as the trajectory velocities along those components are positive for forward arm reaching movements.

After verifying that the trajectory meets these three criteria, the finalization of the movement is determined by identifying the zero-crossing points of $v_x(t)$ such that $t > t_{max}$. If such points exist, movement termination is defined as the previous sample to the point associated with the first change of sign of $v_x(t)$ after t_{max}. Figure 2 shows an example of how the trajectory towards the left target in the previous figure was adjusted. The red dots in both figures indicate the segment of the trajectory that was removed.

This method then was used to adjust the point of movement termination of the trajectories from the Simon task. Performing this preprocessing step was necessary prior to computing the geometric descriptors of curvature that are presented in the next section.

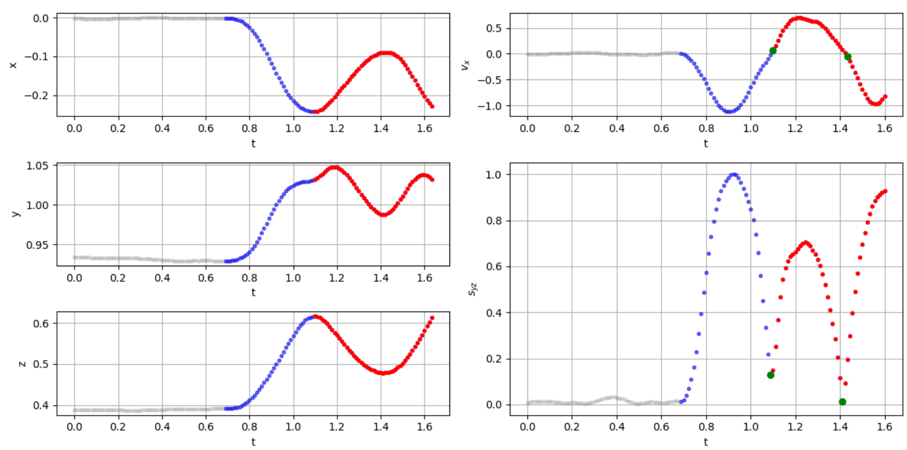

Figure 2: Example of the method to adjust movement termination. The resampled trajectory, the discarded trajectory segment, and the final trajectory are shown in grey, red, and blue, respectively. The green dots indicate minima.

References

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