Analyzing Motion of Target Object (Fish)

Scientist are paying considerable attention to tracking and capturing motion of fish. As a result tracking and analyzing fish motion is a very significant field. In this paper, I am going to propose a model to track and analyze motion e.g. swimming speed, amplitude, velocity and frequency of fish tail swing, body swing amplitude, posture and angle, movement track. Finally we will implement the ideas in a program and demonstrate the result.

1 Introduction

Blah blah blah blah blah

2 Model

Here I am going to propose a model that is composed of two parts:

1. Target fish detection
2. Target fish tracking
3. Calculation using head, centroid and tail point

2.1 Fish Detection:

2.1.1 Background Detection:

- Using Background Subtractor method at first each frame is turned into binary image. Background subtraction (BS) is a common and widely used technique for generating a foreground mask (namely, a binary image containing the pixels belonging to moving objects in the scene) by using static cameras.

- As the name suggests, BS calculates the foreground mask performing a subtraction between the current frame and a background model, containing the static part of the scene or, more in general, everything that can be considered as background given the characteristics of the observed scene.

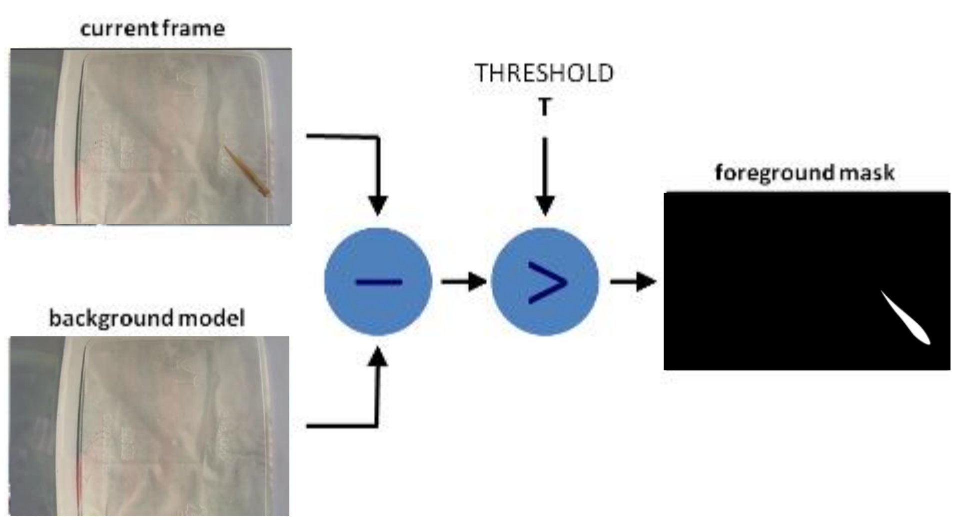


Figure 1 : Background Detection

- Background modeling consists of two main steps:

  1. Background Initialization;
  2. Background Update.

  In the first step, an initial model of the background is computed, while in the second step that model is updated in order to adapt to possible changes in the scene.

  Let $I(x, y)$ be the pixel intensities of the raw image, and $R(x, y)$ be the pixel intensity after masing.

$$R(x,y) = \begin{cases} 1, & if, \quad (x,y)\ contains\ fish\ information \\ 0, & else\ , every\ where\ zero \end{cases}$$

2.1.2 Head, Tail, Centroid Detection

After turning the frame into black and white, perimeter of the fish is detecting by drawing contour.

Contours can be explained simply as a curve joining all the continuous points (along the boundary), having same color or intensity. The contours are a useful tool for shape analysis and object detection and recognition.

