Probabilistic Scene Models for Image Interpretation

Alexander Bauer

Fraunhofer IOSB

Outline

- Motivation
- Related Work
- Probabilistic Scene Models
- Evaluation and Results
- Application
- Conclusion and Outlook

Aerial Image Interpretation

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Challenges in Image Interpretation

- Image interpretation strongly depends on prior knowledge
  - Typical object features
  - Typical spatial arrangement of objects
  - Typical scenes and their characteristic object occurrences
- Challenges
  - Modeling of prior knowledge
  - Matching observations with hypotheses
  - Inference
- Applications of computer based image interpretation
  - Supporting human image interpreters
  - Other fields: Robotics, surveillance systems or any other cognitive system

Related Work

- *Image Retrieval*

  Classification and search for image scenes (e. g. beach, mountain, street etc.) based on material detectors (sky, grass, sand) etc.

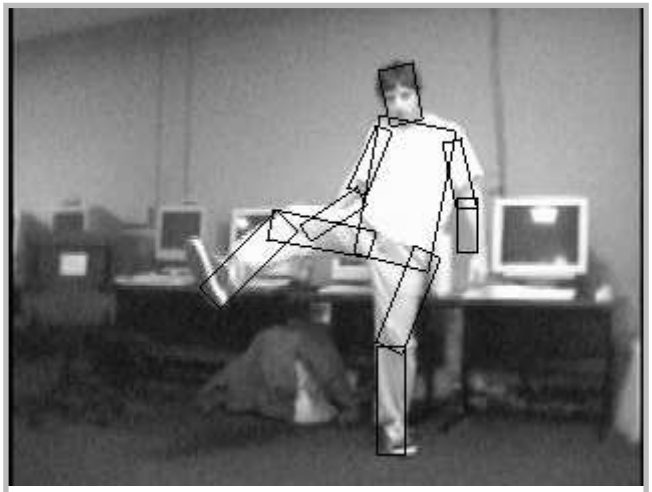
- *Part-Based Object Recognition*

  Recognition of deformable objects based on its solid parts

- *Image Understanding*

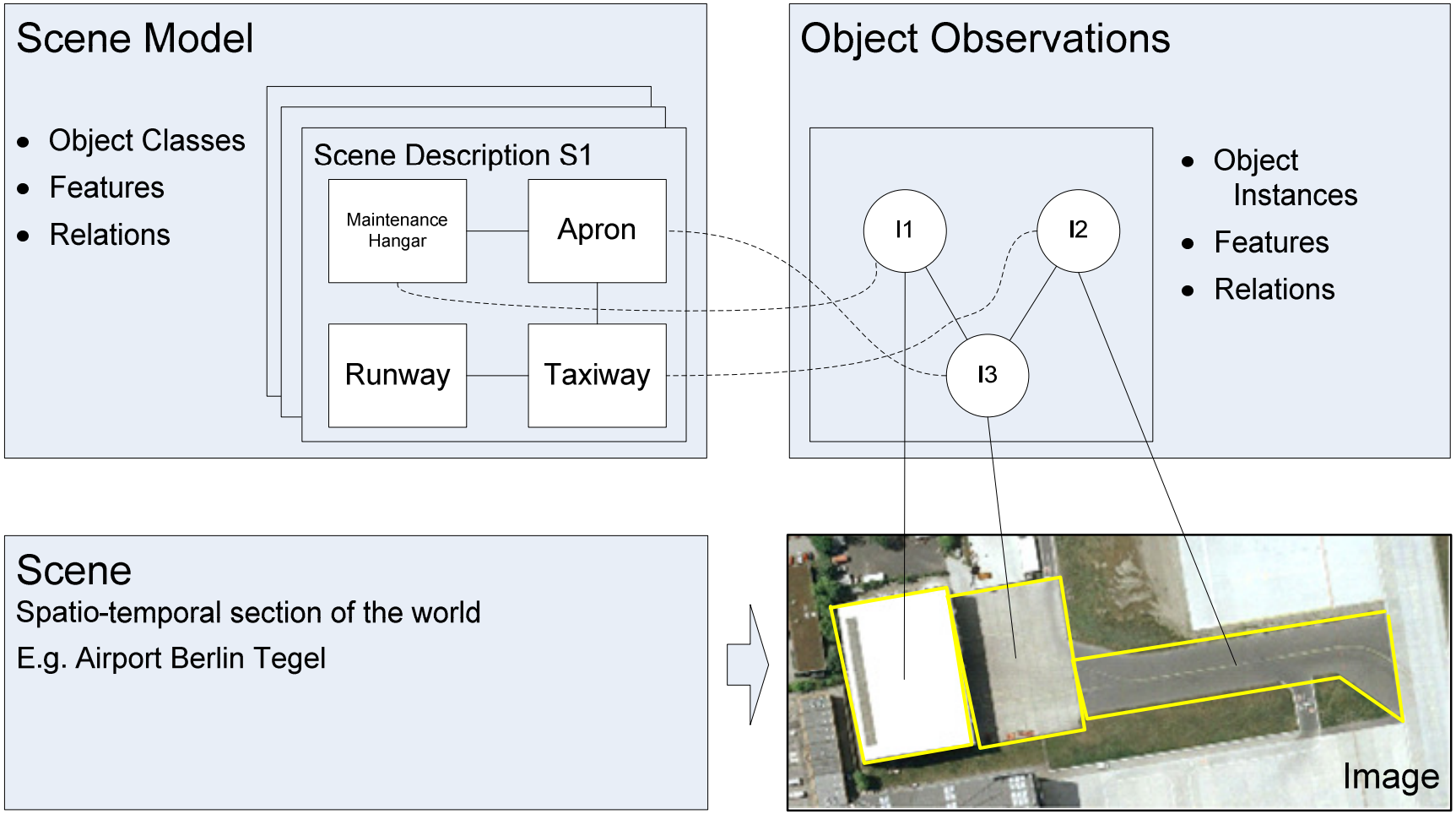
  Improving object recognition using context

