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Detecting & Tracking the Unseen

A Popular Scientific Summary

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Enhancing artificial intelligence for detecting what is yet undetectable, by ”the more the merrier” principle. This paper proposes a filtering algorithm for tracking detection, with broad field application named Cascade Matched Filtering (CMF), digging out the desired signal from the noise floor.

Yesterday’s and today’s innovations in artificial intelligence (AI), are shaping the future of the world we live in, for the better or the worse? AI is one of the most talked about technological topic in modern time, getting a lot of attention in the scientific world as well as in the media, splitting people between being hyped and afraid of the technology. The ongoing digitization of the construction industry, more known as ”Construction 4.0”, have only yet seen the surface of what AI could lead to in the future. Computer vision and robotics are some of the subdomains of AI, where computer vision is the eyes of the system, and robotics the motion and manipulation of the system. With optical tracking of defined targets through computer vision, robotics can guide an electronic distance measurement (EDM) to measure the distance to the tracked target. This technology describes the modern surveying equipment, called total stations. These systems can determine positions within a millimeter accuracy, over several hundred meters of distance. So how can one enhance the performance of such an intelligent system?
There is a limitation of what computer vision can detect due to, e.g., dynamical range, operational wavelength and noise level. After a certain increment in distance, the system will not be able to track or detect the target any longer, failing to determine its position even if the capability exist. By enhancing the computer vision of the system with signal processing, the system will regain the ability to detect and track the target again for the same distance. There is a performance improvement limit for these algorithms, which results in lost detection after the distance is incremented further. By modifying a standard filtering method, namely Matched Filtering (MF), to not only include one pulse period, but several consecutive pulse periods in a pulsed system, one gets the general idea of the purposed Cascade Matched Filter (CMF). Adding more pulse periods into the algorithm,

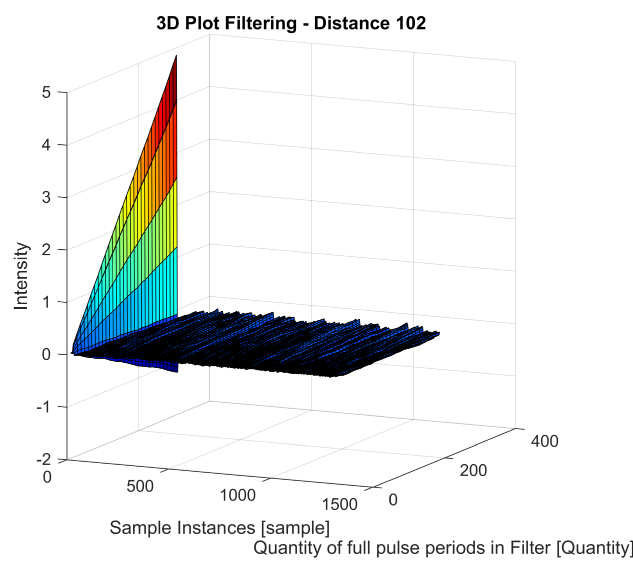

Fig. 1. Cascade matched filter output for different filter lengths.

leads to more amplification of the signal. The purposed detection algorithm have been proved to be able to increase the detection with a factor of 7 dB, equal to an amplitude ratio of 1000. CMF was developed for a near-infrared (NIR) tracking detection system, but can also be applied to many other applications. For illustrating the enhancement with an acoustic example, the MF algorithm is able to enhance a whisper to a normal conversation level, while the CMF can enhance the whisper to a rocket launch level. This is how powerful the algorithm can be, and it is even able to perform these results in an embedded real-time system. As MF the CMF is a linear filter and is perfect for time synchronized systems where the timing is essential but the received signal intensity is to weak to detect even for a MF. By using less costly sensors one could still enhance the received signal to the same desired level of detection, moreover, even where the best sensors fail to detect due to longer distances or too weak signal intensity, the CMF could still detect the signal. The development of the NIR tracking detection system testifies the strong performance of the filtering method. The system performance from filtering a power and frequency fixed rectangular pulse train signal at various distances in real-time operation, is observable in Fig. 1, 2 & 3 . Figure 2 illustrates the minimal filter length required to detect a tracking signal at different signal distances and noise levels. With a MF the filter length is either 0 or 1, so the comparison between CMF and MF is illustrated from direct observations of Fig. 2. The best MF performance is achieved in the lowest realistic noise level possible and with a filter length of 1, this results in a tracking distance of 247 meters and in maximum noise level 78 meters. These two noise levels are the equivalent of tracking an object at a really cloudy day and in direct intense sunlight. This is the best performance of the MF, which is

