Pattern Recognition Lecture
Summary, Applications, and Conclusions

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Institute for Vision and Graphics
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Topics

Date	**No**	**Topic**
17/04	PR01	Introduction and Outline
18/04	PR02	Feature Generation
02/05	PR03	Feature Selection
08/05	PR04	Linear Classifiers
15/05	PR05	Bayes Decision Theory
05/06	PR06	Context-Dependent Classification
06/06	PR07	Clustering Basics
26/06	PR08	Sequential Clustering
03/07	PR09	Hierarchical Clustering
10/07	PR10	Summary, Applications, and Conclusions

General Research Vision

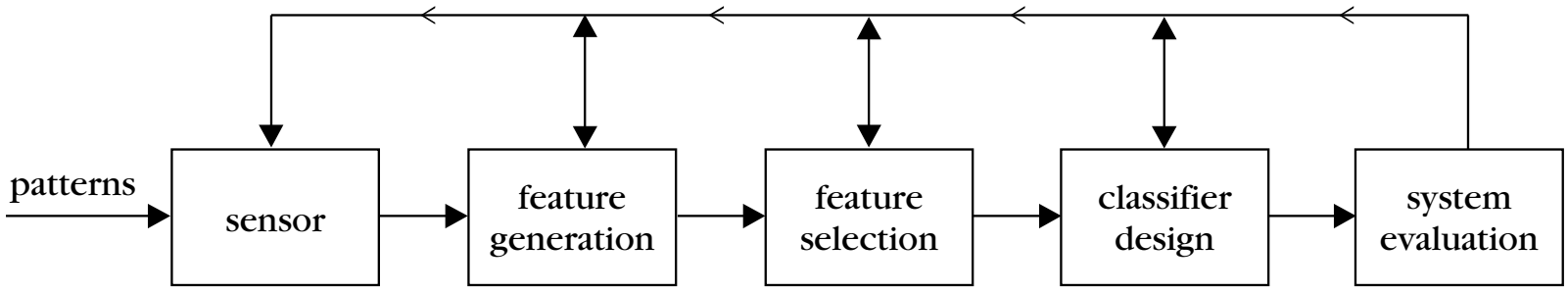
Adaptive Learning of Context

for Pattern Recognition

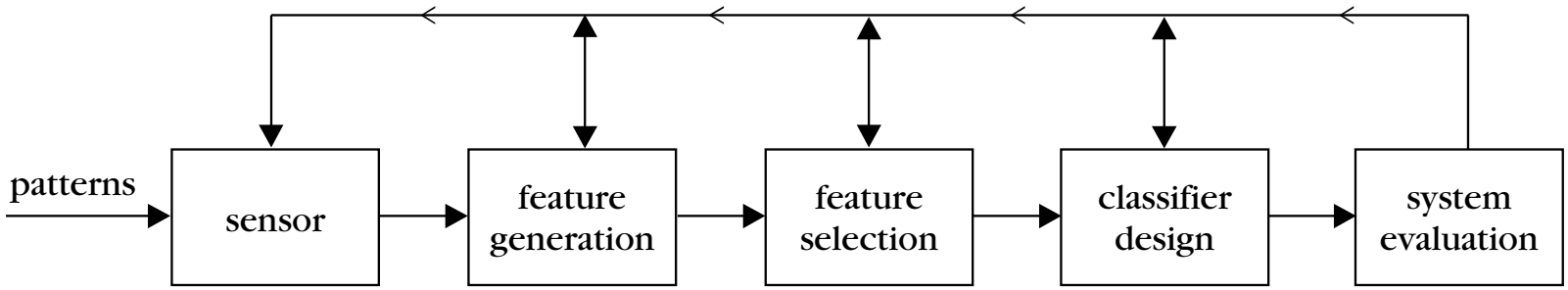
Overview

Overview

Basic Stages of Pattern Analysis

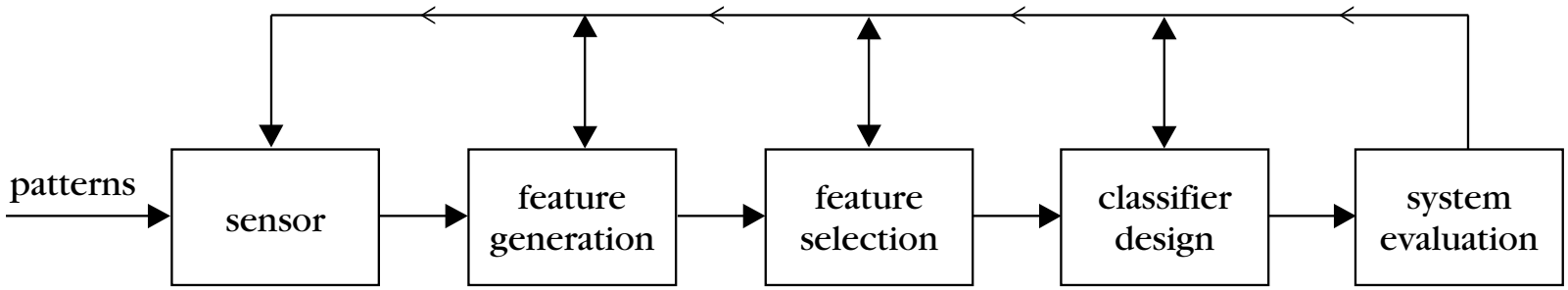


Basic Stages of Pattern Analysis



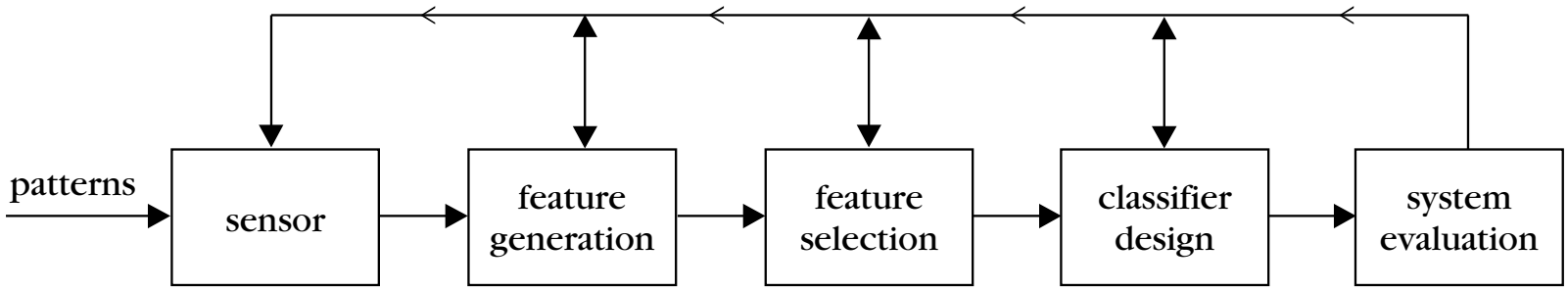
- Adaptive Runtime Optimisation

Basic Stages of Pattern Analysis



- Adaptive Runtime Optimisation
- Integration of Background Knowledge

Basic Stages of Pattern Analysis

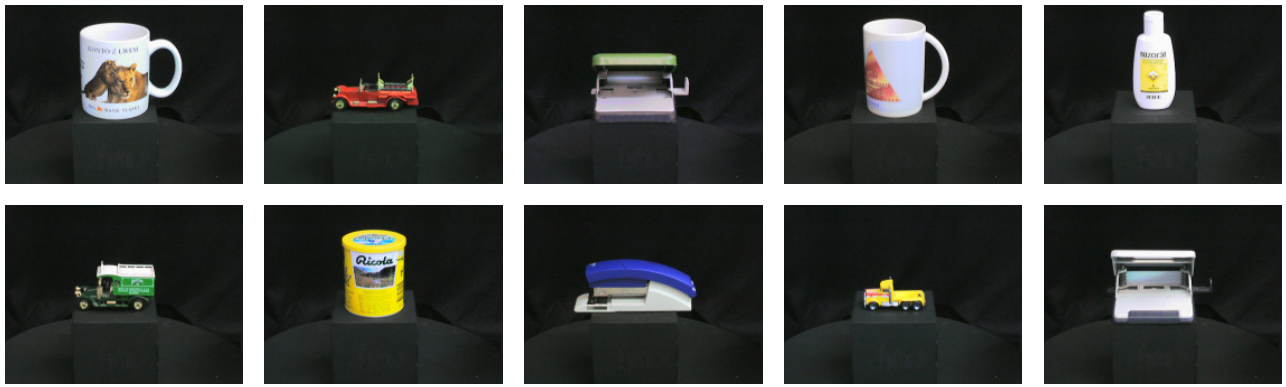


- **Adaptive Runtime Optimisation**
- Integration of Background Knowledge

Scientific Methods for Pattern Recognition

