

# BAYESIAN BUILDING EXTRACTION FROM HIGH RESOLUTION POLARIMETRIC SAR DATA

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## 1. INTRODUCTION

Building extraction from high resolution Synthetic Aperture Radar (SAR) has many promising applications in urban analysis. However, partial geometry and appearance information of buildings are not available in SAR images due to SAR imaging mechanism and geometric layout of urban areas. SAR images are slant range projection of scatterer reflections. With the increasing resolution of new SAR images, some geometric ambiguities are gradually resolved. Accurate building detection and localization become feasible. In meter-resolution SAR images buildings are generally represented by bright layovers, roofs regions and dark shadows regions. Building detection is usually accomplished by extracting layover regions. These regions are strong reflections from scatterers formed by buildings. Some tree regions with relatively strong reflections are a major source of false positives. Another factor that influences layover detection rate is the building-sensor orientation (building pose). The appearances of buildings in SAR images partially depend on their orientation angle.

Given these constraints, building extraction models should follow the mechanism through which building reflections are acquired by SAR. Further statistical modelling of urban scene geometry and SAR imaging mechanism in a probabilistic framework would be promising. Models should resolve and analyze the interaction of SAR imaging and urban scene configuration [1]. Bayesian network provides an elegant way to model the interaction of different sources that directly or indirectly affect the detection system. Local object detection and context were modelled using Bayesian network in [2]. Context is very important in scene understanding. The scene geometry and presence of other objects can reduce search space and ambiguities. Therefore context is complementary to local detection. With context information we consider the likely place where an object could be found. The relationships governing the structure of the scene can be learned in a Bayesian network. The geometric model exploiting context information is expected to improve building detection since visibility of buildings is low.

In this paper we model the interdependence of layover detection, geometric surface and building-sensor orientation angle for object detection. The interplay among them is modeled in a Bayesian network. Geometric surface evidences are generated by classifying SAR images into layover, shadow, tree, field and water. The adjacency of shadow with layover is also exploited. A layover and accompanying shadow usually have similar shapes. The location of shadow is determined by orientation angle and radar look direction. The information from other surface types, e.g. tree, also helps to improve layover detection when we have confidence that some regions are not buildings. We can increase detection rate and at the same time eliminate some false positives. In turn, other object detections can also benefit from layover confidences. Our goal is to demonstrate the improvement over low-level detection by reasoning the underlying scene structure. The contribution is a derivation and discussion of the relationship between building and SAR geometry.

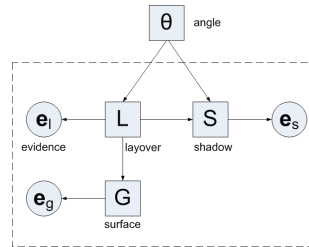
## 2. GRAPHICAL MODEL

We propose a graphical model for modeling the contextual interplay among four elements of urban SAR scene: building-sensor orientation, layover identity, building shadow and rough geometric surface. The objective is to accurately detect layover object identities. The orientation angle affects the position and appearances of layovers and shadows. Shadows are situated next to layover regions. A layover with a specific orientation has particular polarimetric characteristics due to the angle-dependent scattering. Local detector considers all locations in the image as equally likely and uses low-level appearance-based and polarimetric features. We assume that geometric surfaces are independent and that object identities are independent. We estimate the rough geometric surface in the scene, which can be used to adjust the probability of finding a layover at a given image location. Geometric surfaces directly affect the position of objects in the image. The proposed graphical model also allows probabilistic object hypotheses to refine surface information. We consider that objects, shadows and surface produce

image evidence. The estimate of an element in a urban scene will be more accurate when the interactions among all correlated elements are taken into account. Our aim is to combine all pieces of evidence into a coherent Bayesian network.

The decomposition of the model shown in Fig.1 is given in (1). The elements in the model are orientation angle  $\theta$ , layover  $L$ , building shadow  $S$ , geometric surface  $G$ , layover evidence  $e_l$ , shadow evidence  $e_s$  and geometric surface evidence  $e_g$ . The dashed box indicates repetition of layover objects. This is a tree-structured directed acyclic graph model. The inferences in each direction can be efficiently computed using belief propagation.

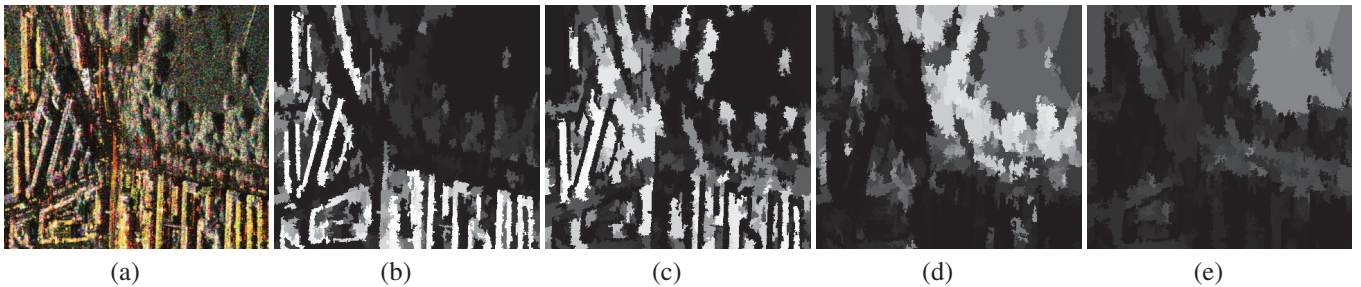
$$P(\theta, \mathbf{L}, \mathbf{S}, \mathbf{G}, \mathbf{e}_l, \mathbf{e}_s, \mathbf{e}_g) = P(\theta) \prod_i P(L_i|\theta)P(e_{li}|L_i)P(S_i|L_i, \theta)P(e_{si}|S_i)P(G_i|L_i)P(e_{gi}|G_i) \quad (1)$$



**Fig. 1.** Graphical model for angle  $\theta$ , building layover identities  $L$ , shadow  $S$  and geometric surface  $G$ .

### 3. EXPERIMENTS

Fully polarimetric SAR data of Copenhagen acquired by EMISAR are used in the experiments. The spatial resolution in range and azimuth are 1.499m and 0.748m, respectively. Fig.2 shows an example image and its estimated surface evidence maps.



**Fig. 2.** Surface evidence: (a) original image, (b) layover, (c) shadow, (d) tree and (e) field

### 4. REFERENCES

- [1] M. Quartulli and M. Datcu, "Stochastic geometrical modeling for built-up area understanding from a single sar intensity image with meter resolution," *IEEE Transactions on Geoscience and Remote Sensing*, vol. 42, no. 9, pp. 1996–2003, Sept. 2004.
- [2] D. Hoiem, A. Efros, and M. Hebert, "Putting objects in perspective," *International Journal of Computer Vision*, vol. 80, pp. 3–15, Oct. 2008.