  - Mastuyama (1985): Rule-based
  - Rimey (1993): Bayes Nets
  - Lin et al. (2009): Stochastic Grammars



Part-based object recognition (Felzenszwalb 2005)

Scene Models for Image Interpretation



Scene Description: Functional Scene Decomposition

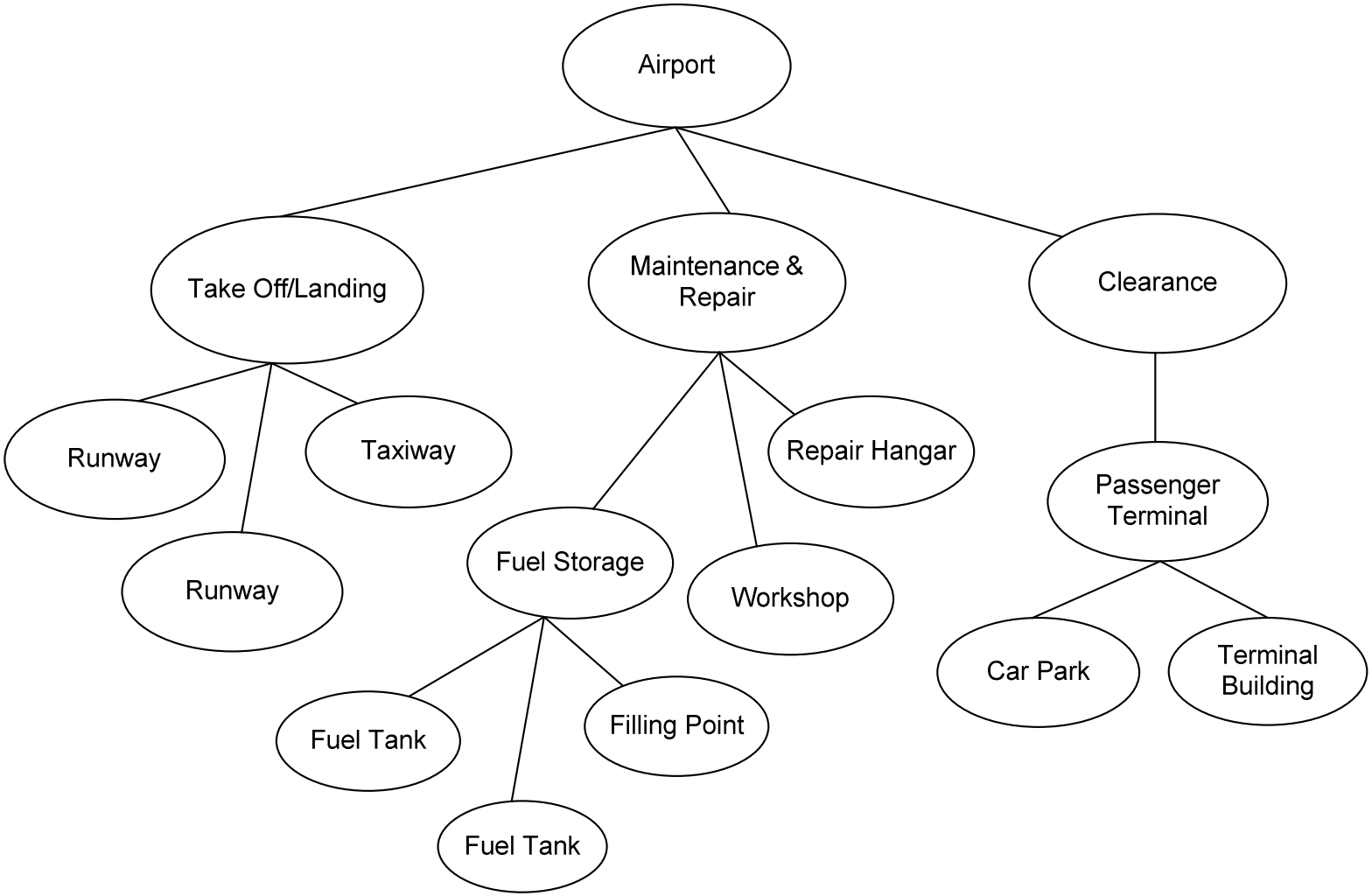


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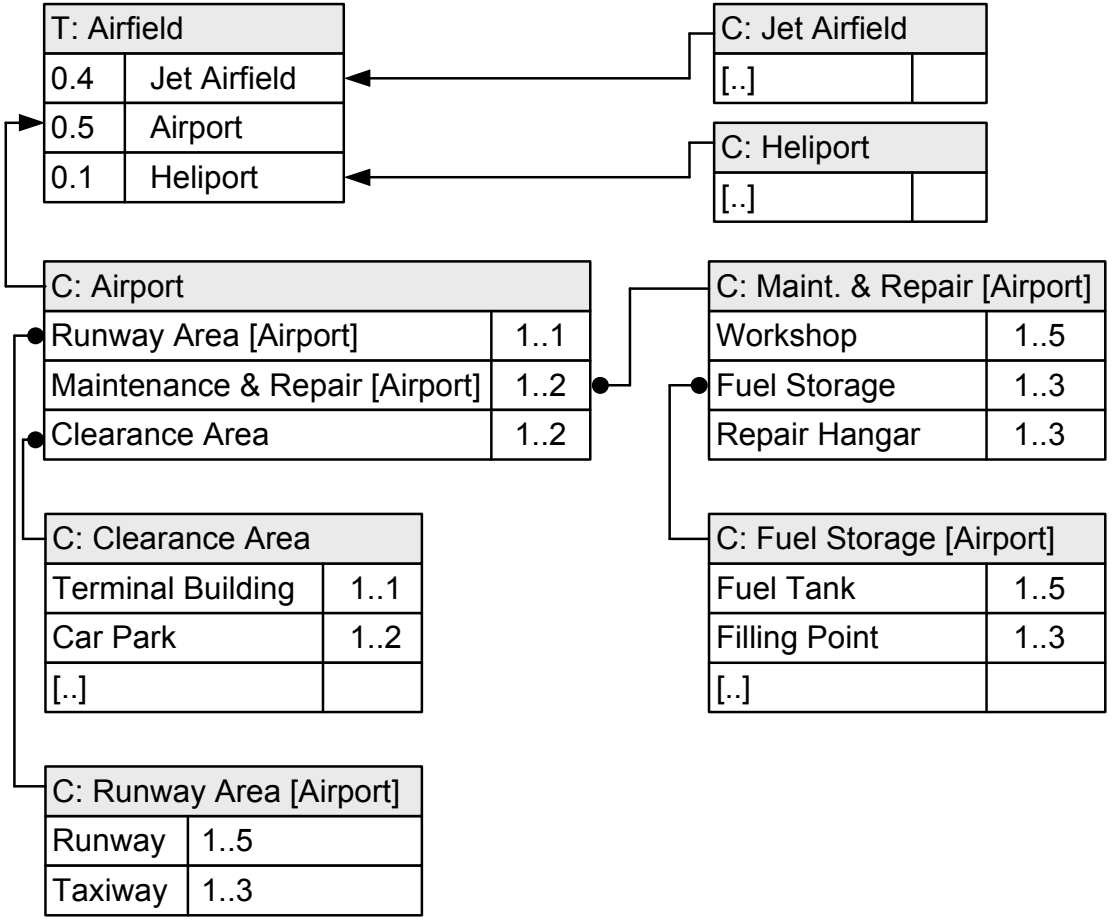
Image Interpretation as Bayesian Inference Problem