Centroid can be calculated from the contour are using moments. Image moments M_{ij} of the masked image $R(x, y)$ are calculated by

$$M_{ij} = \sum_x \sum_y x^i y^j\, R(x,y) \ldots \ldots \ldots (1)$$

Using formula 1,

$$M_{00} = \sum_x \sum_y R(x,y) \qquad \ldots \ldots \ldots (2)$$

$$M_{01} = \sum_x \sum_y x \times R(x,y) \ldots \ldots \ldots (3)$$

$$M_{10} = \sum_x \sum_y y \times R(x,y) \ldots \ldots \ldots (4)$$

We can finally calculate centroid $\{\bar{x}, \bar{y}\} = \{\frac{M_{10}}{M_{00}}, \frac{M_{01}}{M_{00}}\}$

After calculating centroid, we can determine head and tail. Let Z be the set of contour points.

$$Z = \{(x_1, y_1), (x_2, y_2), \ldots, (x_n, y_n)\} \ldots \ldots \ldots (5)$$

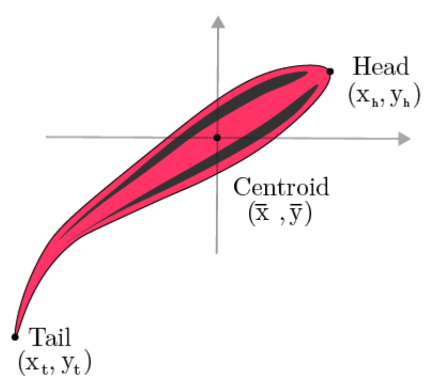


Figure 2 Simplified Fish Model (Head, Centroid, Tail)

As tail is the farthest point from centroid it can be calculated,

Tail coordinate, $x_t, y_t = \{(x_i, y_i): \max((\bar{x} - x_i)^2 + (\bar{y} - y_i)^2)\}$

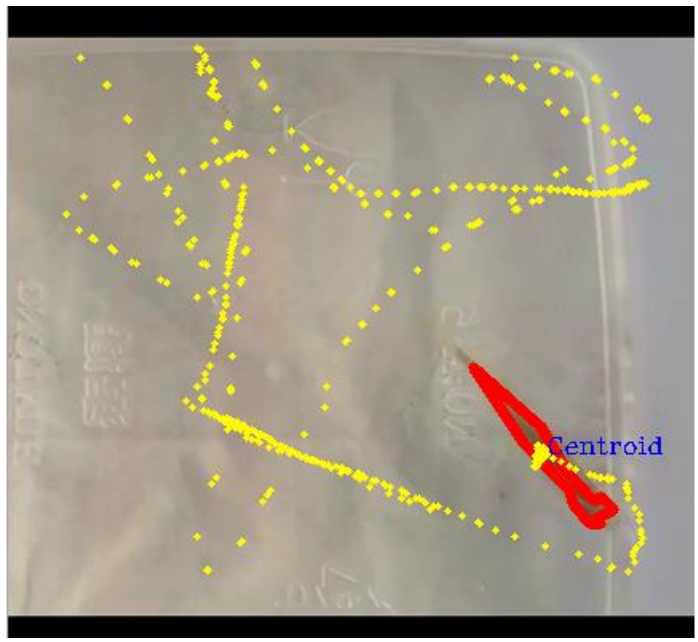
After calculating tail we can calculate head using the fact, head is the farthest point from centroid opposite of tail.

Head coordinate, $x_h, y_h = \{(x_i, y_i): \max((\bar{x} - x_i)^2 + (\bar{y} - y_i)^2)\ \textit{and opposite to tail}\}$

3 Motion Analysis:

Let, C(x,y), H(x,y) and T(x,y) be the set of points of Centroid, Head and Tail respectively, abstracted from the frames.

3.1 Track from video:



3.2 Total distance travelled:

$$
\begin{aligned}
&for\ \ i \in C(x,y)\\
&\qquad dx = (\overline{x_{\iota+1}} - \overline{x_{\iota}})^2\\
&\qquad dy = (\overline{y_{\iota+1}} - \overline{y_{\iota}})\\
&\qquad ds = \sqrt{dx^2 + dy^2}
\end{aligned}
$$

Total distance = $\sum ds$, which is summed in every frame.

