INVESTIGATING METHODS OF SURFACE WAVE RECONSTUCTION

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PROBLEM STATEMENT

A diagnostic tool to resolve the surface wave topology of a flowing liquid metal is under development. The setup uses a single camera to acquire an image being reflected off of the liquid metal surface. The current algorithm used to process collected data was in its early stages of development. Various other algorithms with the goal of decreasing computation time and error were recently developed. A 1D simulation of the problem is created for various methods using MATLAB to study the efficacy of each algorithm. This poster discusses the differences between the methods and compares the relative error and computation time required for each method.

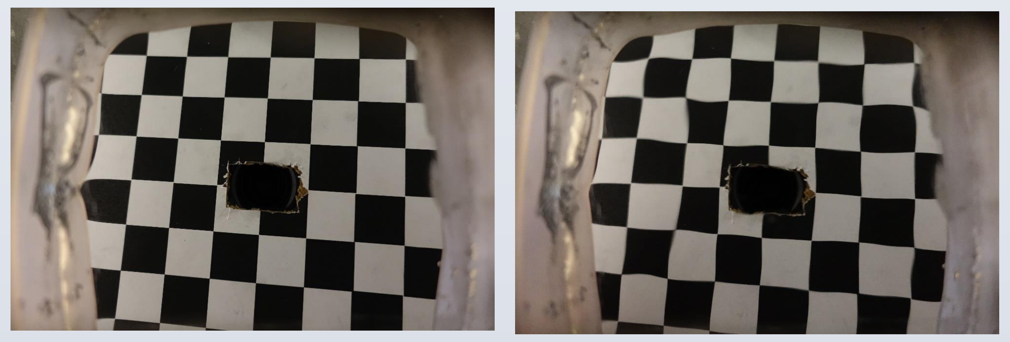

Figure 1: Shown here a distorted version (right) of a test image (left). The goal here is to recreate the surface by undoing this distortion.

PROBLEM SETUP [1]

GENERATRING A TEST WAVE

- A 1D test wave is generated with known number of Fourier components.
- The test wave is then used to generate a distorted grayscale image.
- Note that the test image is generated using non linear method. High resolution images are then compressed depending on resol to mimic camera's functionality.

$$y(x)=\sum A_i \sin(k_i x)+\sum B_i \sin(k_i x)+A_0$$

RECONSTRUCTING THE SURFACE

- Problem is initialized by using a guess wave.
- Each method uses functions found in MATLAB's Global Optimization Toolbox. The code uses a scatter search algorithm to scan for local minima in the parameter space defined by user.
- Each method (discussed later) then outputs grayscale image. The error between the test image and the generated image is then calculated. The most probable wave is the one which will yield the least amount of error.

ASSUMPTIONS

- The relative distance of the wave to the camera is known. Additionally, the image is on the plane of the camera.
- No secondary reflection take place.

METHODS USED TO GENERATE IMAGES

BIN METHOD (BM)

The x domain is divided into equally spaced divisions. The y-coordinate and the derivative of the wave are then calculated for the corresponding x-values. The derivative is used to calculate the color value on the wave. The image is then compressed by taking the average of the color values in the vicinity of the incident rays.

TABLE LOOK-UP (TLU) (INTERP.) METHOD

The x domain is divided into a equally spaced divisions. A table containing y-coordinate and the derivative of the wave is then calculated for the corresponding x-values. This table is then used to calculate the approximate the color value at the point of intersection of the incident ray and the wave.

LINEAR METHOD (LM) [1]

Linear method assumes that the wave amplitudes are small enough such that y-coordinate of the point of intersection of the ray and the wave is always a constant. Note that the method accounts for the derivative to generate an image.

NON-LINEAR METHOD (NLM) [1]

The exact point of intersection between the camera ray and the wave are calculated by using Newton's method. The derivative and the y-coordinate at the point of intersection at the wave are then used to calculate the color value at the location.

