Ship motion estimation from sea wave vision

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Abstract

Improving ship stabilization in difficult sea state will require observing incoming waves to anticipate their effect. With this goal in mind, we address the problem of predicting a ship's motion, i.e., pitch and roll angle from sea wave videos. We built a Blender simulation to create a dataset and compare several neural network architectures that, given an image sequence, are trained to predict the future pitch and roll angles of the boat. Current work aims at augmenting the time ahead the deep learning model is able to perform the prediction.

Background

Ship motion is defined by the six degrees of freedom that a ship can experience, which are pitch, roll, yaw, heave, sway and surge (Fig. 2). We mainly focus on pitch and roll as prediction targets as a first step, because yaw is mainly controlled by man (fixed in our case), and heave, sway and surge are more difficult to measure, and relatively less important.

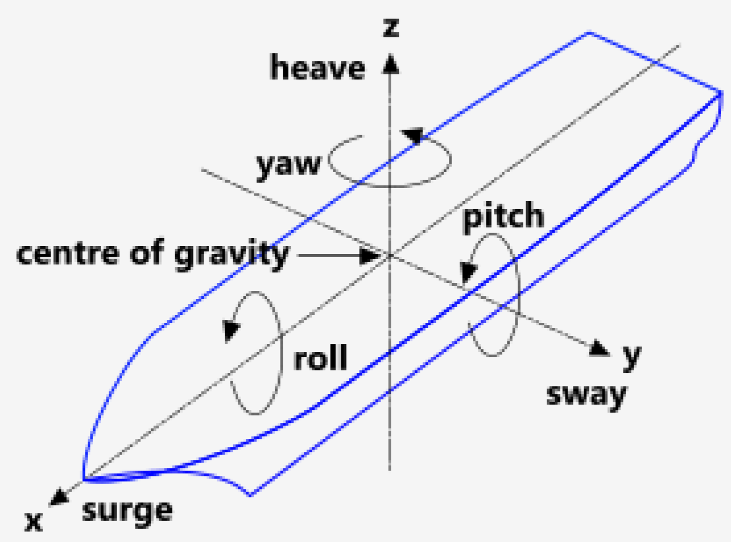

Figure 1: Ship's degrees of freedom[a].

[a] http://www.calqlata.com

A Blender open source sea wave simulator

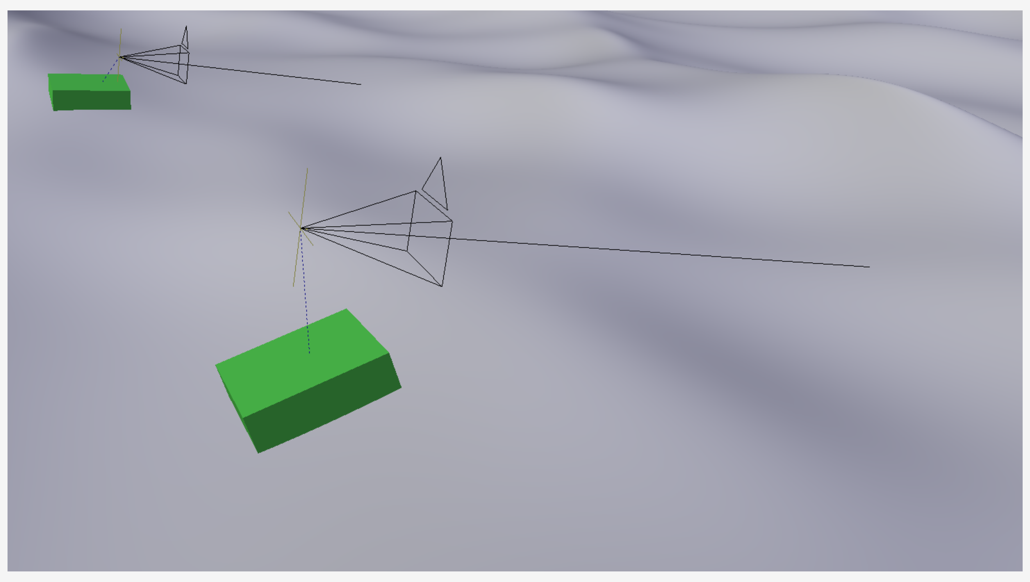

Figure 2: Blender simulation with "boats" floating

Sea waves and vessel movement dataset generation: We built a simulator using Python and Blender that generates 96x54 pixels images seen from a stabilized camera placed at the top of a boat, and simultaneously logs, according to different sea currents, the boat pitch and roll angles. Data augmentation is performed by changing image saturation and brightness.

The boat is floating (i.e., not navigating, in the initial simple setting) according to a simple simulation as a cube aligned with the sea surface. The simulator allows to configure several parameters (wave choppiness, wind scale, wind velocity and wind-wave alignment, sea depth -influences the height of the wave-, camera height and angle in the boat, image frequency and resolution).