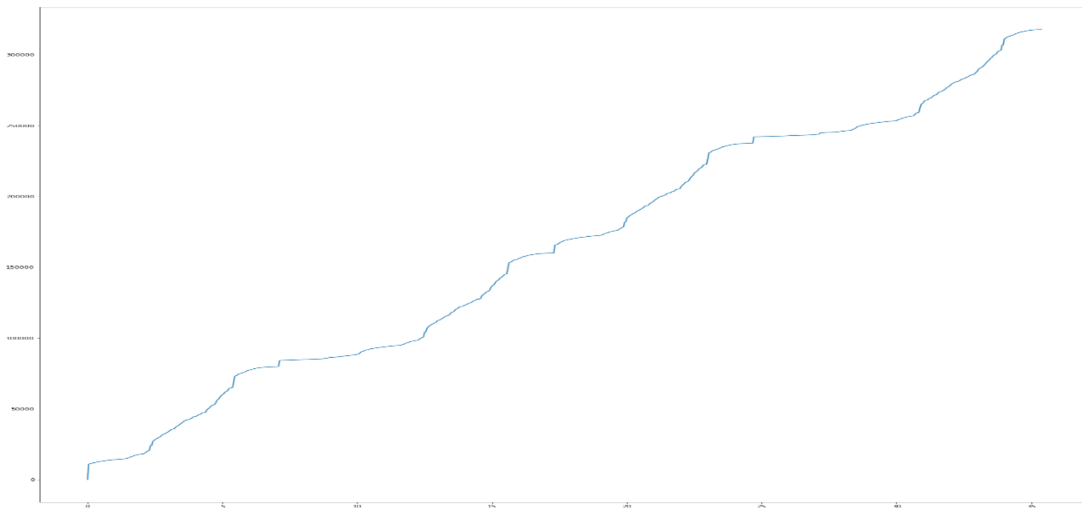


Figure 3: Travlled distance vs time

3.3 Swimming Speed Calculation:

$$v = \frac{ds}{dt} = ds \times 24,$$

as we have sampled 24 frames per second and ds represents distance per frame

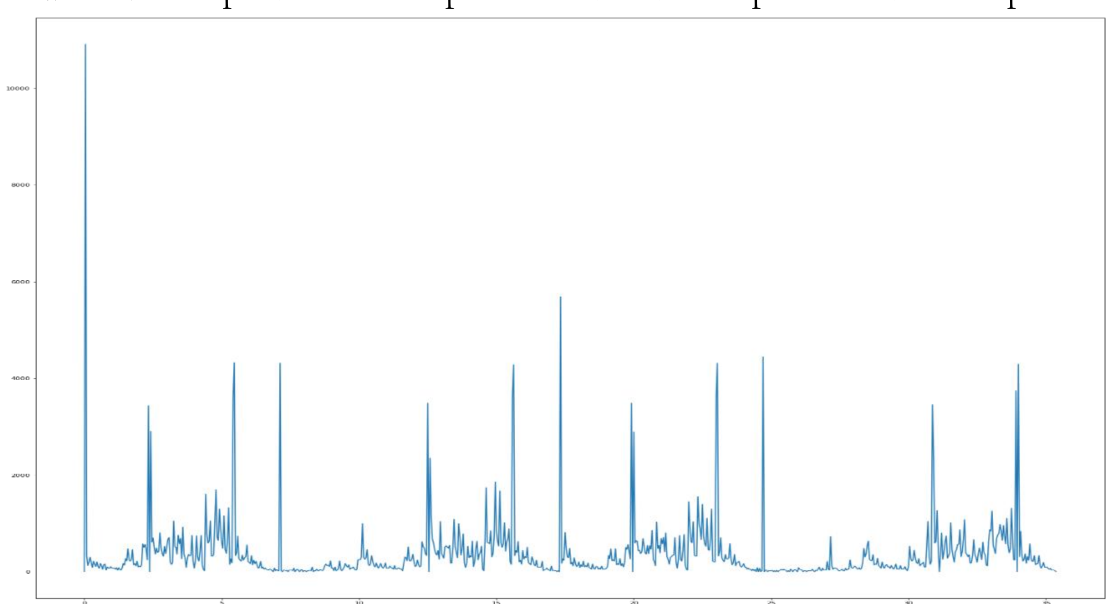


Figure 4: Speed vs time plot

3.4 Velocity direction:

$$\theta_p = \tan^{-1}\frac{y_h - \bar{y}}{x_h - \bar{x}}$$

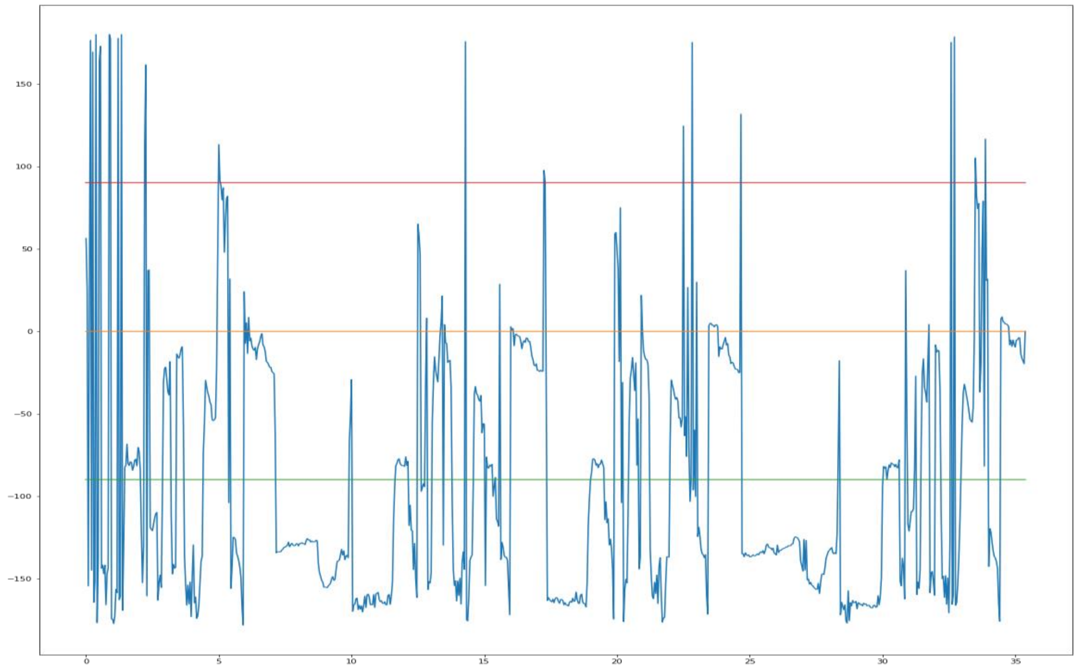


Figure 5: Velocity direction vs time

Here,

- 90 Degree(Red line) refers to Vertical UP
- -90(Green Line) Degree refers to Vertical down
- 0 Degree (Yellow Line) refers to Horizontal Right,
- 180 Degree refers to Horizontal Left

3.5 Swimming amplitude

The perpendicular distance from a point $P(x, y)$ to a line $L(x, y) = ax + by + c$ is given by

$$d = \frac{|ax+by+c|}{\sqrt{a^2+b^2}}$$

Now, a line is drawn from tail to head and its repective a,b,c values are calculated

$$a = y_h - y_t$$

$$b = x_t - x_h$$

$$c = x_h \times y_t - y_h \times x_t$$

Now the distance from centroid $(\bar{x}, \bar{y})$ to this line is the fish body swimming amplitude. Shown in Figure 6

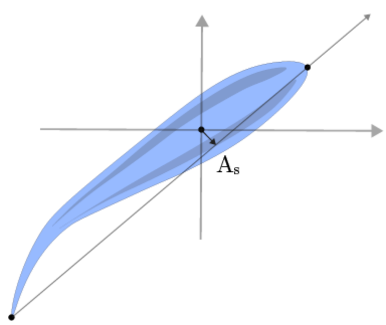


Figure 6: Fish Body Amplitude (A_s)