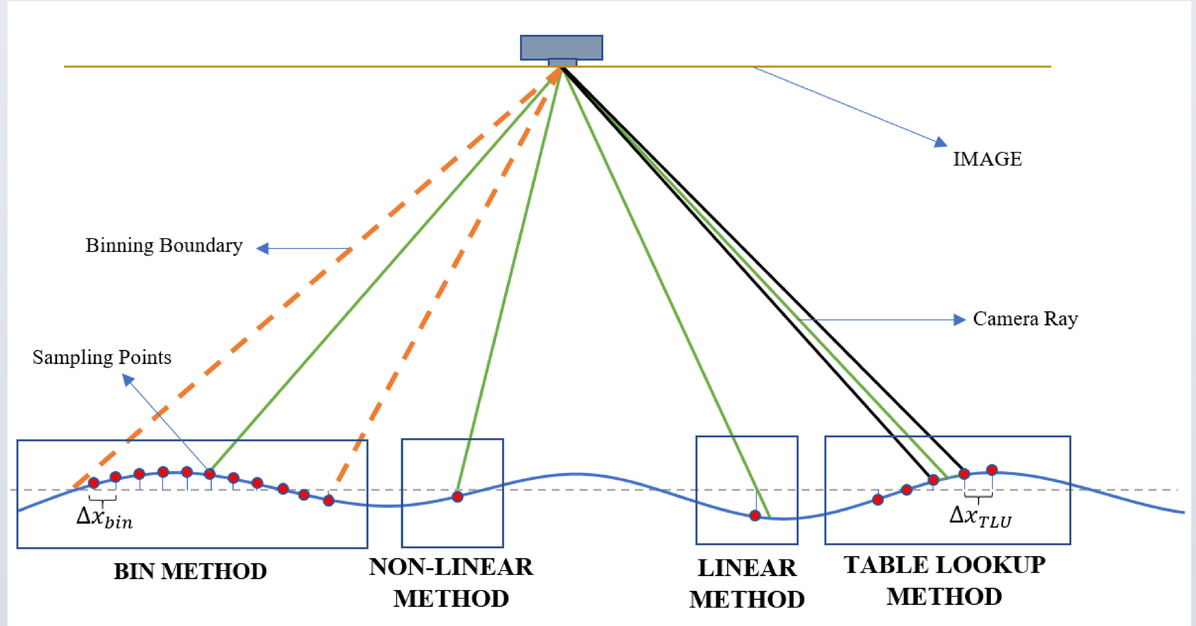

Figure 2: Shown here the differences and assumptions made by various methods used in this study. ..

RESULTS

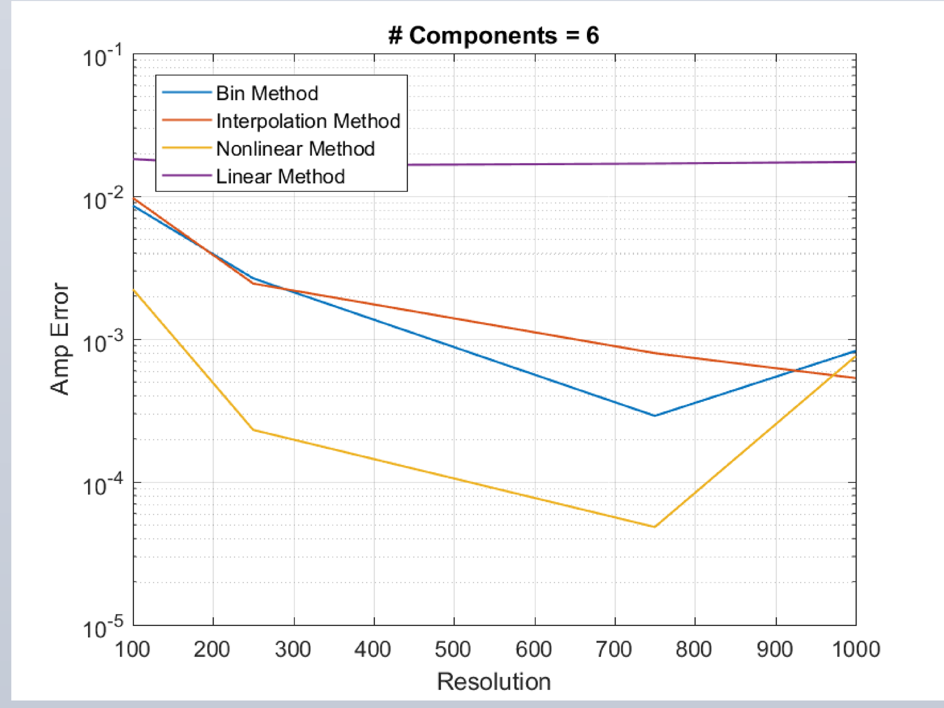

Figure 3: Shown here is the calculated error in for each method as a function of the resolution for a wave with 6 Fourier Components

