Image Analysis Based Fish Tail Beat Frequency Estimation For Fishway Efficiency

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Abstract

We propose image analysis based methods for estimating fish tail beat frequency, which is an indicator of fish energy consumption at fish passage structures. For this purpose, average magnitude difference and autocorrelation function based periodicity detection techniques are utilized. Actual fish images are acquired using a visible range camera installed in a brush type fish pass in İkizdere River, near Rize, Turkey, which is very rich in biodiversity. Results show that image analysis based periodicity detection methods can be used for fishway efficiency evaluation purposes. To the best of authors' knowledge, this is the first study that automatically estimates fish tail beat frequency using image analysis. The findings of this study are expected to have implications for fish monitoring and fishway design.

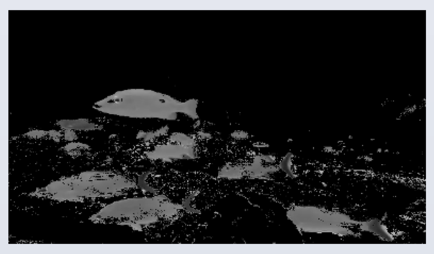
Methods

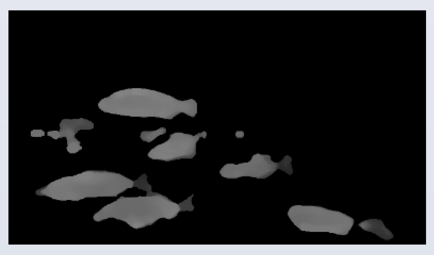
I. FISH DETECTION

We investigated traditional and recent background subtraction techniques for detecting fish regions.We further investigated recent approaches since the accuracy of contour area of fish during segmentation is important when calculating tail beat frequency. We compared GMM based and other background subtraction approaches. Sample-based algorithm called Visual Background Extractor (ViBe) proposed by Barnich et al. performed better in our tests and it was robust enough in the high water turbulence conditions. Therefore, we chose ViBe algorithm for fish segmentation. After applying median filter and shape based (aspect-ratio e.g.) post-processing operations to the detected foreground areas, connected component labeling operation is performed to group regions.


Frame difference


AGMM


ViBe


ViBe (post-processing)


Detection Result

I. FISH TAIL PERIODICITY DETECTION

The goal of this section is to analyze fish tail beat movement by quantifying recurrence in the tail regions from an image sequences.

A. Average Magnitude Difference Function

Average Magnitude Difference Function is calculated by computing total difference between signal and its lagged version.

$$F(l) = \sum_{n=1}^{N-l+1} |\vec{s}(n+l-1) - \vec{s}(n)|_{1}, \qquad l=1,2,..,N$$

Algorithm 1 Detect periodicity using AMDF

```
procedure AMDF(ImageBuffer, BufferSize)
    k = BufferSize
    initialize array amdfMagnitudes ← 0
    for each integer l in k do
        initialize matrix SumMatrix ← 0
        for each integer n from 0 to k − l  do
            SumMatrix ← SumMatrix + ImageBuffer[n + l] − ImageBuffer[n]
        end for
        amdfMagnitudes[l] = mean(SumMatrix)
    end for
    Return max(secondDerivative(amdfMagnitudes))
end procedure
```