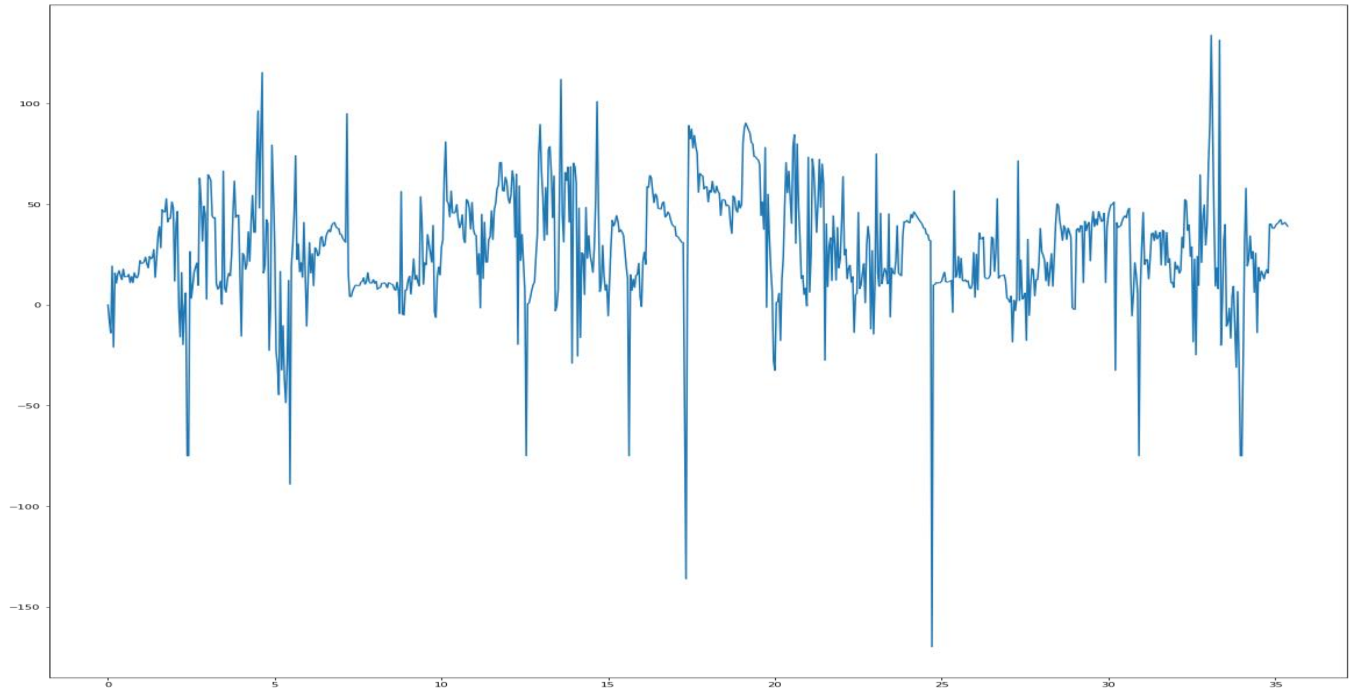


Figure 7: Fish body swing amplitude vs time

3.6 Fish Tail Amplitude:

Same as procedure 4, where line is drawn from head to centroid and perpendicular distance from tail is calculated. Here respective a,b,c is calculated by

$a = y_h - \bar{x}$

$b = \bar{x} - x_h$

$c = x_h \times \bar{x} - y_h \times \bar{x}$

Now the distance from tail (x_t, t_t) to this line is the fish body swimming amplitude. Shown in Figure 8