Example

- Generic Appearance-Based Statistical Object Recognition



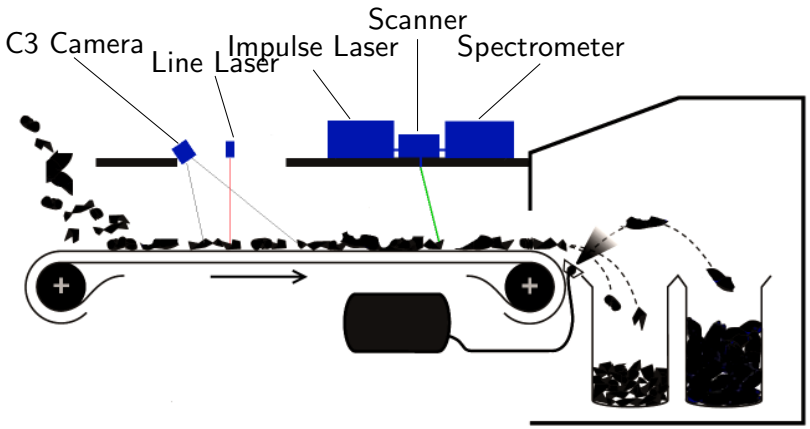
Properties

- Generic Methodology without Fixing the Application
- Limited Robustness in Real-World Environments

Industrial Systems for Pattern Recognition

Example

- Automatic Sorting of Aluminium Alloys



Properties

- Concrete Application Domain
- Problem-Specific Features
- Limited Portability

Adaptive Learning for Pattern Recognition

Development Phase

- Generic System for Pattern Recognition
- Multiple Sensors, Features, and Classifiers

Adaptive Learning for Pattern Recognition

Development Phase

- Generic System for Pattern Recognition
- Multiple Sensors, Features, and Classifiers

Supervision Phase

- Application for a Concrete Task
- Labelling of Misclassified Patterns by a Supervisor
- Adaptive Optimisation of the Processing Chain

Adaptive Learning for Pattern Recognition

Development Phase

- Generic System for Pattern Recognition
- Multiple Sensors, Features, and Classifiers

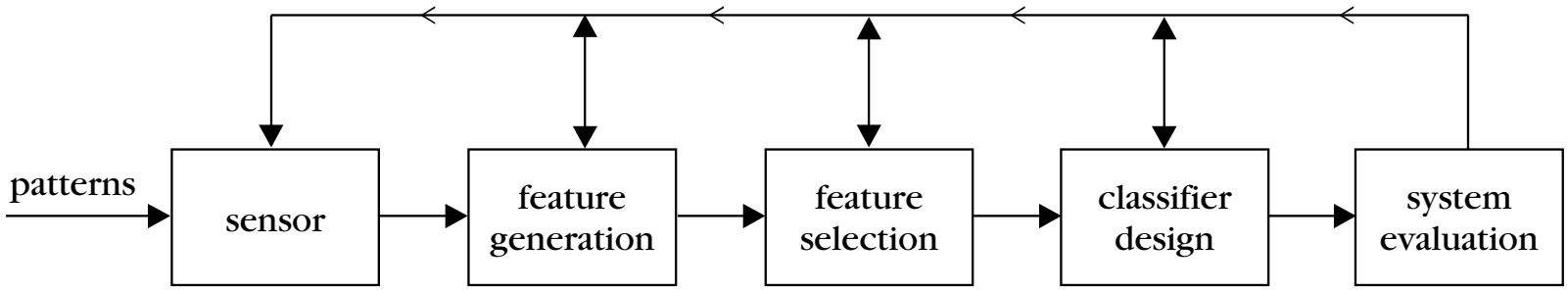
Supervision Phase

- Application for a Concrete Task
- Labelling of Misclassified Patterns by a Supervisor
- Adaptive Optimisation of the Processing Chain

