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Tracking and Predicting Fine Scale Sea Ice Motion by Constructing Super-Resolution Images and Fusing Multiple Satellite Sensors

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LONG-TERM GOALS

Tracking and predicting the fine scale sea ice motion will be particularly critical to safe Navy operations in the Arctic Ocean. It is also very important to monitor and track the size, shape, and location of sea ice in near real-time (within several hours of data acquisition), and predict the motion of sea ice for ice hazard forecasts in a finer scale than is currently possible. The log-term goal of this project is to explore new algorithms for the purpose of constructing and analyzing super-resolution images from multiple satellite sensors for automatic tracking and prediction of fine scale sea ice motion in Arctic Ocean.

OBJECTIVES

The objective of our proposal is to: 1) construct super-resolution images from satellite sensors which will significantly improve the tracking of sea ice motion from a coarse scale to a finer scale; and 2) implement data fusion methods to combine data from passive microwave and other satellite sensors to produce more accurate tracking and prediction of sea ice motion.

APPROACH

We propose to explore new algorithms to construct and analyze **super-resolution** images from multiple satellite sensors for automatic tracking and predicting **fine scale** motion of Arctic sea ice. Our research efforts will focus on the following main tasks:

a) ***Constructing super-resolution images from multiple satellite sensors (Dr. Yingli Tian and students):*** There are many methods for constructing super-resolution images for video surveillance and image retrieval. We will extrapolate and adapt selected techniques to construct super-resolution images from satellite imagery that has a resolution at least 5 times higher than that of the original satellite imagery.

b) ***Tracking sea ice motion from multiple satellite sensors and passive microwave sensors (Drs. Tian, Meier, and students):*** We will develop robust methods to automatically track sea ice motion from passive microwave sensors and multiple satellite sensors respectively.

c) ***Fusion of passive microwave sensors and multiple satellite sensors to track fine scale sea ice motion (Drs. Tian, Meier, and students):*** We will develop new fusion algorithms to effectively integrate data from multiple sensors for sea ice motion monitoring.

d) ***Predicting the fine scale sea ice motions (Drs. Tian, Weiss, and students):*** We will develop prediction models to represent the motion and changes of ice parcels by using motion history obtained from the sea ice tracking.

WORK COMPLETED

Our current research is focusing on "***Tracking sea ice motion from multiple satellite sensors and passive microwave sensors***" and "***Fusion of passive microwave sensors and multiple satellite sensors to track fine scale sea ice motion.***" The progresses we have accomplished in the last year are described as following:

1. Developing New Super Resolution Algorithms: We have proposed a novel hybrid example-based single image super-resolution method [1] which incorporates learning image-level statistics from an external dataset and gradient-level self-awareness with internal statistics. Compared with our previous super-resolution framework [2], this system benefits from both external and internal statistics. Moreover, the offline learnt regression models and the selective online self-refinement ensure a more efficient upscaling process. Experimental results have demonstrated that this framework is effective and outperforms the recent state-of-the-art single image super-resolution algorithms both quantitatively and qualitatively.

To be more specific, the proposed super-resolution framework consists of three steps to upsample an image: firstly, given a low-resolution image, a proxy high-resolution image is generated with a group of pre-built regression models. The regression models are trained on an external natural image dataset with more than 6,000 images. To ensure a targeted learning, the input feature space is modeled with Gaussian Mixture Models where an individual regression model is trained for each Gaussian component. Secondly, after obtaining the proxy image, a gradient-level coarse-to-fine self-refinement is performed guided by gradients of the input low-resolution image. This process aims to replace the high-variance gradient patches in the proxy image with more accurate representations to recover more visually plausible outputs. Finally, the

targeted high-resolution image is restored through minimizing a uniform cost function with the refined gradients. Experimental results are presented in the 'RESULTS' section.

2. Tracking ice movement on passive microwave images with Super-Resolution: The sea ice motion algorithm was successfully implemented and tested at NASA Goddard. The code was run on over a four-month winter period (January through April) using AMSR2 brightness temperatures. The output fields were as expected and provided reasonable indications of large-scale circulation patterns. The AMSR2 gridded resolution of 10 km is significantly better than SSMI and SSMIS (25 km), so it is able to provide more accurate daily motion estimates. However, single-day motions are still somewhat noisy because the detectable displacement is limited by the spatial resolution and the time separation. Using a three-day average provides a less noisy and more accurate motion field, but at the expense of lower temporal resolution (Fig. 1).