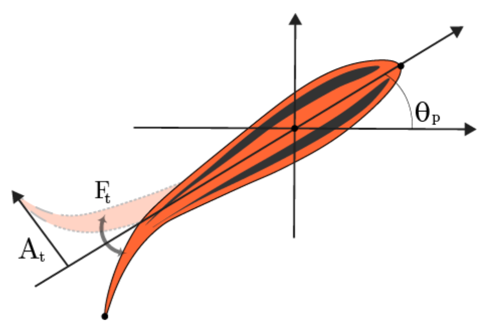


Figure 8: Fish tail amplitude (A_t), Fish tail frequency (F_t) and Posture θ_p

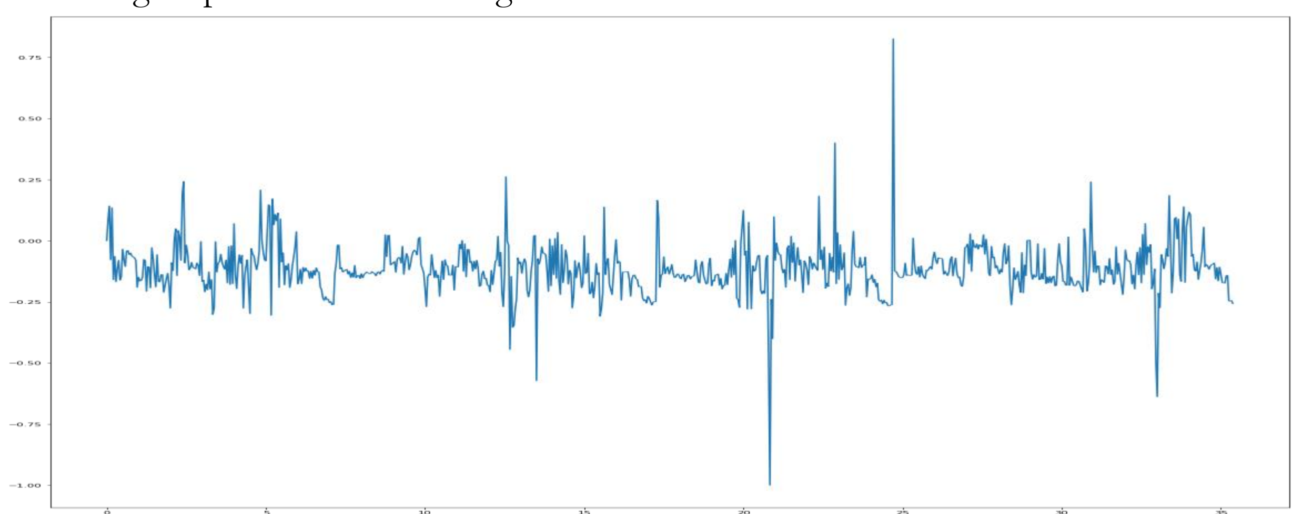


Figure 9: Fish tail Wave vs time

3.7 Fish tail Velocity:

Using procedure 2 and 3, fish tail velocity is calculated

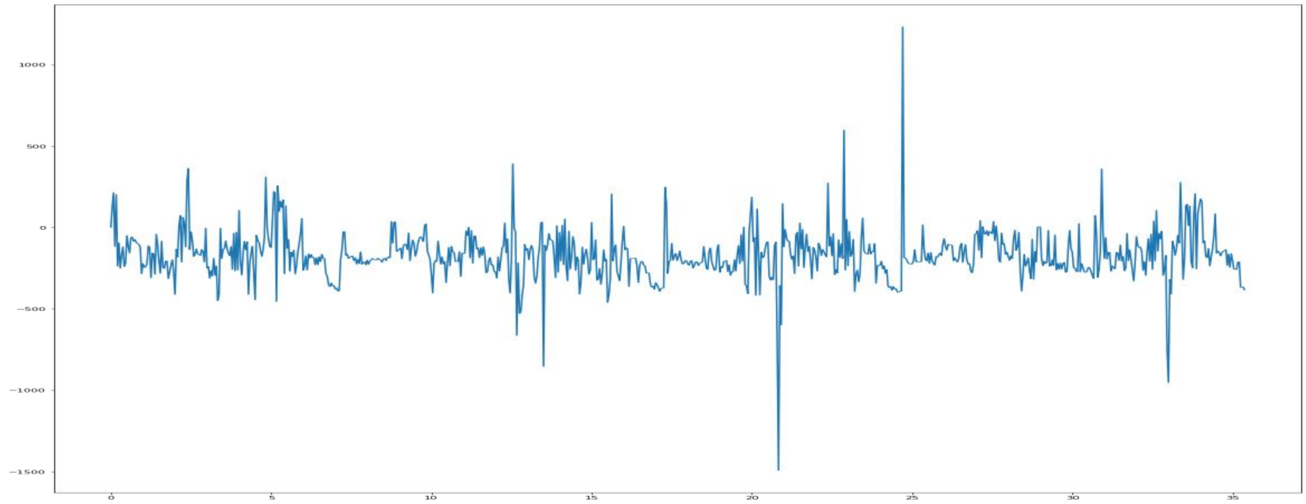


Figure 10: Fish tail velocity vs time

3.8 Fish tail beat frequency:

After finding the amplitude graph Fourier transformation is implemented. From the frequency spectrum, further decisions are taken. We can see the peak is located at around $15\ Hz$.