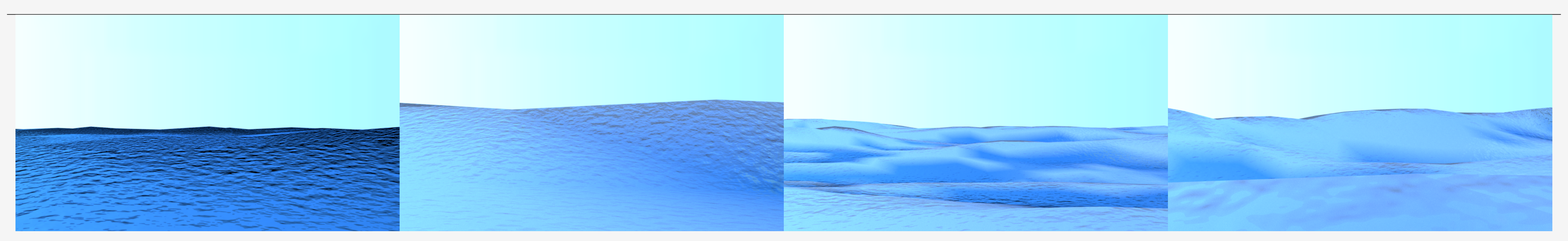

Figure 3: Varied sample images from our simulator

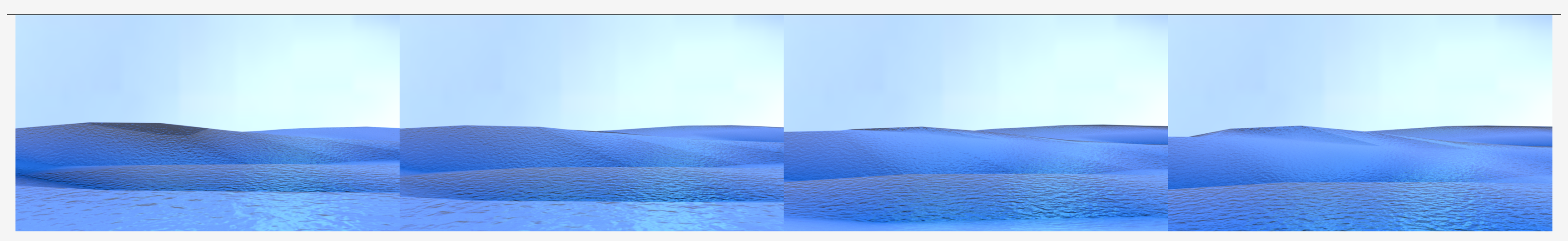

Figure 4: Sample sequence from our simulator

A deep network to predict pitch and roll from images

We use deep neural networks that take images as input and predict the ship pitch and roll for a given time shift in the future.

We tested three architectures: a feed forward CNNs using 1 or 2 images as input (3 and 6 resp. RGB channels), and a recurrent CNN-LSTM model.

