Near real-time flood detection in urban and rural areas using high resolution Synthetic Aperture Radar images

Conference or Workshop Item

Accepted Version

Presentation

Near real-time flood detection in urban and rural areas using high resolution SAR images

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• Flooding is a major hazard in both rural and urban areas worldwide, and has occurred regularly in the UK in recent times. The Pitt Report considered what lessons could be learned from the UK floods of 2007. Among its many recommendations, the report highlighted the need to have real-time or near real-time flood visualisation tools available to enable emergency responders to react to and manage fast-moving events, and to target their limited resources at the highest-priority areas.

2. Flood extent from high resolution SAR

•A near real-time flood detection algorithm giving a synoptic overview of the extent of flooding in both urban and rural areas, and capable of working during night-time and day-time even if cloud was present, could be a useful tool for operational flood relief management. The latest generation of high resolution SAR satellites now make such technology possible. A near real-time algorithm might allow the emergency services to view the geo-registered flood extent over the whole area overlaid on a base map a few hours after overpass.

•The vast majority of a flooded area may be rural rather than urban, but it is very important to detect the urban flooding because of the increased risks and costs associated with it. Flood extent can be detected in rural floods using SARs such as ERS and ASAR, but these have too low a resolution (25m) to detect flooded streets in urban areas. However, a number of SARs with spatial resolutions as high as 1m have recently been launched that are capable of detecting urban flooding, including TerraSAR-X, RADARSAT-2, ALOS PALSAR, and the first three of the COSMO-SkyMed satellites.

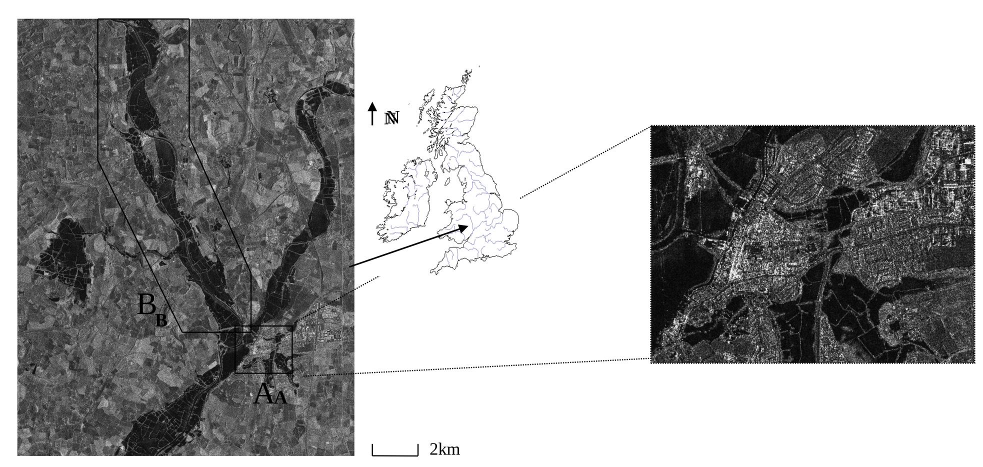
3. Fusion of existing algorithms

•An automatic near real-time flood detection algorithm using single-polarisation TerraSAR-X data has been implemented by Martinis et al (2008). This is very effective at detecting rural floods, but would require modification to work in urban areas containing radar shadow and layover. A semi-automatic algorithm for the detection of floodwater in urban areas using TerraSAR-X has also been developed previously (Mason et al., 2010). This takes shadow and layover into account, but is aimed at detecting flood extents for validating an urban flood inundation model in an offline situation, and requires user interaction at a number of stages.

•The objective of this work is to build on a number of aspects of the existing algorithms to develop an automatic near real-time algorithm for flood detection in urban and rural areas.

•The algorithm assumes that high resolution LiDAR data are available for at least the urban regions in the scene, so that a SAR simulator may be run in conjunction with the LiDAR data to generate maps of radar shadow and layover in urban areas. It is therefore limited to urban regions of the globe that have been mapped using LiDAR. However, in the UK most major urban areas in flood-plains have now been mapped, and the same is true for many urban areas in other developed countries.

4. Study area and data set



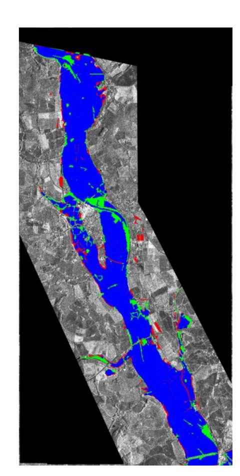
•The algorithm was developed using the data set acquired for the 1-in-150 year flood at Tewkesbury in July 2007. A 3m resolution TerraSAR-X image was acquired just after the flood peak. Aerial photos were used to validate the SAR flood extent. Rectangle A covers Tewkesbury, and LiDAR data here were used to provide a DTM. LiDAR data in region B were used to validate the SAR flood extent in a rural area, but a less accurate map-based DTM was used by the algorithm in rural areas.