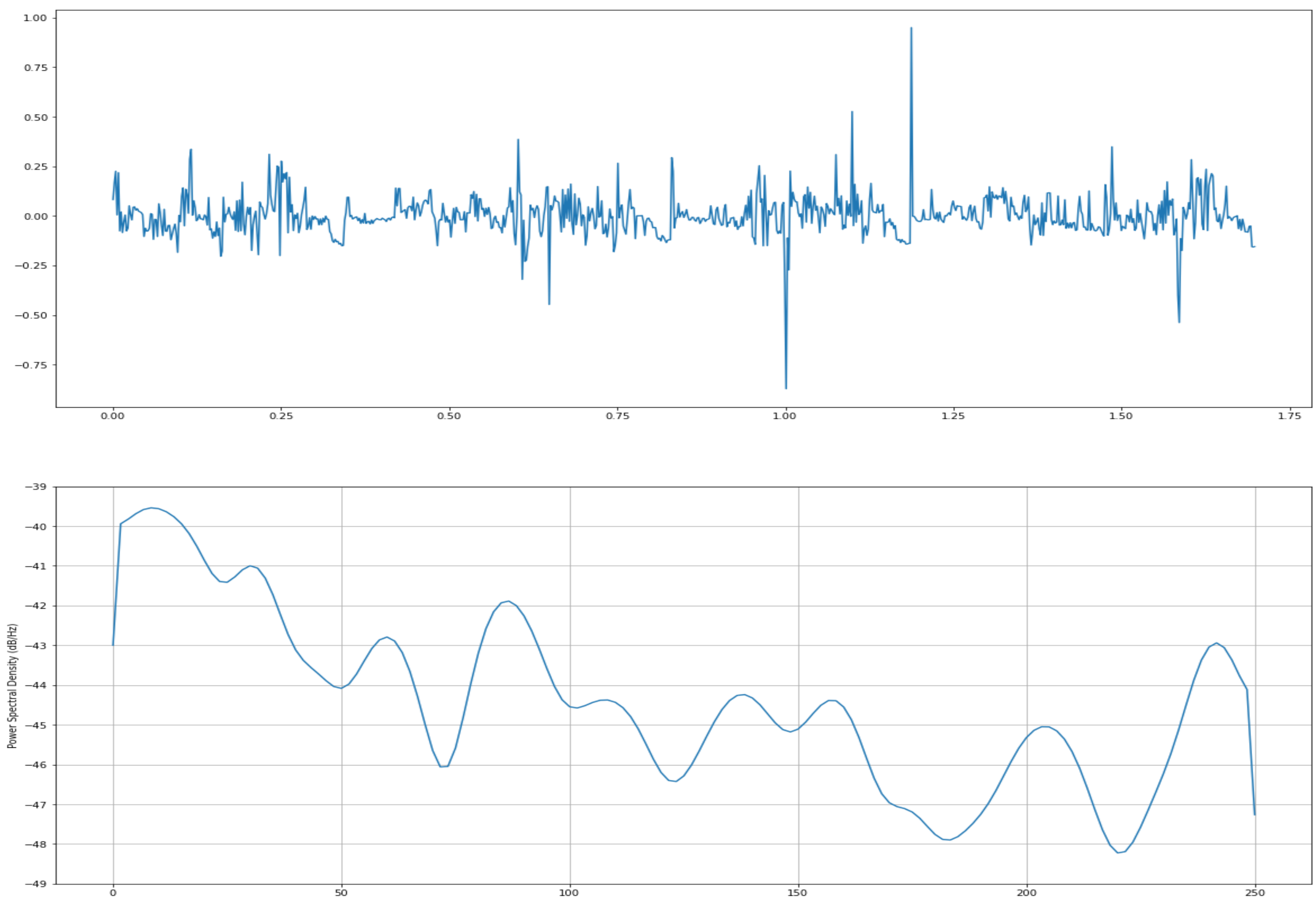


Figure 11: FFT of fish tail wave

4 Python Code