An Active Satellite Data Service based on Disaster Prediction Models

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ABSTRACT: Due to the advance of satellite imaging technology, we can retrieve large-coverage, periodical, and multi-spectral ground surface information. By analyzing the satellite images, we can continuously monitor ground cover changes due to natural causes or disaster events. In order to effectively evaluate the changes caused by events, satellite images that are taken just before and after the events are preferred. However, satellites are usually tasked to acquire images after disasters have happened. In this case, if the pre-disaster images are unavailable or were taken long before disasters, the disaster assessment and management become challenging due to the lack of suitable information. Although a naïve solution to retrieve the most-recent pre-disaster images is to continuously take photos to cover every ground surface, this solution is costly and will collect many unnecessary images. Therefore, this research proposes a cyber-infrastructure that combines disaster prediction models with a satellite image publish/subscribe system. By applying disaster prediction models to estimate areas that have high disaster risk, satellites can be tasked to take images covering these areas. In addition, model designers and users can use the areas as criteria to subscribe images in a publish/subscribe module. Therefore, whenever a satellite image covering the areas is taken, model designers and users can directly receive notifications of a new image to adjust the prediction model or conduct image analyses. In general, this study designs and develops a cyber-infrastructure connecting two disaster prediction model, a landslide model and a flood model, a publish/subscribe module, and a National Space Organization (NSPO) web service for tasking satellite and discovering archived images. Overall, with the proposed cyber-infrastructure, satellite imaging technologies can target high-risk areas and provide timely and comprehensive information for disaster management.

1. INTRODUCTION

Satellite technologies provide large-scale, periodical, and multi-spectral satellite images for various applications. Among the applications, natural and man-made disaster monitoring and assessment can be achieved by comparing satellite images collected before and after the disaster events. However, disaster damage assessment and management are usually activated very close to or after disaster events, which means that satellites are tasked to acquire images after disasters have happened. In this case, if the pre-disaster images are unavailable or were taken long before disaster events, the damage assessment and management become challenging due to the lack of suitable information.

Although a naïve solution is to task satellites to acquire images on every ground surface, this solution is costly and will collect a large amount of unnecessary images. Therefore, in order to acquire images that are most close to disaster events while reducing unnecessary cost, satellite imaging tasks should target at necessary areas in a specific time period. In other words, a knowledge-based satellite imaging system is required. In this research, we propose to integrate satellite imaging system with disaster prediction models to actively assess areas that have high disaster risk, and then automatically task satellites to acquire images at specific areas and time period.

In addition, efficient information dissemination during disaster assessment and management is critical. In order to provide users and model designers the most recently acquired images, we argue that satellite imaging systems should also connect to a publish/subscribe module. A publish/subscribe module can transform the traditional request/response pull-based communication model into a more efficient push-based communication model (Babcock at al. 2002). To be more specific, users can first send subscriptions to the publish/subscribe module to subscribe areas of interest (along with other criteria, such as satellite types, cloud cover percentages, etc.). As the publish/subscribe module connects with satellite imaging system, when a new satellite image is acquired, the publish/subscribe module will match the image with users' subscriptions. If the image matches with users' subscription criteria, the publish/subscribe module will automatically send a notification to users. In this case, users can receive near-real-time notifications of images that match with their pre-defined subscriptions.

Overall, this research aims at designing and developing a cyber-infrastructure combining a satellite imaging system, a publish/subscribe module, and disaster prediction models to actively collect and provide comprehensive pre-disaster and post-disaster satellite images for disaster assessment and management.

2. METHODOLOGY

Figure 1 shows the high level system architecture of the proposed cyber-infrastructure. In general, the system contains a cloud service hosting the publish/subscribe module and connecting with other system modules. In the cloud service, a web service connector was developed to connect with the National Space Organization (NSPO) web service for tasking satellite and discovering archived images. In terms of disaster prediction model, the publish/subscribe module also connects with a landslide model and a flood model.