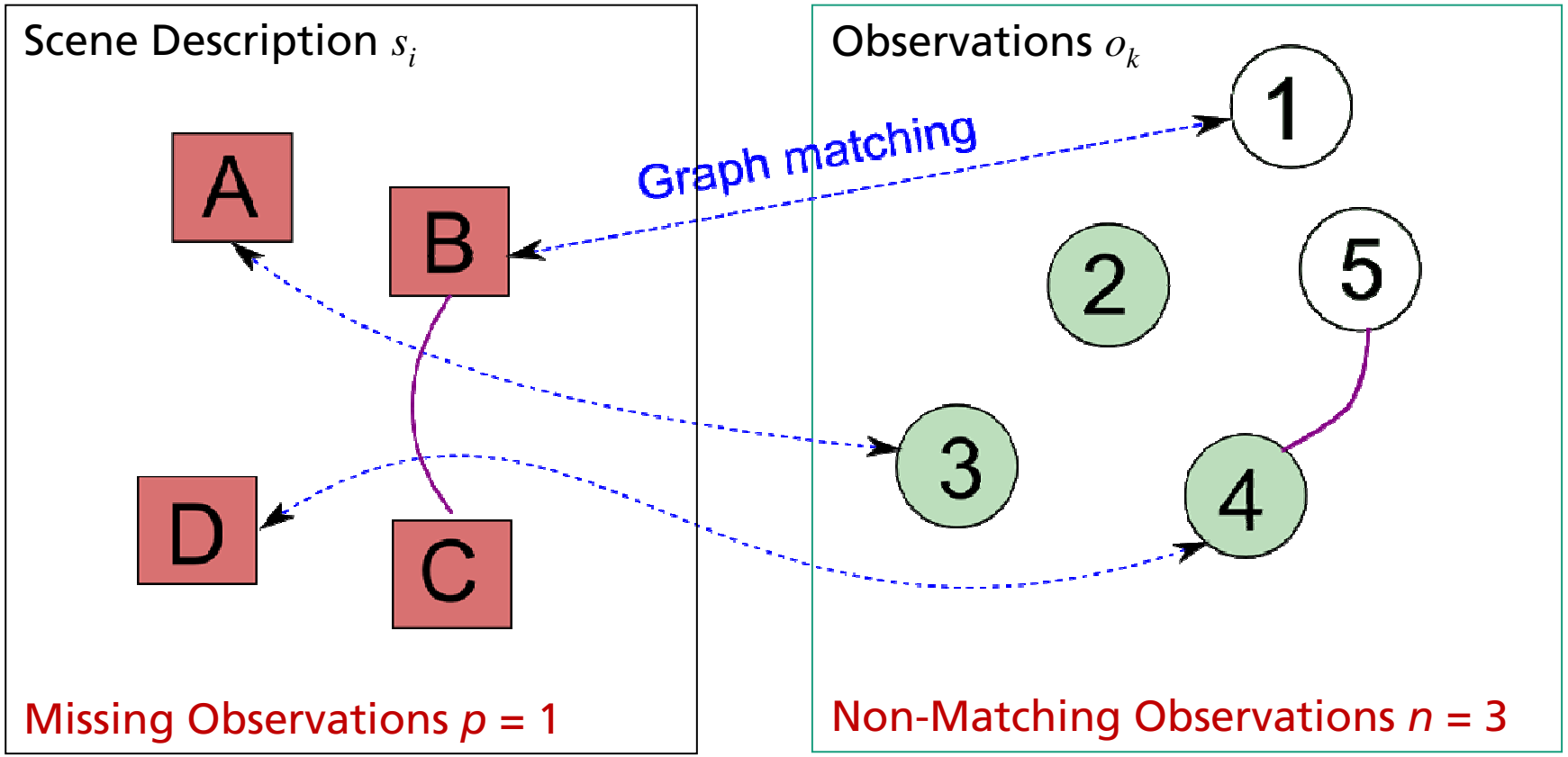
$$P(S \mid O) \propto P(O \mid S) \cdot P(S)$$

