# CURVELET-BASED CHANGE DETECTION FOR MAN-MADE OBJECTS FROM SAR IMAGES

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## 1. INTRODUCTION

The new spaceborne SAR systems enable a continuous high resolution survey of urban areas. Our focus lies on change detection in settled areas for urban development and natural disasters. The interpretation of SAR images, mainly automated interpretation, is fundamentally restricted by geometric and radiometric distortions. Especially in settlements single buildings cause layer-over and shadow effects that overlay with those of other buildings while single strong scatteres outshine and hide low scattering regions (Fig. 1(a) & 1(c)). Hence, automated single building extraction seems to be nearly impossible, but the structure of the city may be captured, if we find a way to discriminate structure from the surrounding noise. For this purpose the Curvelet representation is chosen.

In this article a new approach of change detection with Curvelets is proposed. The Curvelet transformation is used three-foldly: for despeckeling if the image, for enhancing regular structures by weighting coefficients of orthogonally oriented Curvelets, and for a new change detection method. The results on TerraSAR-X Spotlight data on a fine-structured dense urban area are surprisingly correct and noise free.

## 2. CHANGE DETECTION WITH CURVELETS

### 2.1. Curvelet approach

The theoretical derivation and the discrete implementation of the Curvelet transform can be found in publications of Candès [1] and Donoho [2]. In the context of SAR image denoising and structure enhancement following important properties should be summarized: The smallest components of the Curvelets are the so called Ridgelets, slight ellipses that resemble to a linear fragment. Each Ridgelet is defined by its length (according to the scale), its direction and its position. The influence on the image is weightened by an attached real coefficient. More information and the source code in Matlab® and C++ is available free of charge on the Curvelet homepage [3].

### 2.2. Despeckeling and regular structure enhancement with Curvelets

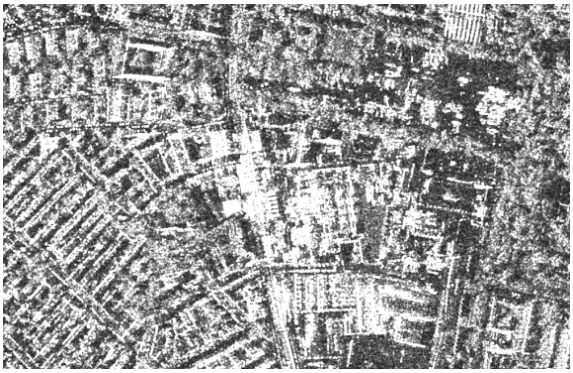
After the transformation from the spatial domain into the Curvelet coefficient domain, the single Ridgelets can be selected by manipulating the attached coefficient. Low coefficients can be set to null by applying a simple threshold or by reducing the number of coefficients used to a certain percentage of the original quantity. A weighting can be applied either by scale or by direction. To emphasize the mainly orthogonal structures in urban areas it is even possible to weight coefficients by their geometric relations to other Curvelet coefficients, e.g. Curvelets with parallel or orthogonal directions. So structures are emphasized and noise is reduced, see Fig. 1(b).

### 2.3. Change detection with Curvelets

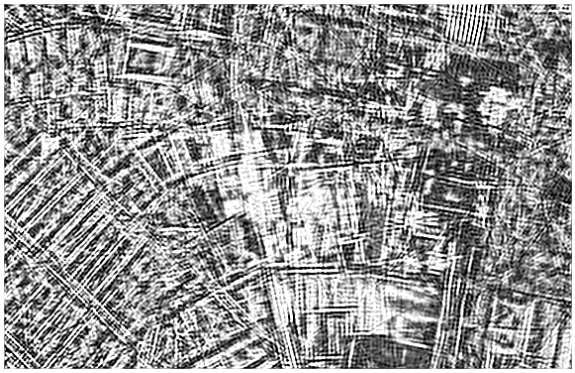
For change detection the Curvelet representations of the input images are compared and only the desired differences are transformed back into the image space. In the context of natural disasters only larger changes e.g. building destructions are of interest, whereas changes in single pixels are seen as noise. Controlling the scale of the Curvelets used for the reconstruction of an image difference out of time series helps to control the size of the changes mapped independently of the changes in the backscattered power. Fig. 1(d) shows an example, where identical image parts are canceled out and just changes remain.

## 3. RESULTS

In the change detection over the city of Mannheim (Germany) only one location shows distinct changes (see right upper corner in Fig. 1(d)) whereas the surrounding stays completely identical. To verify these results an optical image and the event calendar of Mannheim are consulted. The detected changes can be attached to the "Oktobermess" festival, that took place on the fairground during the second image acquisition. Apart from urban applications the mining activities at the copper mine of Chuquicamata (Chile) have been surveyed over a period of several months. Especially the comparison of the kind of changes (darkened or brightened up) and their relative allocation help to infer the real changes in the mining area.

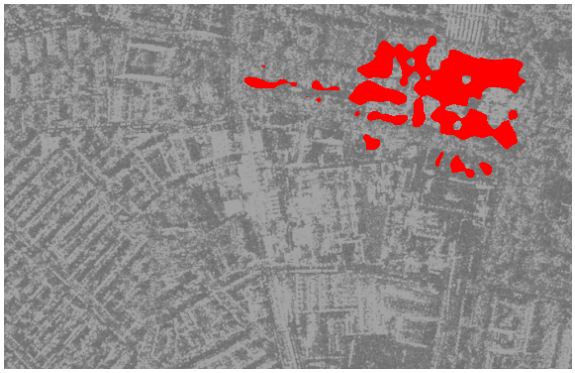


(a) Original SAR image 1



(b) Enhanced SAR image

(c) Original SAR image 2



(d) Detected changes underlayed with Fig. 1(a)

**Fig. 1**. Some results from TerraSAR-X data acquired over the city of Mannheim (Germany)

## 4. CONCLUSION

The Curvelet transformation turns out to be a very suitable tool for SAR image denoising and structure enhancement as well as change detection. Especially in fine structured areas where most filter techniques fail the Curvelet representations enables us to select the type of structure to be emphasized or to be suppressed. Once adapted to a certain application this algorithm works fast, without any interaction and delivers robust results.

## 5. REFERENCES


[1] E. J. Candès and D. L. Donoho, *Curve and Surface Fitting*, chapter Curvelets – a surprisingly effective nonadaptive representation for objects with edges, pp. 105–120, Innovations in Applied Mathematics. Vanderbilt University Press, Nashville (TN), Saint-Malo (France), 1999.

[2] D. L. Donoho and M. R. Duncan, "Digital Curvelet Transform: Strategy, Implementation and Experiments," in *Aerosense 2000, Wavelet Applications VII, Orlando (FL)*, 2000, pp. 12–29.

[3] L. Demanet, "curvelet.org," http://www.curvelet.org, 2007, (accessed on 26 March 2009).