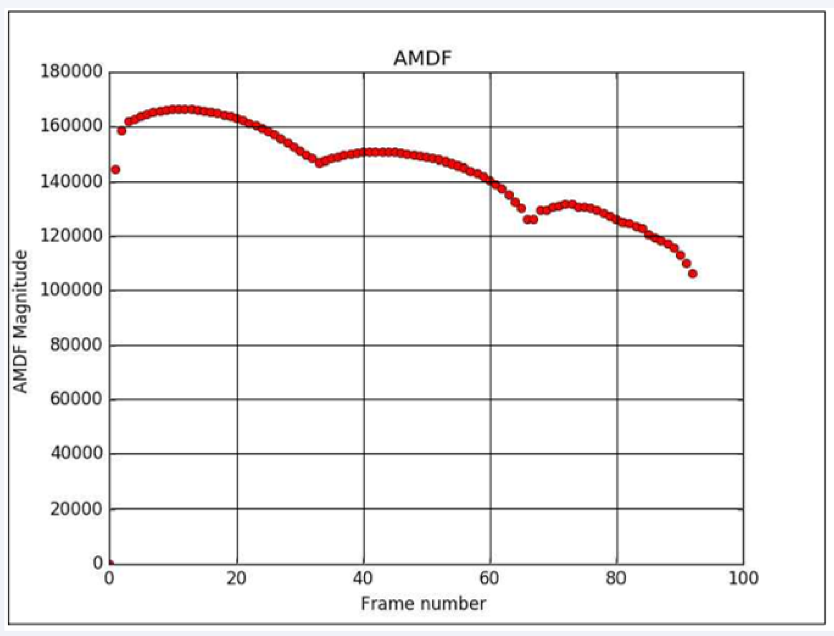
A. Autocorrelation Function

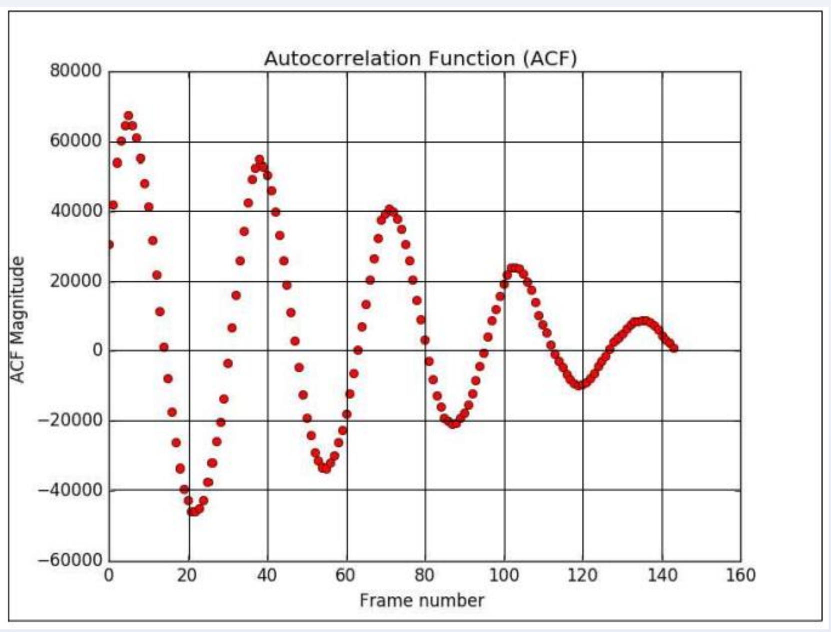
Autocorrelation is a function that identifies correlation of signal with its lagged version. Autocorrelation function is useful for identifying an appropriate time series model of a signal.

$$ACF(i,j) = \frac{1}{M}\frac{1}{N}\sum_{m=0}^{M-1}\sum_{n=0}^{N-1} x_{m,n}\overline{x}_{m+i,n+j}$$

$$\mathcal{F}_R(f) = \mathcal{FFT}(x(n))$$
$$\mathcal{S}_R = \mathcal{F}_R(f)\mathcal{F}_R^*(f)$$
$$ACF() = \mathcal{IFFT}(\mathcal{S}_R)$$

Methods (cont.)

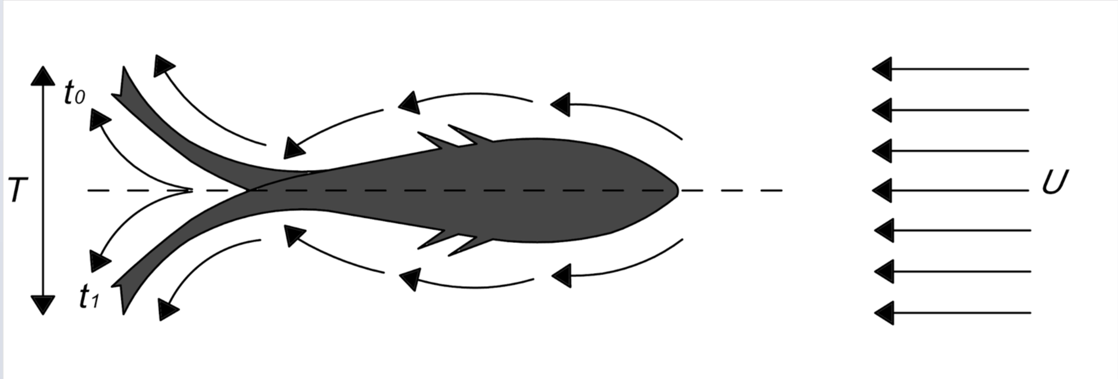




Results

In order to evaluate the performance of our tail beat frequency detection system we collected ground truth from videos by inspection.We evaluate tail periodicity as a time difference between two opposite end points denoted by T which is the fish tail oscillation between the opposite end points from time t_0 to t_1. Tail beat frequency f_{TB} can be denoted as inverse of periodicity:

$$T = |t_1 - t_0|$$
$$f_{TB} = 1/2T$$



Videos	Troutfs.avi	rize1.mp4	uvs-012.avi
Frame Rate (fps)	30	60	25
Number of Frames	159	660	450
Strouhal Number	0.042	0.3	1.1
AMDF (Hz)	**0.882**	2.35	**1.398**
ACF (Hz)	0.87	**2.5**	1.471
Ground Truth (Hz)	0.943	3	1.428

Method	Total Number of Frames	MSE
AMDF	1269	0.142
ACF	1269	0.086

Conclusion

Efficient fishway design has become increasingly important with the growing human activity at global scale in river ecosystem. Lack of adequate data and tools for identifying biological, hydraulic, and other physical parameters is the main challenge in fish passage design.

In this paper, we proposed image analysis based methods for fish tail beat frequency estimation. Tail beat frequency is an indicator of fish energy expenditure and swimming speed, and it is a parameter of the Strouhal number. Experiments suggest that proposed image processing based fish tail beat frequency estimation approach may be utilized for fish passage analysis.

Acknowledgement

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