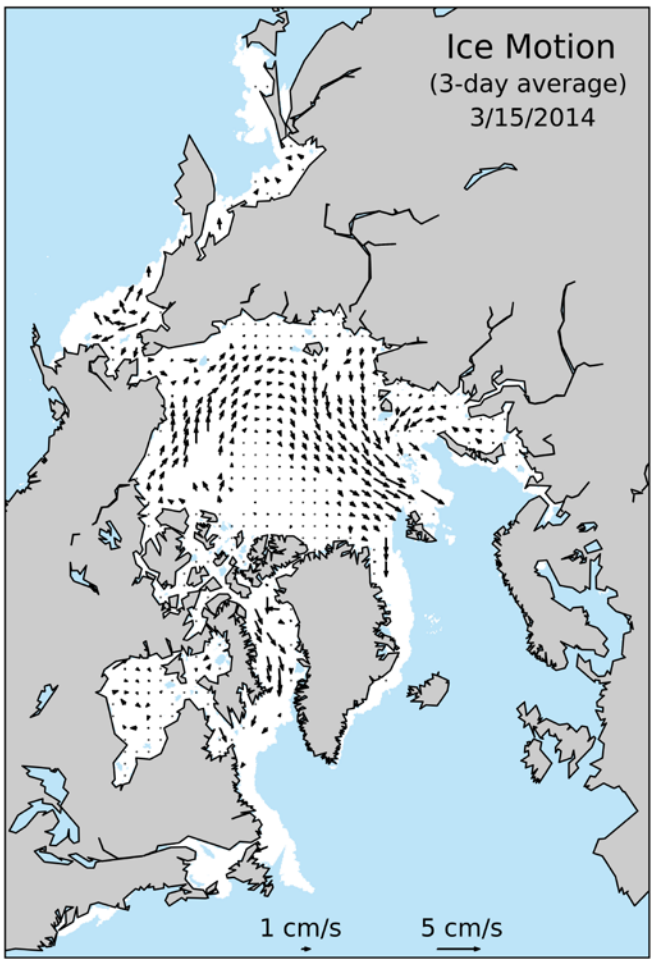

Figure 1. Example of three-day average ice motion from processing implemented at NASA Goddard.

Brightness temperatures were provided to collaborators to create super-resolution imagery from them. This involved converting the gridded binary brightness temperatures to image format

(PNG) for use in the super-resolution method. The motion algorithm requires gridded binary data, so the images needed to be converted back to obtain ice motion estimates.

3. Satellite data collection and geographic locations for our research: Accessing data from the VIIRS camera on the Suomi satellite, specific sea ice fragments in the Beaufort Sea were identified and successfully manually tracked for eleven days. The images of these sea ice fragments were supplied to the tracking algorithm for testing. Using data from one of the eleven days, multiple levels of zooming in were generated, down to the pixel level. These zoomed in images were supplied to the super resolution algorithm for testing.

Working plan for Oct. 2015 -- Sept. 2016:

1. We will continue to improve and refine the tracking methods on satellite images and passive microwave images.

2. We will continue to evaluate the proposed SR and tracking methods on more data at specific geo-locations and time. The data should be annotated to track specific ice fragments and analyzed for predicting ice moving model. The super-resolution algorithms will be applied to generate images with finer resolution than the original MODIS and VIIRS imagery. The motion of the ice fragments will be tracked on the finer resolution images. The ice fragments will be first manually initialized on the first image frame while our research focusing on tracking method.

3. We will develop new methods to predict the fine scale sea ice motions.

RESULTS

1. Results of the proposed super-resolution algorithm: The listed experimental results below demonstrate the feasibility of our super-resolution algorithm in large upscaling factors with complex inputs. Samples in Fig. 2 contain complicated rattan textures which we can barely recognize from the input image. Result generated by the proposed super-resolution framework perfectly reconstructs the embedded structure with minimal visual artifacts. Fig. 3 provides another set of example illustrating the effectiveness of our approach in handling rich patterns.
2. The passive microwave sea ice tracking. The initial results were not encouraging. The super-resolution images did not produce improved ice motions, and in fact, the motions were degraded from using the original source data (Fig. 4). One possible source for the degradation was the conversion of the gridded binary data to/from image format. However, comparison between motions from gridded data and image format showed similar performance Discussion within the group revealed that the issue is related to discrepancies in the creation of the super resolution images. These discrepancies will be investigated further to understand the performance issues and obtain improved super-resolution results.
3. Satellite data collection and geographic locations: The next phase will be to obtain and provide more images of sea ice fragments over greater periods of time and with clarity that allows the super resolution algorithm to operate at its greatest capabilities on real images of real sea ice fragments.