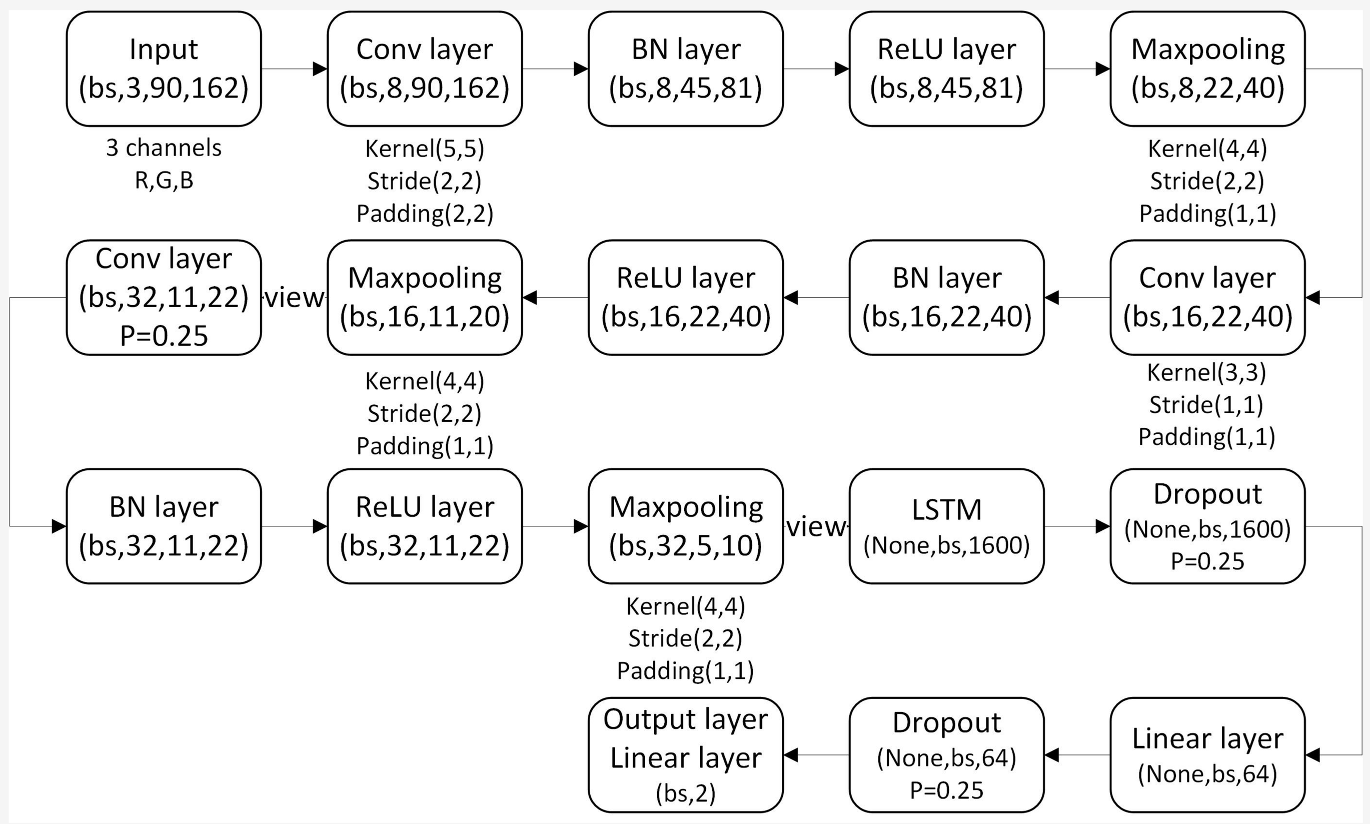

Figure 5: Architecture of our CNN-LSTM architecture

Preliminary Results

Table 1: Models performance for predicting 31 frames in the future.

Error	CNN 1 image		CNN 2 images		CNN-LSTM	
	Roll	Pitch	Roll	Pitch	Roll	Pitch
MSE of all data	12.064	2.232	12.400	2.270	**7.889**	**1.528**
MSE of test data	25.911		27.930		**17.850**	

We tested motion prediction with a shift between 10 and 40 frames in the future. The best performances were obtained for a shift of 31 frames. Table 1 gives the Mean Squared Error (MSE) for the pith and roll prediction.

- Training time from 5K images is around 4h (90x162 images).
- Due to the characteristics of the hull itself, the prediction of pitch is more difficult than roll.
- Current results show overfitting as test performances are much lower.

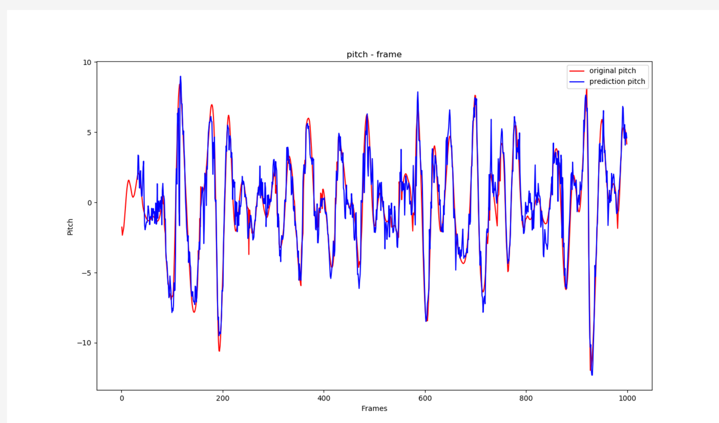

Figure 6: Pitch prediction result of CNN-LSTM network

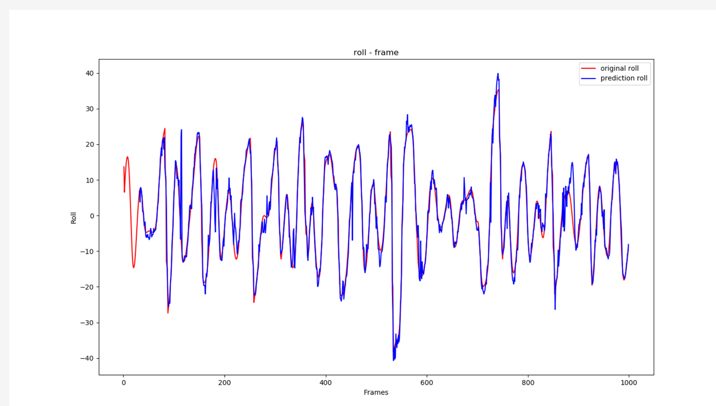

Figure 7: Roll prediction result of CNN-LSTM network model

Conclusions

We developed a Blender simulator and a neural network approach to predict ship motion from wave images.

- We compared the performance of CNN versus CNN-LSTM models. The later outperforms CNNs using 1-2 input images.
- The current model is able to predict 32 frames ahead, i.e., 31/24 fps = 1.25s ahead from movement-stabilized camera images.

Future work

- Usage of larger datasets (10k episodes of 500 images each) to improve the model's current overfitting with strategies to achieve more accurate ship state but also earlier ahead in time.