Recognition Phase

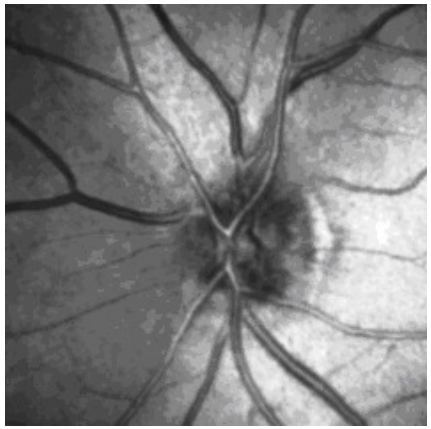
- Further Application without Supervision

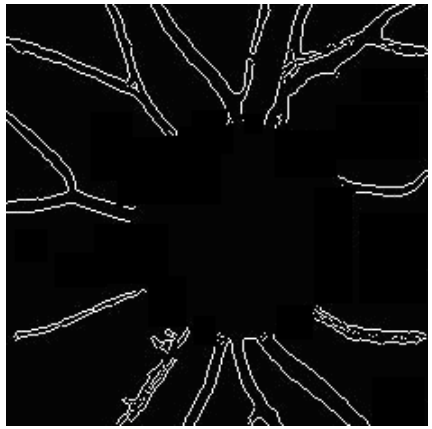
Basic Stages of Pattern Analysis



- Adaptive Runtime Optimisation
- **Integration of Background Knowledge**

Semantic Gap in Image Understanding





Background Knowledge

Semantic Image Description

Semantic Image Interpretation

Overview

Research Areas

Object Recognition

- Adaptive Learning of Context for Object Recognition
- Origin: Univ. of Erlangen-Nuremberg

Multimedia Retrieval

- Adaptive Learning of User Preferences based on Relevance Feedback
- Origin: Queen Mary, University of London

Image Understanding

- Integration of High-Level Background Knowledge from Ontologies into Low-Level Image Processing
- Origin: University of Koblenz-Landau

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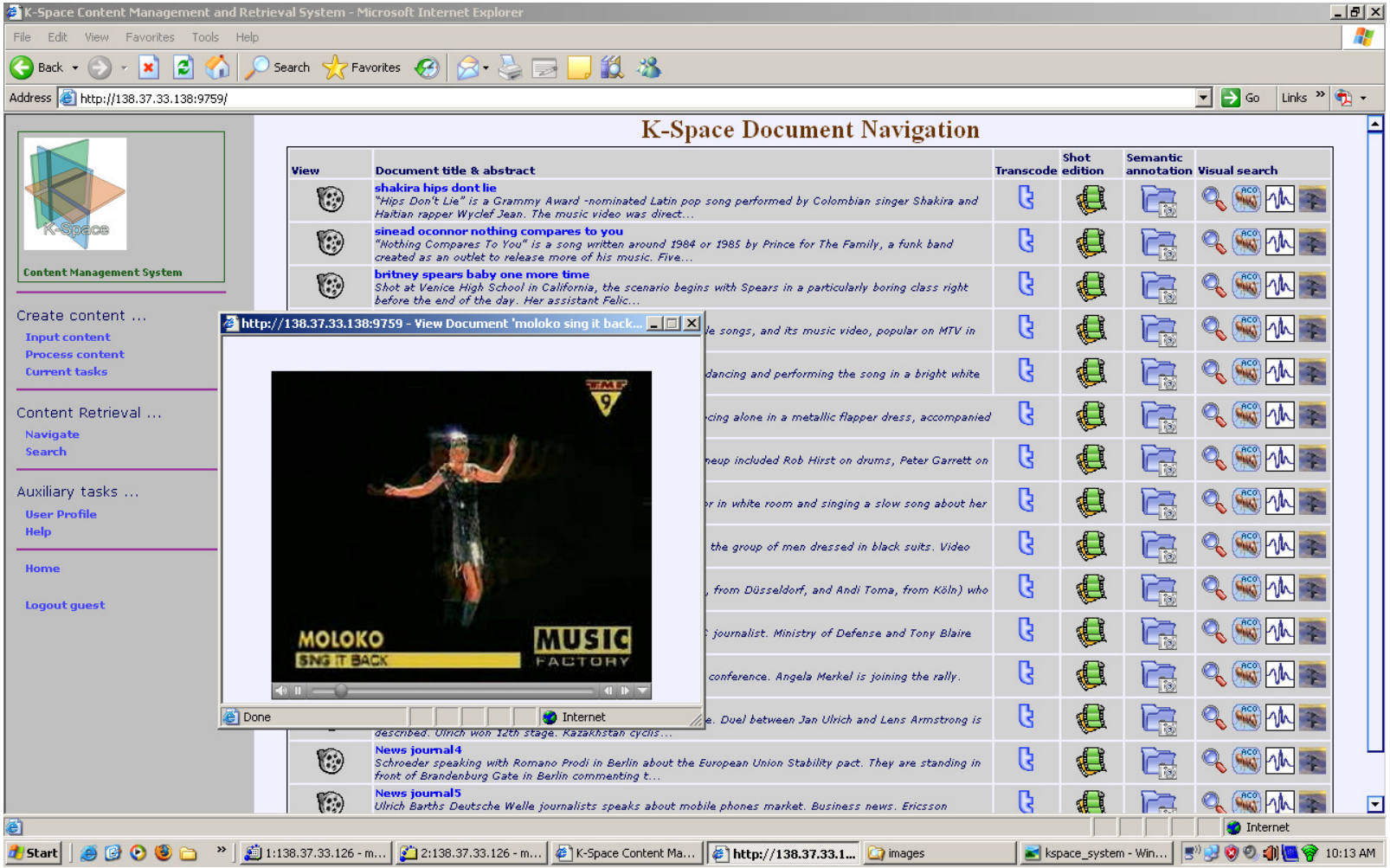
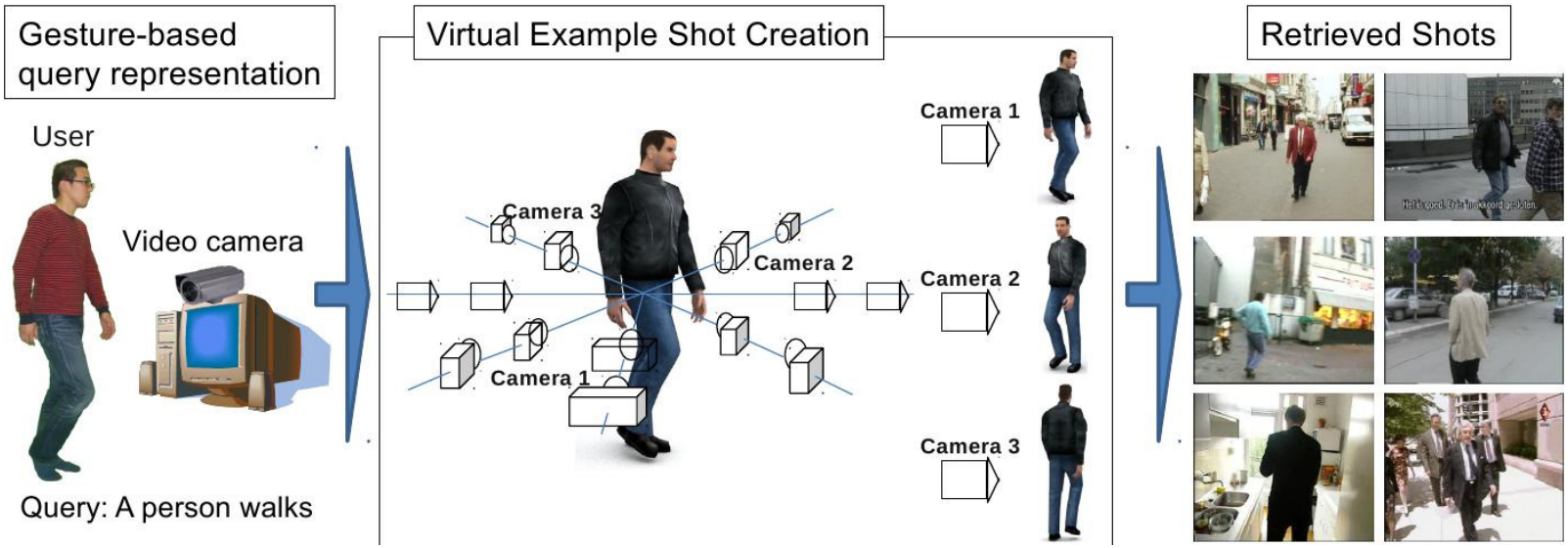
Multimedia Content Management and Retrieval