- S: Set of scene descriptions
- O: Set of object observations, it's features and relations
- P(S): Prior distribution on scene description occurrence
- P(O | S): Likelihood for observations given a specific scene description hypothesis

P (S) : Modeling of Scene Description Prior Distribution



P(O | S): Observation Likelihood



$$P(O = o_k \mid S = s_i) \propto \exp(-[\lambda_n \cdot n(o_k, s_i) + \lambda_p \cdot p(o_k, s_i)])$$

Inference from P (S | O)

- Event probability expressed as expected value of event indicator function

$$E_{S|o_k}\{I(S,o_k)\}$$

  - Occurrence probability of an object class

$$I_{\Phi}(s_i,o)=\begin{cases}1 & \text{Unobserved object class } \Phi \text{ is part of } s_i \\ 0 & \text{else}\end{cases}$$

  - Probability of a scene class (root node class)
  - Class of a single object based on its features and object context

- Monte Carlo approximation
  - Importance sampling from P(S)
  - Sampling von P(S | O) using Markov-Chain Monte-Carlo (MCMC)

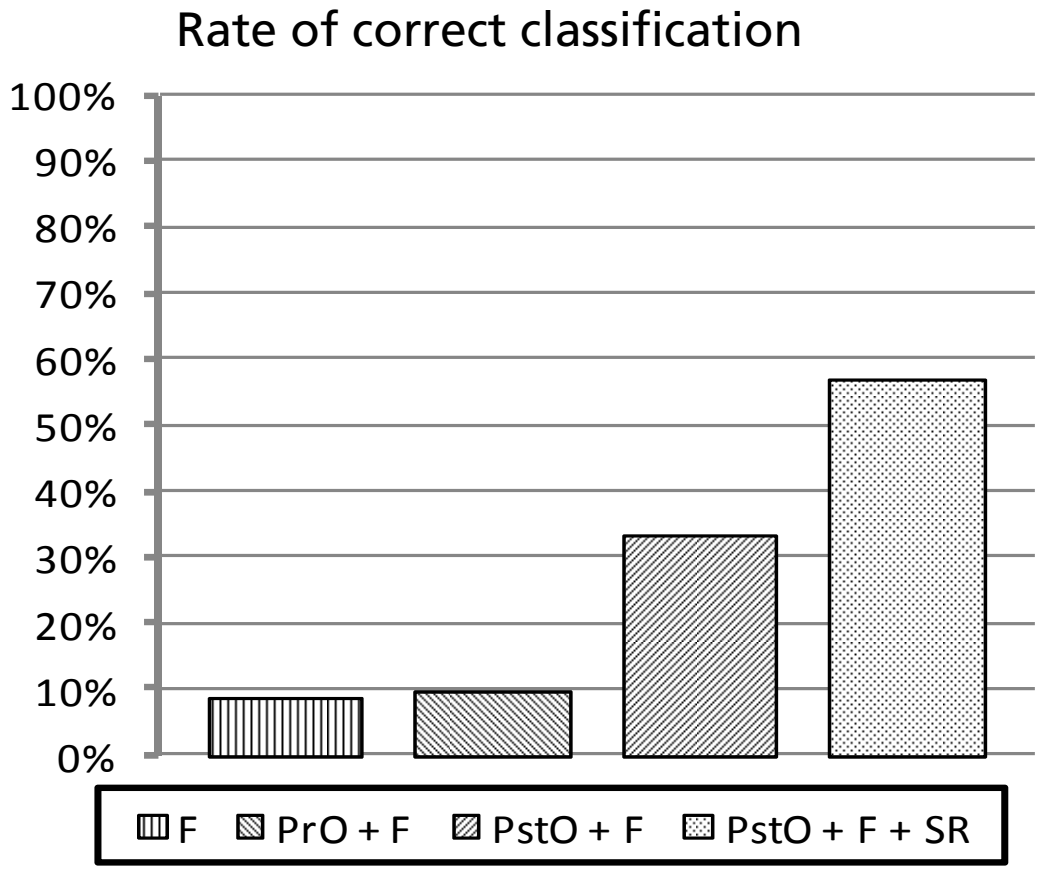
Experimental Evaluation

- Scene Models developed in cooperation with image interpretation experts
  - Domain: Airfields
  - Object features: base signature (building, paved surface, antenna, etc.)
  - 10 possible object classes for each signature (Terminal, Hangar, etc.)
  - 5 different scene types (airport, jet airfield, glider airfield, etc.)
  - Binary nearness relations