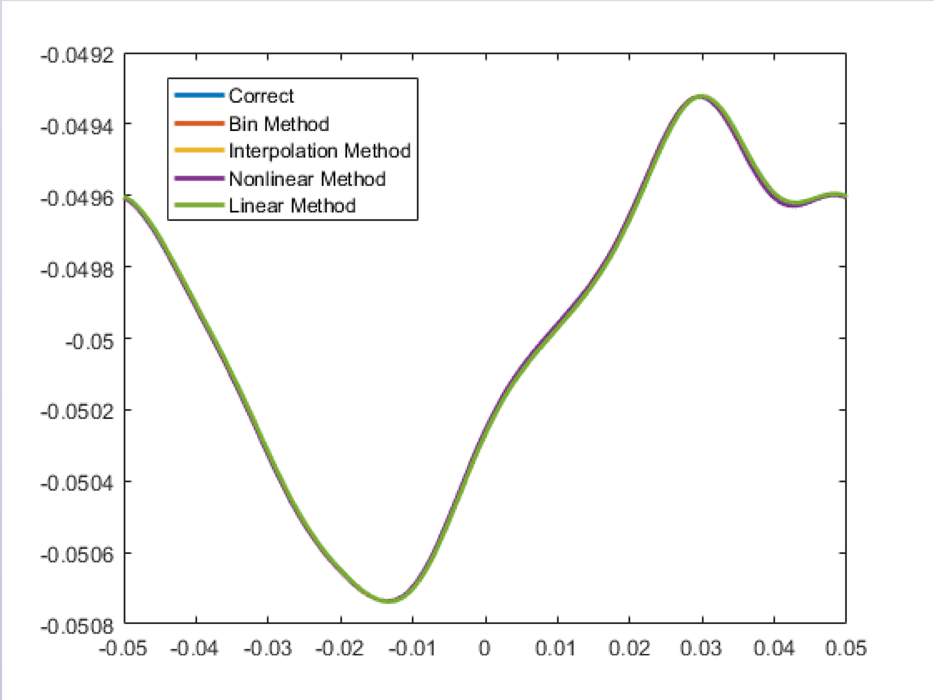

Figure 4: Shown here is the test image wave used to study the methods. The calculated waves using each method is also shown here

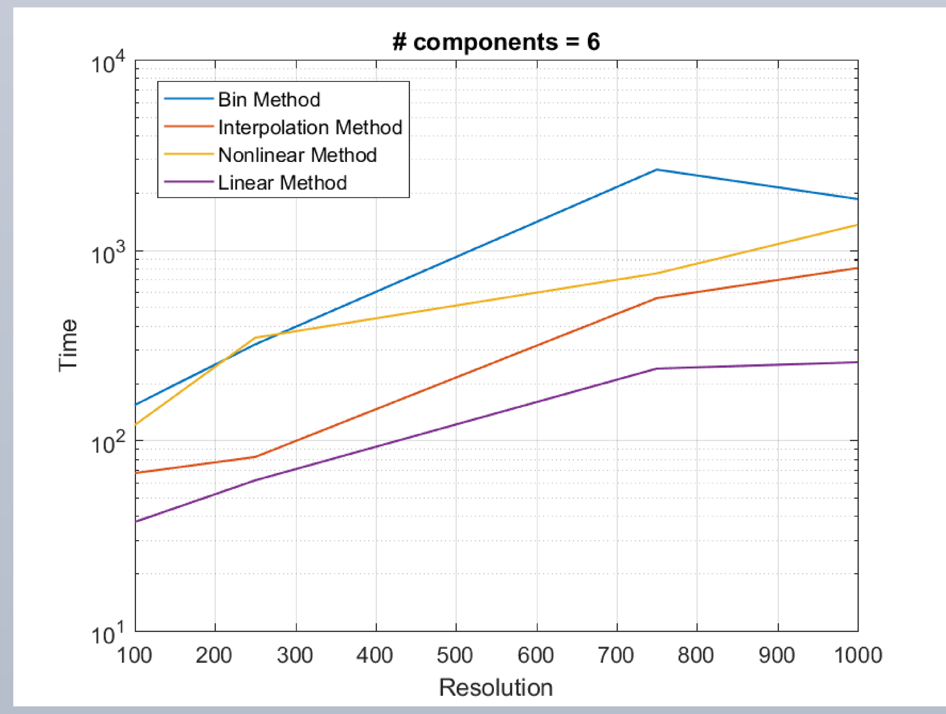

Figure 5: The computation time required for each method as a function of resolution is shown here.