Query by Virtual Gesture



- Background Knowledge Integration by Domain Ontology
- Adaptive Optimisation by Relevance Feedback

Research Areas

Object Recognition

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Multimedia Retrieval

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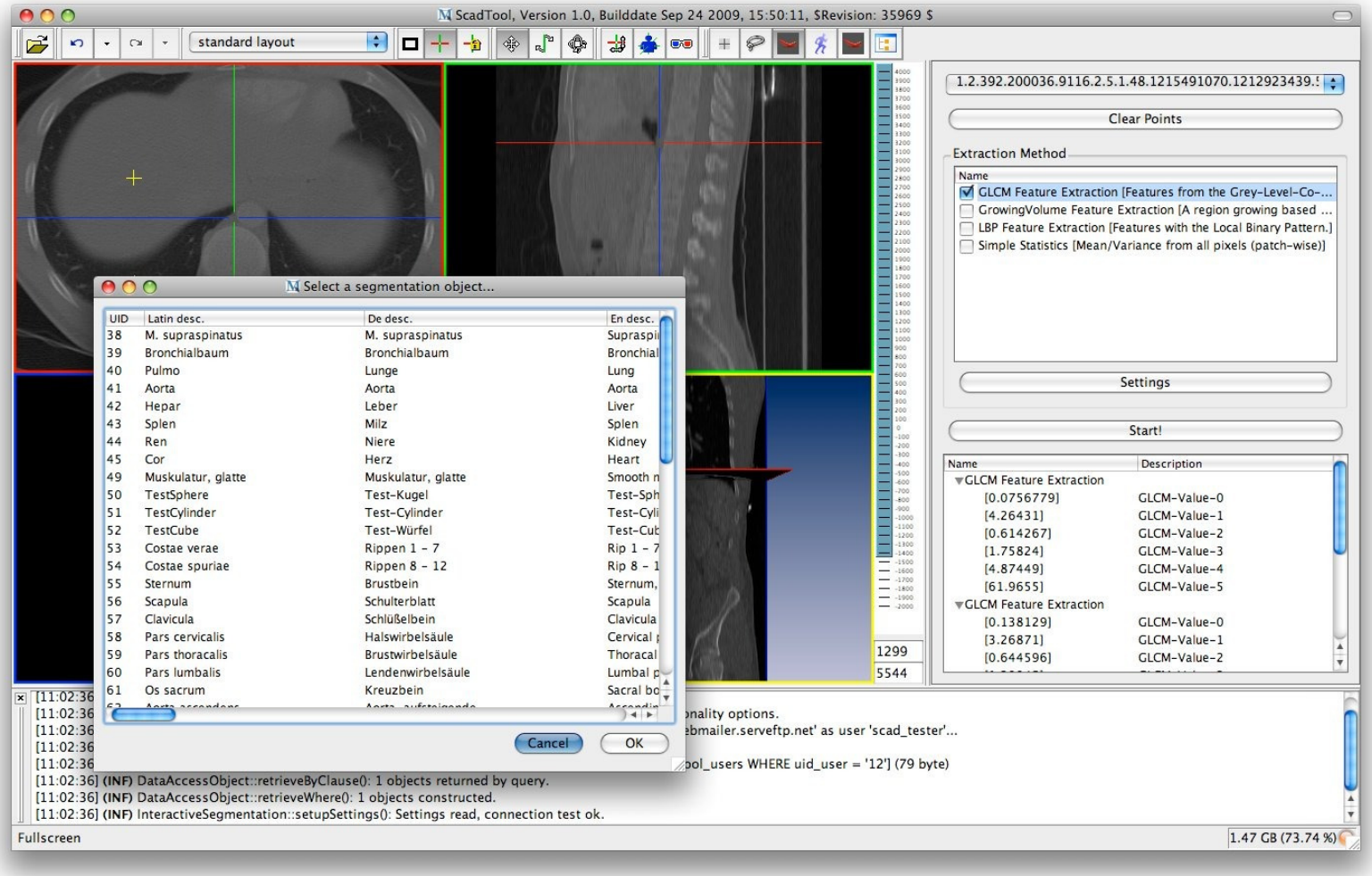
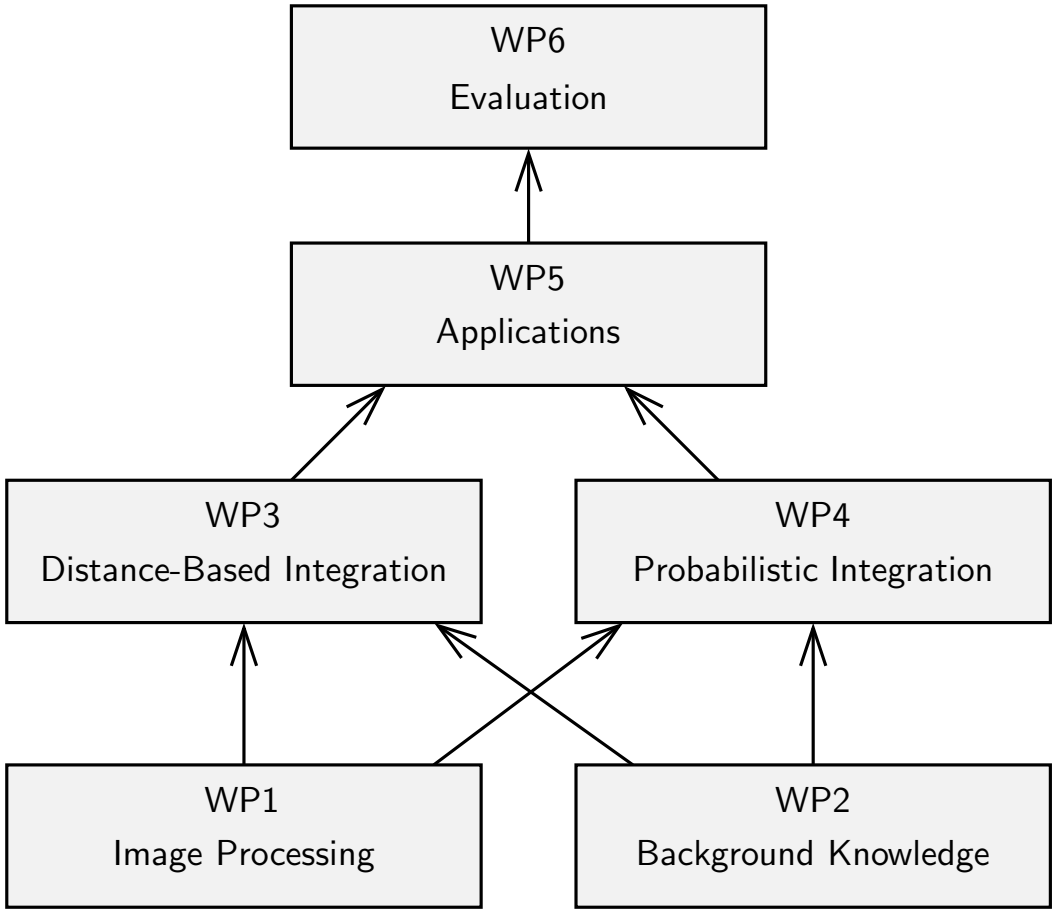
Spacial Reasoning for Medical Image Classification

