Filtering for interactive systems

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The internship is focused on input filtering and signal processing for interactive systems with the primary goal to create an improved version of the 1€ filter [1], which has become an academic and industry standard since we initially proposed it. This filter was designed based on the observations that (1) input noise is less noticeable on fast-moving objects, and (2) that latency – a common side-effect of filtering – is more noticeable at high visual speeds. As a consequence, the core idea of the filter is to dynamically adjust the cutoff frequency based on an estimation of the input speed in order to to filter more at low speed to reduce the perception of jitter, and to filter less at high speed to reduce the perception of latency. The relationship between the cutoff frequency and input speed is currently linear by default, which is a strong assumption that we would like to investigate and perhaps challenge in this work.

The 1€ filter is not only widely used in the HCI academic world but also in the industrial world: companies have proposed implementations in different languages and the filter has been integrated in libraries like libavg, referenced in frameworks like MiddleVR, in game engines like Unreal Engine, in commercial systems like Vicon motion tracking used for professional film production and biophysics research, but also in widespread software like Google Chrome. The goal of this internship is to create the next version of this filter that would be more efficient and easier to calibrate.

The internship involves researchers from Lille and from Waterloo who developed the 1€ filter. It is part of a grant application that can support travelling between France and Canada. This internship can also continue as a Ph.D. on the broader topic of input in interactive systems.

Description

A first objective is to investigate the human factors related to the perception of noise and latency depending on visual speed. This requires designing controlled experiments using protocols known in psychophysics, such as JND (Just Noticeable Difference) experiments. The results will inform how to adjust the cutoff frequency depending on speed to mitigate jitter. It can also help to define new metrics to measure jitter as it is perceived by users. The same work has to be carried out on the perception of latency as a function of visual speed. These questions have never been addressed in the literature to the best of our knowledge and the answers are essential to improve the filtering technique.

Using the above results, the next goal is to facilitate the tuning of the filter's parameters, either semi-automatically or by hand by interaction designers. Tuning a 1€ filter today implies painstakingly varying value combinations and trying them on a pointing testbed. Automated approaches exist, but they shift the "burden of parametrization" from the filter's arguments to some hard-to-assess task requirements [2]. There is likely not a single set of optimal values for a given situation, depending on the characteristics of the input and output devices, on user preference, and on the task requirements: some tasks require more precision than others, making some amount of jitter at least functionally acceptable; some amount of lag is ok when a dragged target is hidden under the user's finger; etc. We aim to facilitate this tuning, either (1) by reducing it to a single parameter expressing a trade-off on a jitter-latency Pareto front, or (2) by devising a new set of two parameters that are functionally equivalent to the current cutoff frequency and beta, but easier to understand and visualize for users that are not mathematicians or signal processing savvy. In both cases, this will imply usability studies to test the efficiency and ease of use of the candidate methods, paired with controlled studies to make participants (other than the ones doing the tuning) assess the tuned outcomes.

Objectives

1. State of the art on filtering techniques for interactive systems
2. Design and development of an experiment to characterize the perception of noise and latency
3. Proposition of solutions to improve the filtering technique
4. Evaluation of these solutions with a comparison to the state of the art

References

[1] Casiez, G., Roussel, N. and Vogel, D. 2012. 1 € filter: a simple speed-based low-pass filter for noisy input in interactive systems. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (New York, NY, USA, mai 2012), 2527–2530.

[2] Taranta, E.M., Koh, S.L., Williamson, B.M., Pfeil, K.P., Pittman, C.R. and LaViola, J.J. 2019. Pitch Pipe: An Automatic Low-pass Filter Calibration Technique for Pointing Tasks. *Proceedings of the 45th Graphics Interface Conference on Proceedings of Graphics Interface 2019* (Waterloo, CAN, juin 2019), 1–8.