Figure 2: Super-resolution result on 'snow' (4 ×). Left is the input image; right is the result after the proposed algorithm. This figure is better viewed on screen with high-resolution display.

Figure 3: Super-resolution result on 'zebra' (4 ×). Left is the input image; right is the result after the proposed algorithm. This figure is better viewed on screen with high-resolution display.

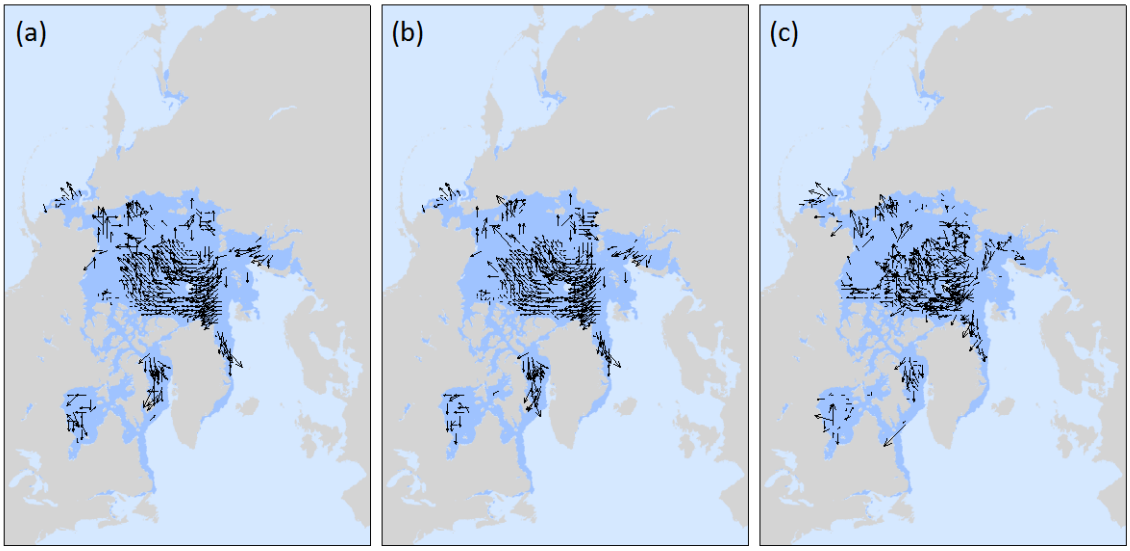

Figure 4. Sea ice motion fields from: (a) original gridded brightness temperatures, (b) brightness temperatures after conversion to image format, and (c) after super-resolution image format.

IMPACT/APPLICATIONS

In addition to ice tracking, the proposed super resolution methods can be used for many other applications. The collaboration among the three PIs (Dr. Tian from CCNY, Dr. Meier from NASA, and Dr. Weiss from NUWC enhance the long-term collaboration among these organizations and will bring research opportunities for the students at CCNY to solve problems in real applications.

RELATED PROJECTS

W. Meier: A Lagrangian to emerging dynamics in the marginal ice zone, ONR, Award Number N000141110977, B. Tremblay, PI – this project uses the passive microwave derived sea ice motions to track parcels of ice to investigate changes in the source and sink regions of Arctic sea ice and to compare with CMIP5 model estimates.

PUBLICATIONS

1. Y. Xian and Y. Tian, Robust Internal Exemplar-based Image Enhancement, IEEE International Conference on Image Processing (ICIP), 2015.
2. Y. Xian and Y. Tian. Hybrid Example-based Single Image Super-Resolution. International Symposium on Visual Computing, 2015
3. Y. Xian and Y. Tian. Single Image Super-Resolution via Internal Gradient Similarity. Under review, Journal of Visual Communication and Image Representation.