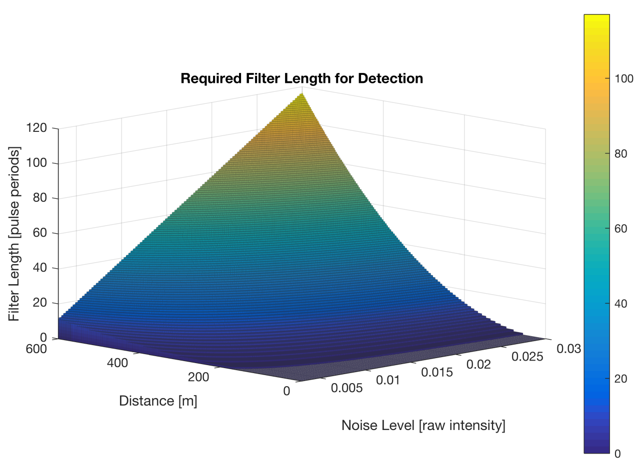

Fig. 2. Required filter length for signal detection.

the optimal liner filter for instantaneously maximizing the signal to noise ratio (SNR) output. With the CMF approach the performance is limited by the sensors noise equivalent power (NEP), memory of the system and the amount of pulses included in the pulse train. For the detection and tracking of the developed NIR tracking detection system, the pulse train consisted of an infinite rectangular pulse train and the sampling of the signal was synchronized to only sample time instances around the estimated time of signal arrival, resulting in a restriction solely by the NEP. By utilizing 300 pulses in the filter length of the CMF, limits of 960 meters in maximum noise noise is achieved and 3 034 meters in low noise environment, like on a cloudy day. The SNR gain of the system utilizing 1-300 pulse lengths in real-time performance is illustrated in Fig. 3, where the system encountered a blocking of the signal at 95 meters from a person walking in-front of the tracking process. The filter output of the same data collection at 102 meters distance from the tracking source is displayed in Fig. 1. One can observe the linear amplification of the system output in the z-axis and the sampled time instances along the x-axis, as the filter length increments in y-axis. The SNR gain curve

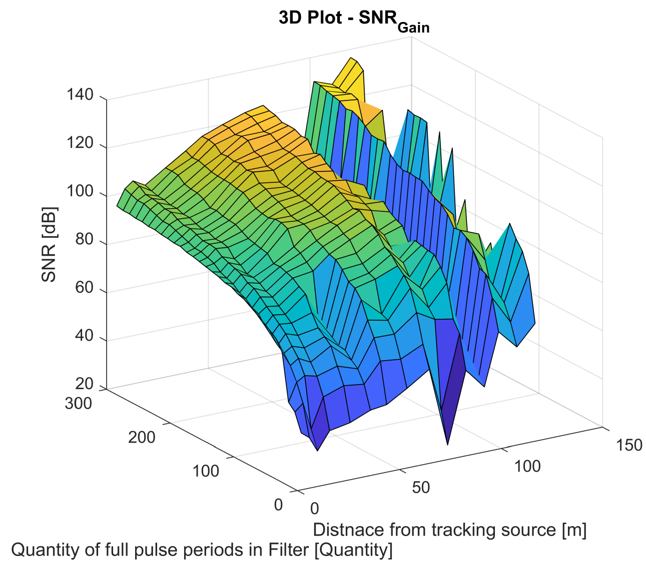

Fig. 3. SNR for different tracking distances and filter lengths.

is illustrating some signal separation issues for the SNR curve calculation, and the blocking of the tracking signal at 95 meters for 1/4 of a second. The performance was also simulated and expected to have the same characteristics as the SNR gain curve registered at tracking distances of 102 meters. Matched filter have a broad field of application from communication devices to detection and tracking devices, such as remote controllers, WiFi, Sonars, Radars, ECG, X-Ray scans, observations of Gravitational-waves to just mention a few applications. Cascade matched filter could be implemented in these applications as well as others, enhancing the system performance. Imagine what we can detect now. What can we explore outside of our solar system, how much safer will the future autonomous car be by detecting objects before it is to late, and by how much can we reduce the exposure time of x-ray scans to get safer medical equipment?

References

[1] Sebastian Elm, *Embedded Real-Time Tracking Detection - Cascade Matched Filtering & Adaptive Threshold Techniques on Optical Tracking Signals under AWGN*. (2018). MSc Thesis. ISRN LUTFD2/TFRT–9999–SE ISSN 02805316, Media-Tryck, Lund University, Lund, Sweden.