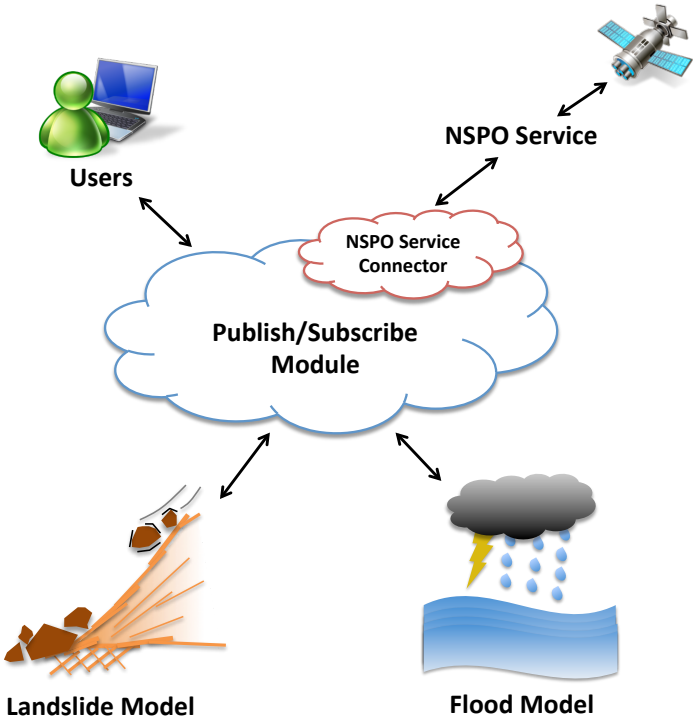

Figure 1 High level system architecture

Overall, the proposed system supports two major workflows. The first workflow is to utilize the knowledge of disaster prediction models and actively task satellite to acquire images at the targeted areas during specific time periods. The landslide model applied in this study was developed by (Chang and Chiang, 2009). And the flood model was developed to integrate the information from altimetry satellite observations and optical satellite images, which is similar to related literatures (Siddique-E-Akbor et al., 2014; Hossain et al, 2014a, 2014b). These two models utilize historical information to predict areas that have high disaster risk. These areas will be first sent to the publish/subscribe module. The publish/subscribe module then forward the areas to NSPO service for tasking satellites to take images at those areas.

The publish/subscribe module will continuously retrieve new satellite images from the NSPO web service. Whenever a new image is retrieved, the publish/subscribe module compares the image metadata with model prediction areas and actively forwards the matched images to the disaster models. In this case, the prediction model can utilize the new image to further improve the prediction accuracy in a near-real-time manner.

The second workflow is mainly for users to subscribe satellite images. Users can send subscriptions to the publish/subscribe module by setting query criteria, including an area, a satellite, image angles, a sensor mode, or cloud cover percentage. These subscriptions will be stored in a database as pre-defined queries. Similar to the previous workflow, whenever the publish/subscribe module retrieves a new satellite image from the NSPO web service, the publish/subscribe module will match the image metadata with every user subscription. If the image matches user subscriptions, the publish/subscription module then actively send notifications to users to inform them this newly-acquired image.

3. RESULT

We have tested the proposed system on two disaster scenarios. For the landslide model, a 2015 typhoon Dujuan event in Taiwan was applied. According to the model-predicted areas, satellite-imaging tasks were sent to the NSPO web service. In addition, to access the landslide damage caused by the typhoon Dujuan, through the developed publish/subscribe module, we have collected five satellite images on the model-predicted area, which shows that landslides happened around the rivers.

For the flood model, a flood event at the northeast Bengal was used as a testing scenario. According to the model-predicted areas, satellite-imaging tasks were sent to the NSPO web service. The predicted areas are also subscribed in the publish/subscribe module. When new images match the criteria, the module automatically send the image entry to the user via email, as shown in Figure 2.

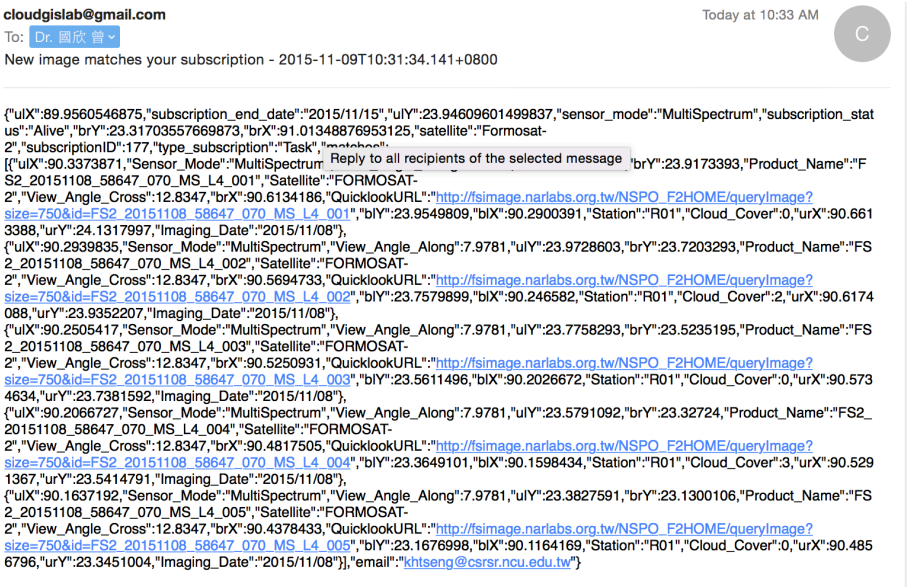

Figure 2 An email notification example for matched images

4. CONCLUSIONS AND FUTURE WORK

This research designs and implements a cyber-infrastructure combining a satellite-imaging web service, a publish/subscribe module, and two disaster prediction models. With the knowledge of disaster prediction models, satellites can be tasked to acquire images at areas that have high disaster risk. In this case, we can obtain satellite images that are closely before and after disaster events in order to provide more accurate disaster assessment. For the future direction of this study, we will implement a user portal for users to search achieved satellite images as well as create subscriptions. In addition, more disaster scenarios will be tested to better examine the contribution of the proposed cyber-infrastructure.

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