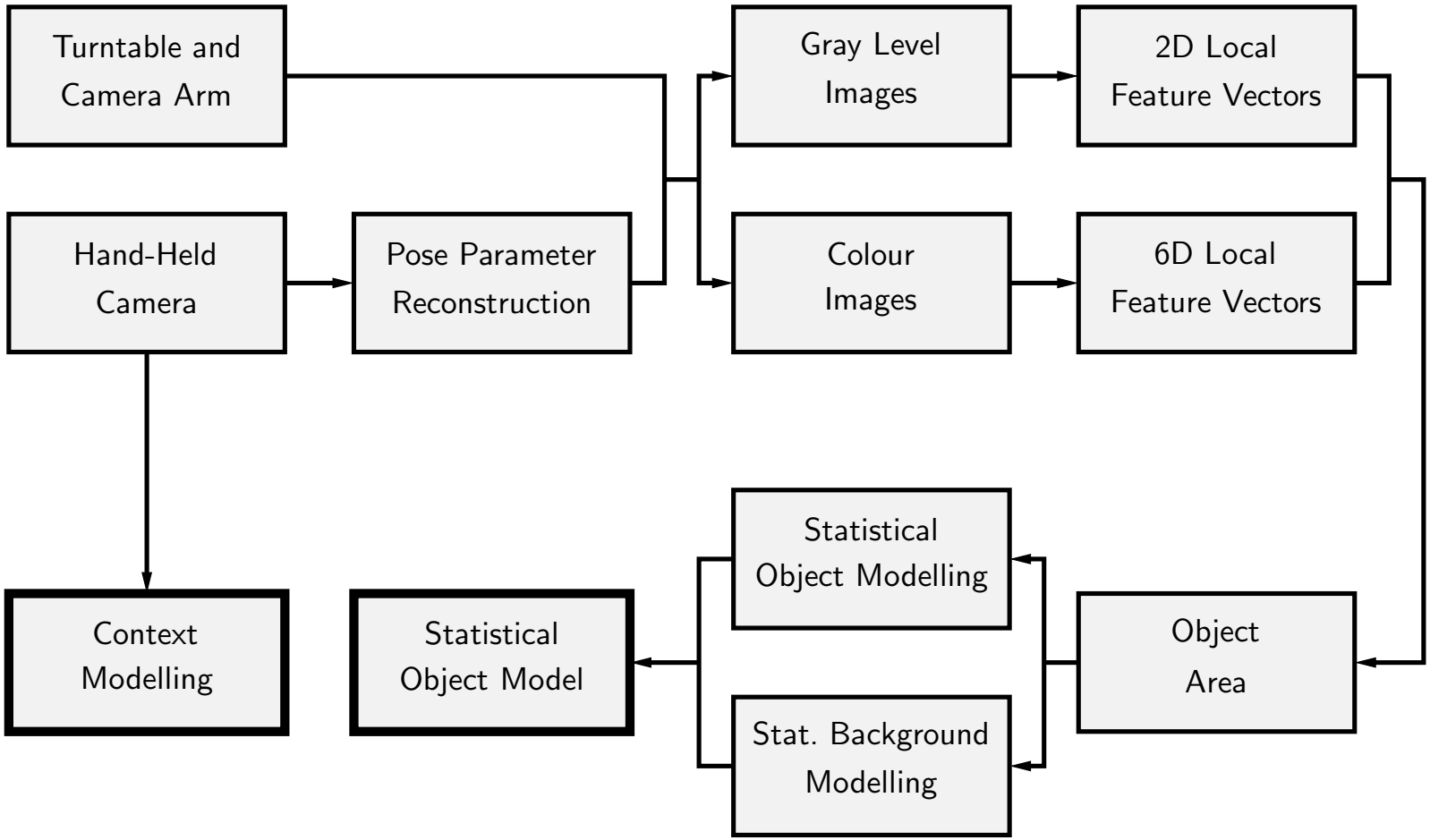


Knowledge-Based Image Understanding

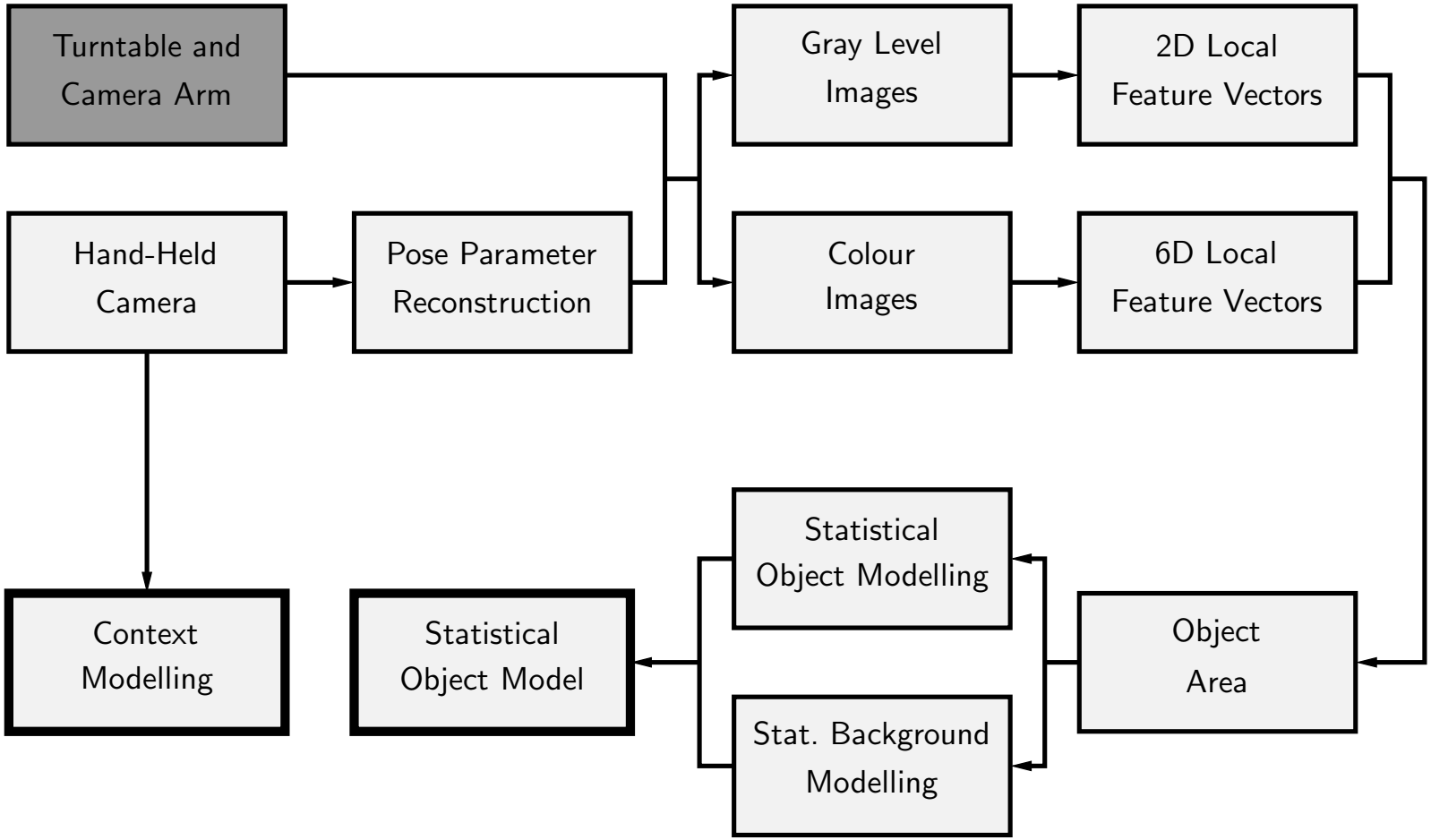


Overview

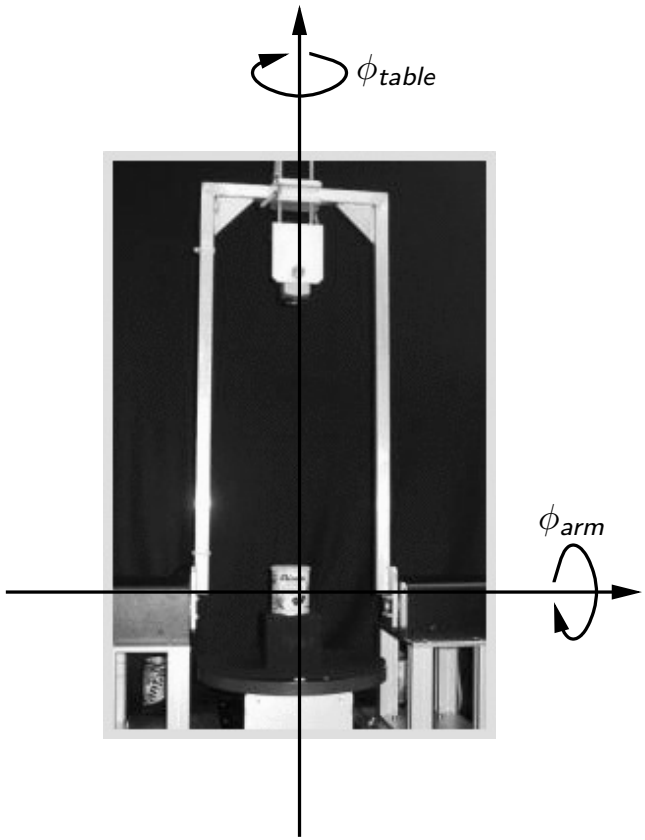
Training Phase

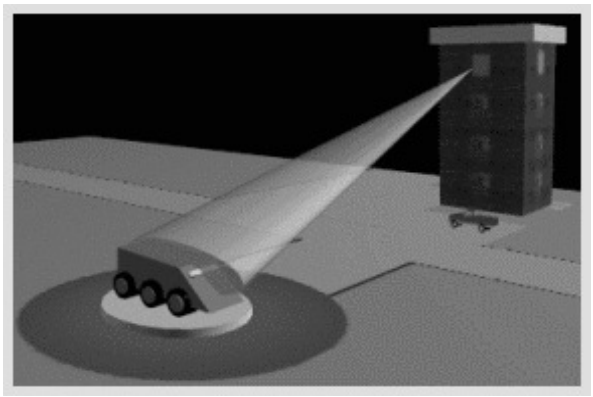


Turntable and Camera Arm



Turntable and Camera Arm



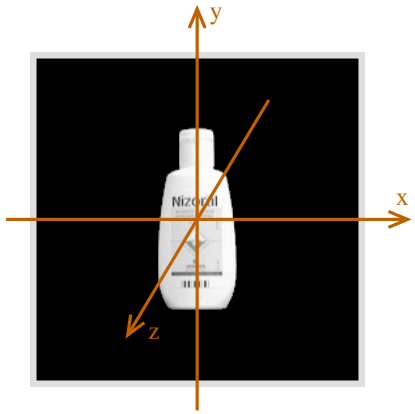


Object poses $(\phi_\rho, \mathbf{t}_\rho)$ for all N_ρ training images $\mathbf{f}_{\rho=1,\ldots,N_\rho}$ are known.