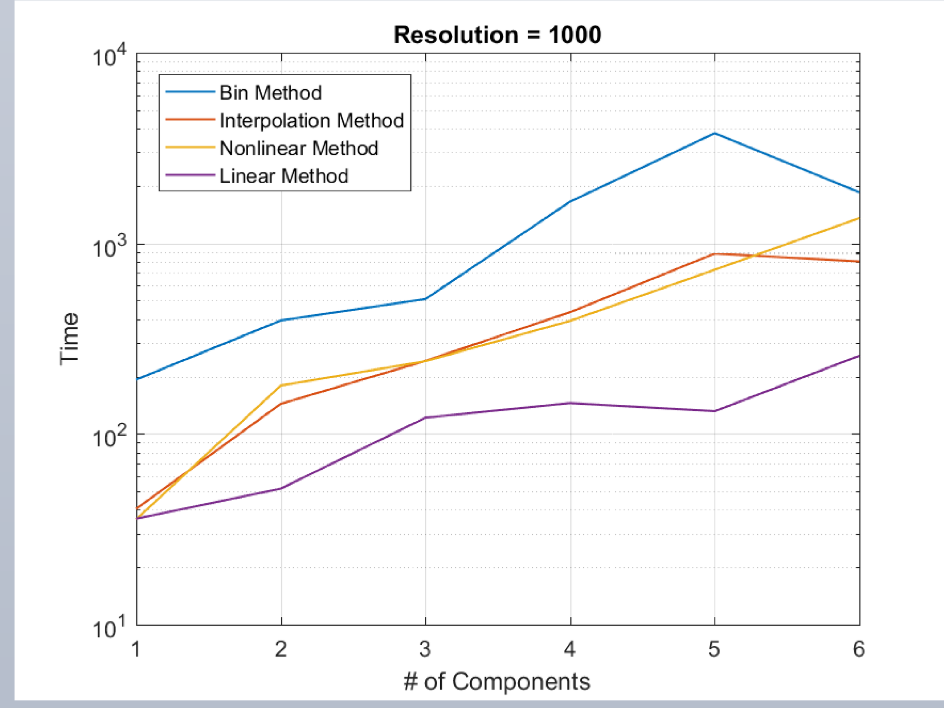

Figure 6: The computation time required for each method as a function of number of Fourier components is shown here.

LIMITATIONS

The current model assumes no secondary reflections off the wave. This method is too unreliable for waves with larger amplitudes. This also affects the view distance and the view angles of the camera.

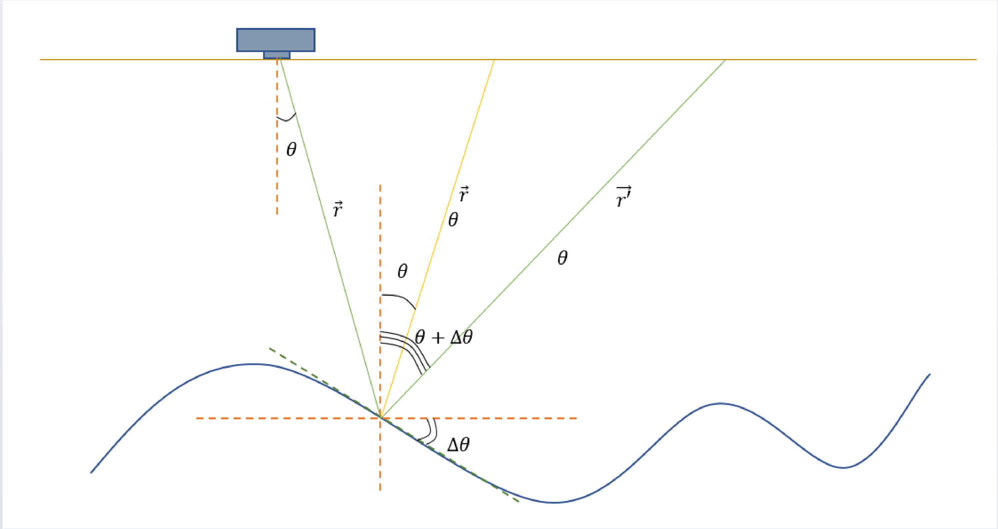

Figure 7: View angle limitations are dependent on the wave parameters.

DISCUSSION

- TLU, NLM and LM required similar amounts of time for lower resolution and fewer Fourier components; however, they showed greater deviations for larger number of amplitudes.
- The error in amplitude for the LM was very high compared to the other methods. This was to be expected as the location of intersection is determined without any iterative schemes.
- Computation time increased with the number of components and resolution. It increases exponentially with resolution. This trend is consistent as the number of components increase; however, it tapers off after 4 components.

CONCLUSIONS

- The added complexity of accounting for the image compression in the Bin Method resulted in very time intensive scheme. The relative error of this method was relatively high, contrary to initial beliefs.
- Diminished computation time using the linear methods far outweighs the disadvantages. It was noted, however, the error introduced would only increase for greater amplitudes.
- Resolution plays a bigger role compared to the number of Fourier components. The diagnostic would, thus, benefit by using lower resolution images.

REFERENCES

[1] Previous work done by Adam E. Fisher,

ACKNOLDEGEMENTS

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