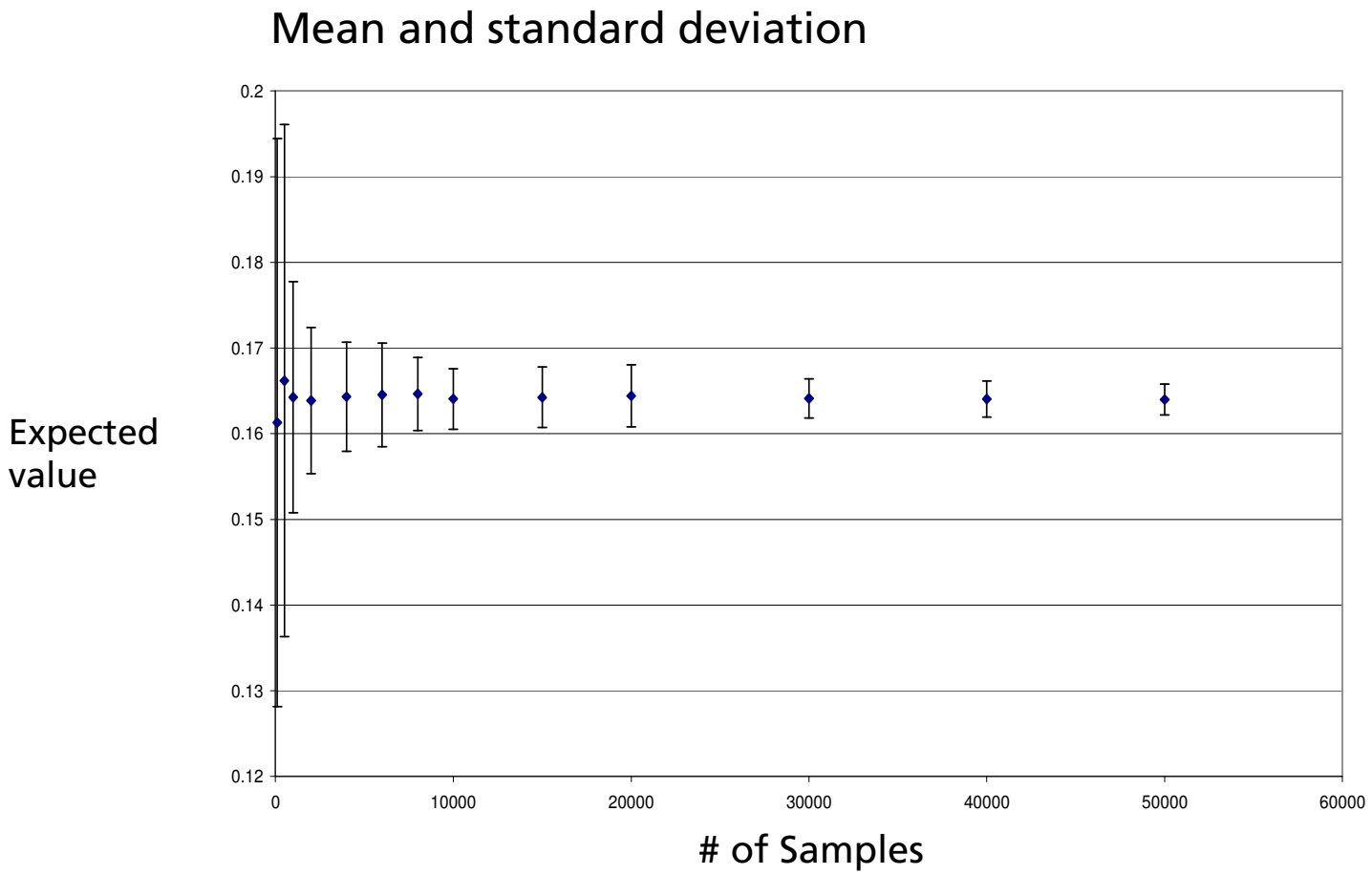
- 10 labeled images (objects as polygons) used as ground-truth data

