Boosting Template Matching with Kalman Filter for Fast Markerless Body Part Tracking

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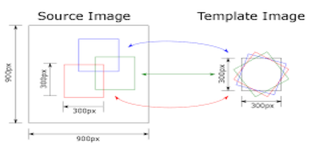
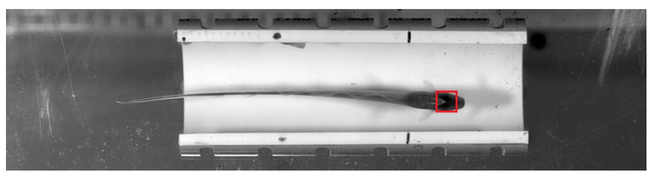
Introduction

- In our work, we introduce a real-time, robust image-processing based detection and tracking system which can detect the fish's position in a water tank in a desired time.
- In recent years, a lot of research has been done on fish movement, especially in the fields of medicine and engineering.
- Of course, there are some limitations of viewing an object and processing a video, the system must have the following properties:
  - ***High-Frequency Rate*** ***Working in Real-Time*** ***Optimized Code***

Specifications and Design Requirements

- **Template Matching** is an image processing method developed to search and locate the template image in a larger image.

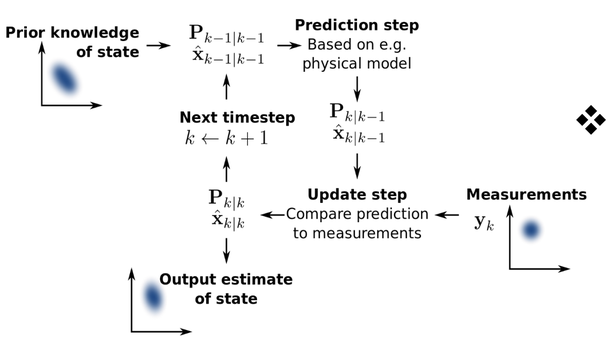




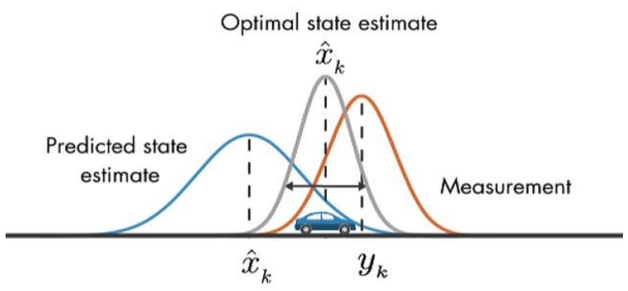
- Template Matching techniques are flexible and relatively straightforward to use, which makes them one of the most popular methods of object localization.
- However, the standard template matching algorithm is not very efficient to work with in real-time systems. Therefore, the algorithm needs to be improved.

Solution Methodology

- Using only template matching is too slow to work with in real-time. To overcome this problem, we have focused on an algorithm named Kalman Filter.



- Kalman Filter algorithm consists of two stages: prediction and update.
- In this project, Kalman Filter is used to predict the position of the object in the next frame after sufficient samples have been given and updates its position after the next frame arrives.



- The Kalman filter is essentially a set of mathematical equations that try to minimize the predicted error covariance.

Predicted state estimate	$\hat{\boldsymbol{x}}_k^- = F\hat{\boldsymbol{x}}_{k-1}^+ + B\boldsymbol{u}_{k-1}$
Predicted error covariance	$P_k^- = FP_{k-1}^+F^T + Q$

Measurement residual	$\tilde{\boldsymbol{y}}_k = z_k - H\hat{\boldsymbol{x}}_k^-$
Kalman gain	$K_k = P_k^- H^T\left(R + HP_k^- H^T\right)^{-1}$
Updated state estimate	$\hat{\boldsymbol{x}}_k^+ = \hat{\boldsymbol{x}}_k^- + K_k\tilde{\boldsymbol{y}}$
Updated error covariance	$P_k^+ = (I - K_kH)P_k^-$

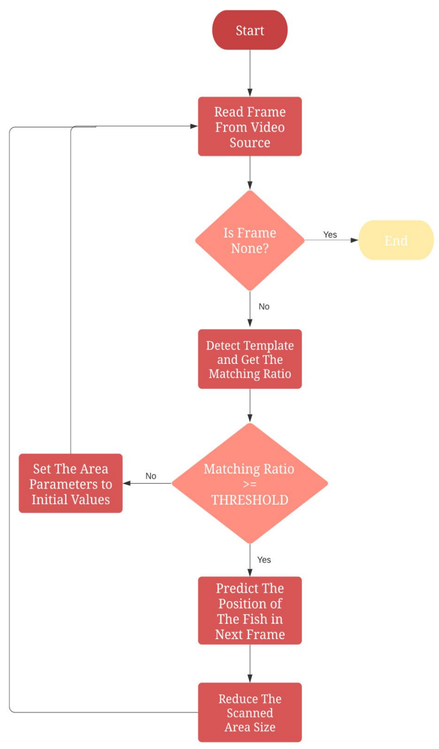
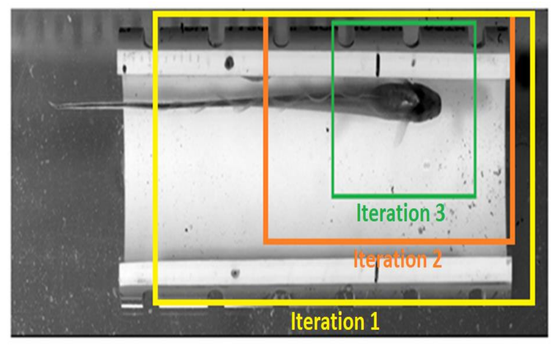


Figure: Flowchart of the code.

Original Attributes

- According to estimation and covariance values obtained from Kalman Filter, this algorithm restricts or increases the area to be scanned by Template Matching. As the error of Kalman Filter decreases with each iteration, Template Matching's scan area decreases as well.



Results and Discussion

- Test results of the algorithm we have developed show that much higher speeds can be obtained than the standard template matching algorithm can.
- We have tested our algorithm on 79 fish videos, each made up of 600 frames.
- Below are the results of the standard template matching algorithm:

	Standard Template Matching	
	Average Time	**Standard Deviation**
NVIDIA Jetson Xavier NX	190.39 ms	12.49 ms
10th generation intel core i5 CPU	76.72 ms	2.33 ms
NVIDIA GTX 1650	24.37 ms	1.55 ms

- Here are the results of the algorithm we developed using Kalman Filter on the same dataset:

	Template Matching with Kalman Filter	
	Average Time	**Standard Deviation**
NVIDIA Jetson Xavier NX	19.49 ms	7.85 ms
10th generation intel core i5 CPU	14.64 ms	1.18 ms
NVIDIA GTX 1650	16.18 ms	0.48 ms

References

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- Hisham, M. B., Yaakob, S. N., Raof, R. A. A., Nazren, A.B A., Wafi, N.M. 'Template Matching Using Sum of Squared Difference and Normalized Cross Correlation', School of Computer and Communication Engineering, University Malaysia Perlis, 2015.

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