5. The method.

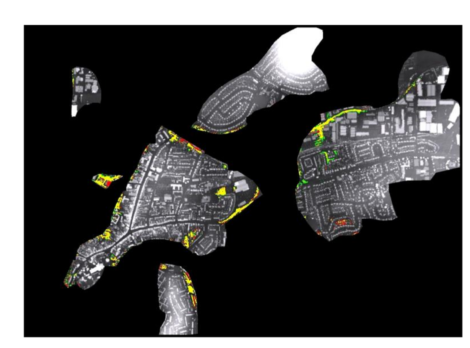
•The algorithm first detects the flood in the rural areas. Instead of using per-pixel classification, the image is segmented into homogeneous regions, which are then classified on the basis of their spectral, textural, shape and contextual features. Classification is performed by assigning all segmented regions with mean SAR backscatter less than a threshold to the 'flood' class. To determine the threshold, training regions for 'flood' are automatically selected from regions giving no return in the LiDAR data (water), and for 'non-flood' from un-shadowed areas well above the flood level. The initial segmentation is refined using a variety of rules e.g. flood regions having mean heights above the local flood height are set unclassified.

•A simpler region-growing technique is used in the urban areas, guided by knowledge of the local waterline heights in adjacent rural areas. A set of seed pixels having backscatter less than the threshold, and heights less than or similar to the adjacent rural waterline heights, is identified. Seed pixels are clustered together provided that they are close to other seeds. Regions of shadow and layover are masked out in the processing.

6. Validation using aerial photography

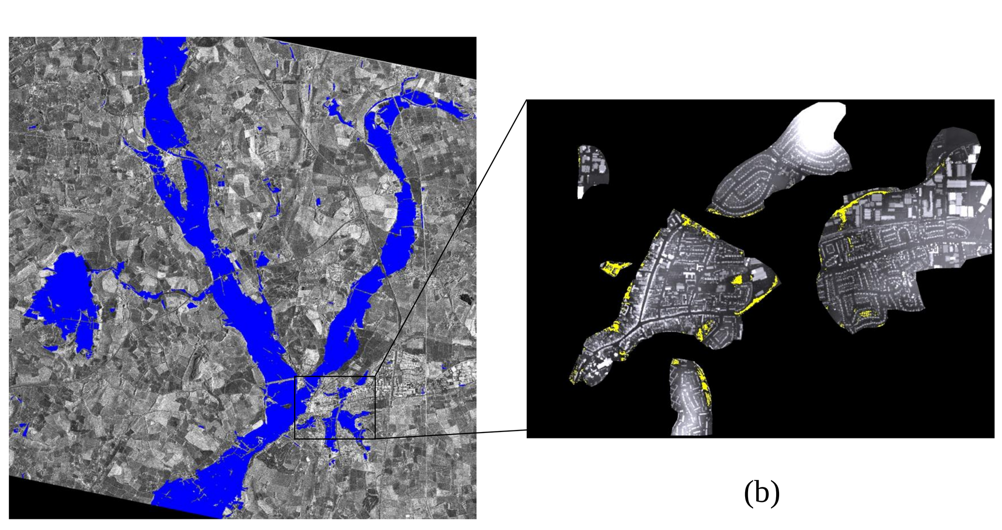


Correspondence between the TerraSAR-X and aerial photo flood extents over the rural validation area (region B), superimposed on the TerraSAR-X image (blue = wet in SAR and aerial photos, red = wet in SAR only, green = wet in aerial photos only). Flood detection accuracy = 89%.



Correspondence between the TerraSAR-X and aerial photo flood extents in main urban areas of Tewkesbury, superimposed on the LiDAR image (yellow = wet in SAR and aerial photos, red = wet in SAR only, green = wet in aerial photos only). Flood detection accuracy = 75%.

7. Multi-scale visualisation of flood extents



(b)

(a)

Possible multi-scale visualisation of flood extents in (a) rural (blue = predicted flood), and (b) urban areas (yellow = predicted flood).

8. Discussion and conclusions

•Preliminary results indicate that the algorithm can detect flooding in rural areas with good accuracy, and in urban areas with reasonable accuracy. As to operational considerations, a number of operations (such as calculation of radar shadow and layover) could be carried out in parallel with tasking the satellite to acquire the image. Download of the image to the ground station, followed by near real-time processing the raw SAR to a multi-look image, geo-registering this automatically, and delineating the flood extent, could in theory be carried out in 4-5 hours after overpass. Future work will aim to test the method on other flood events.

References:

Martinis S, Twele A and Voigt S (2009). Towards operational near real-time flood detection using a split-based automatic thresholding procedure on high resolution TerraSAR-X data. *Natural Hazards and Earth System Sciences*, **9**, 303-314.

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