Evaluation Results: Object Classification

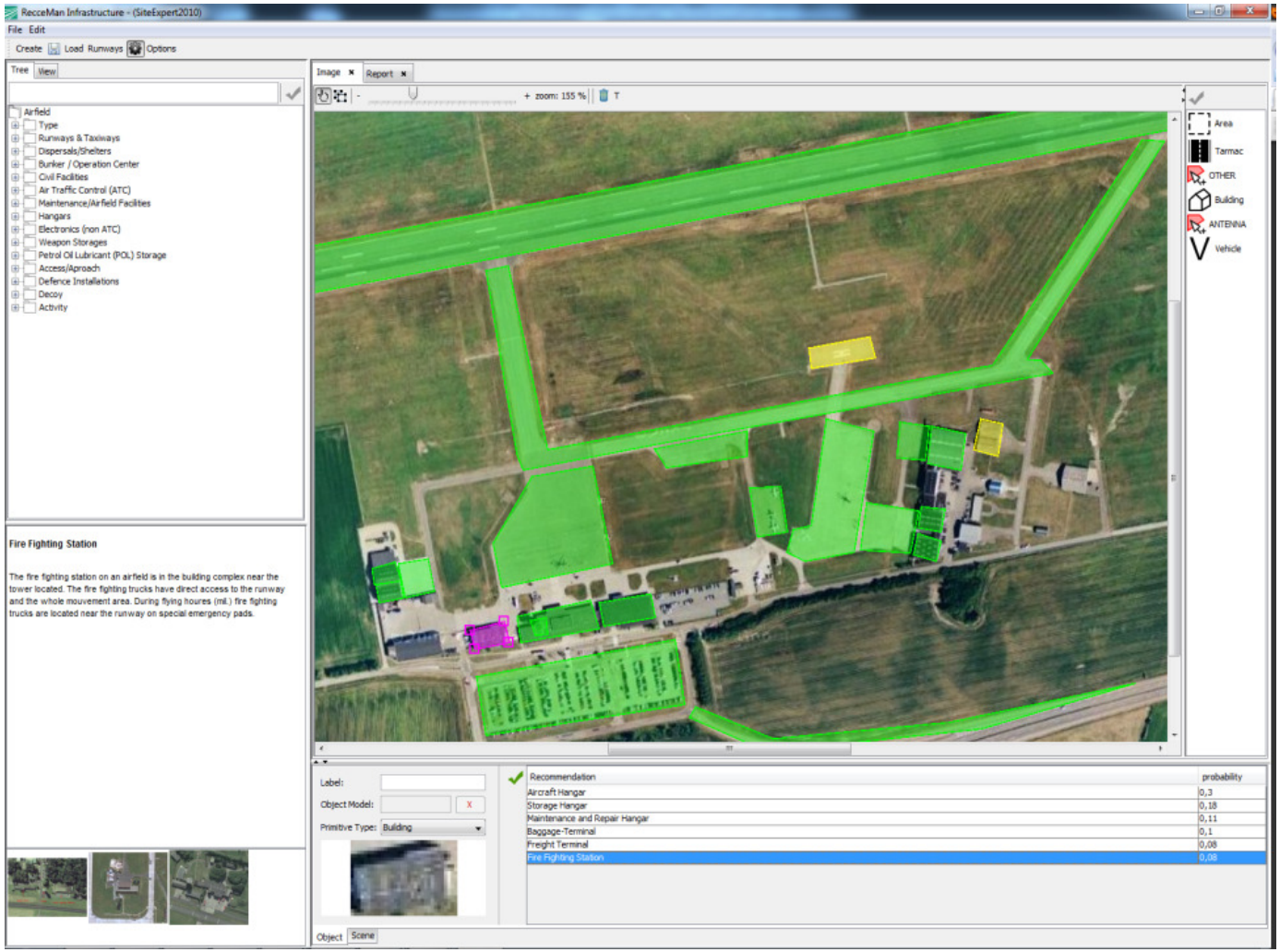
F: Object Features
PrO: Prior Occurrence
PstO: Posterior Occurrence
SR: Spatial Relations



Convergence of Monte-Carlo Approximation



Application: Assistance System for Image Interpretation



Conclusion & Outlook

- Motivation: Exploiting prior knowledge in image interpretation
- Approach: Scene models of scene descriptions, object features and spatial relations in a probabilistic formulation
- Benefit: Enables inference on unobserved objects, object classification and scene classification
- Experimental evaluation in the domain of airfields shows benefit of the scene model for object classification
- Implemented as part of an assistance system for interactive image interpretation
- Outlook
  - Modeling of spatial relations
  - Additional experiments (Harbors, Industrial Installations)
  - Learning of model parameters