Object Pose

$\mathbf{t}_{int} = (t_x, t_y)^\mathsf{T}$

$\phi_{int} = \phi_z$



$\mathbf{t} = (t_x, t_y, t_z)^\mathsf{T} = (0, 0, 100)^\mathsf{T}$

$\phi = (\phi_x, \phi_y, \phi_z)^\mathsf{T} = (0, 0, 0)^\mathsf{T}$

$\mathbf{t} = (50, 25, 100)^\mathsf{T}$

$\phi = (0, 0, 0)^\mathsf{T}$

$\mathbf{t} = (50, 25, 100)^\mathsf{T}$

$\phi = (0, 0, -30)^\mathsf{T}$

$t_{ext} = t_z$

$\phi_{ext} = (\phi_x, \phi_y)^\mathsf{T}$

$\mathbf{t} = (0, 0, 100)^\mathsf{T}$

$\phi = (22.5, 0, 0)^\mathsf{T}$

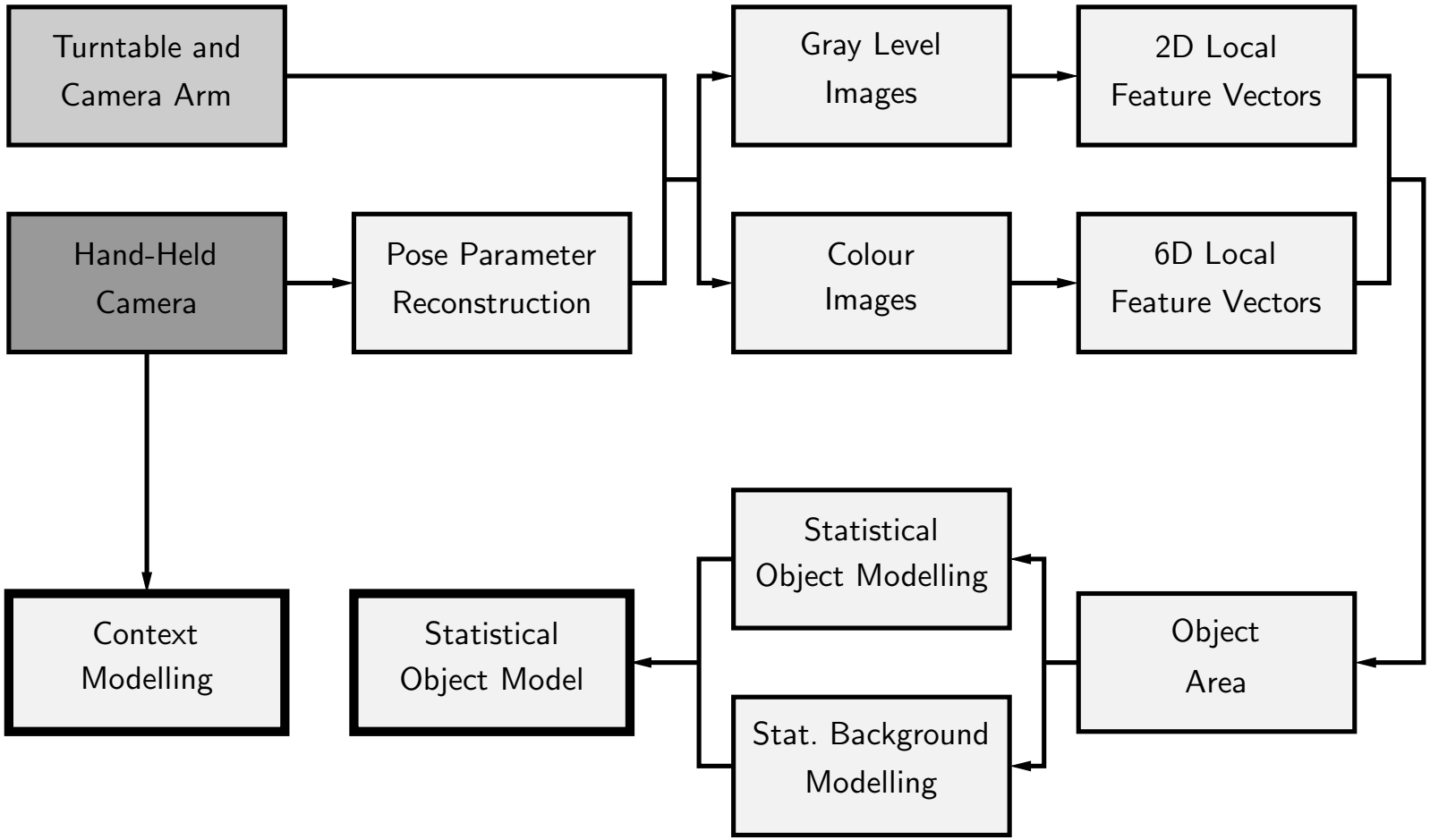
$\mathbf{t} = (0, 0, 100)^\mathsf{T}$

$\phi = (0, 45, 0)^\mathsf{T}$

$\mathbf{t} = (0, 0, 80)^\mathsf{T}$

$\phi = (0, 0, 0)^\mathsf{T}$

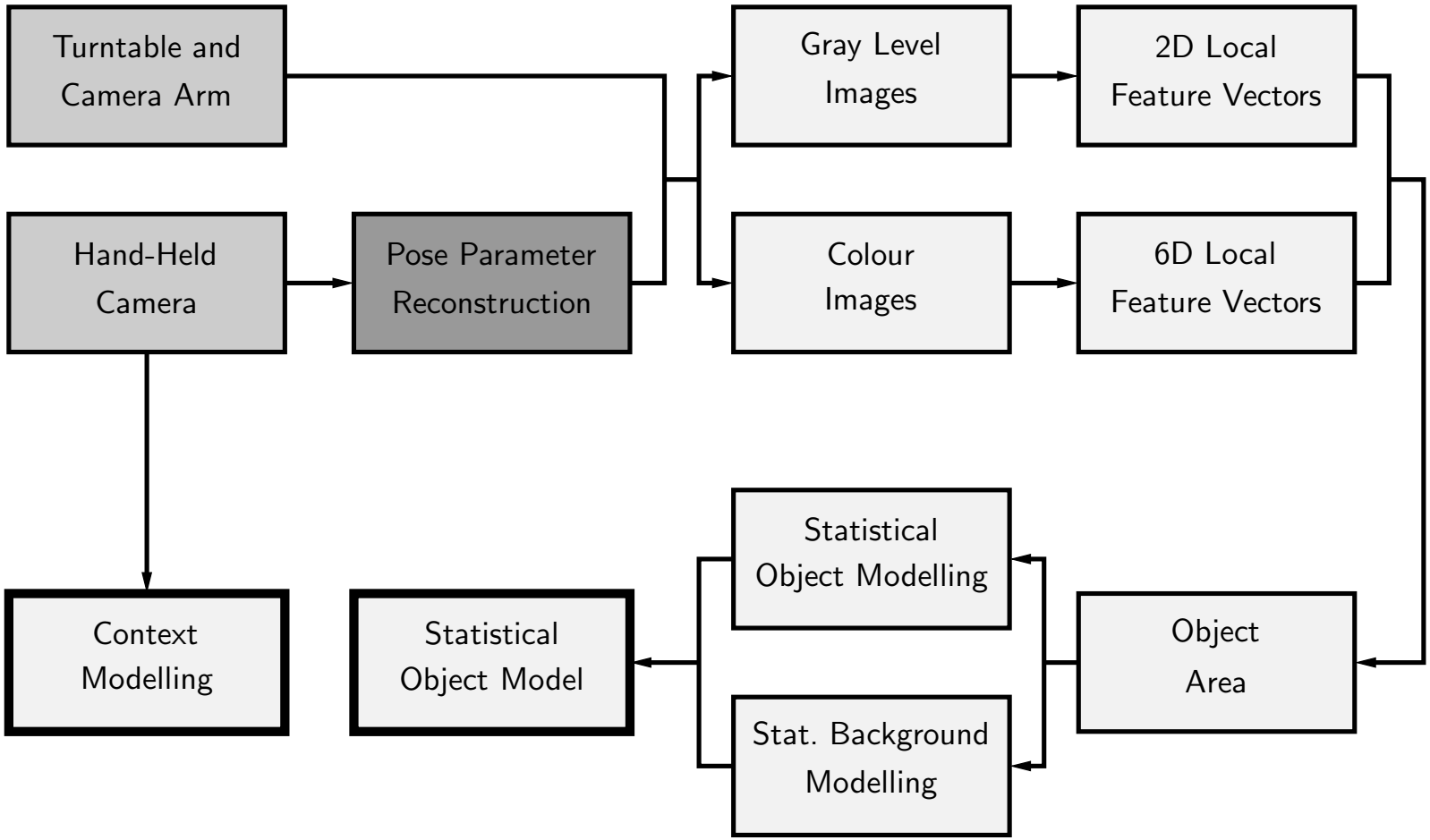
Hand-Held Camera



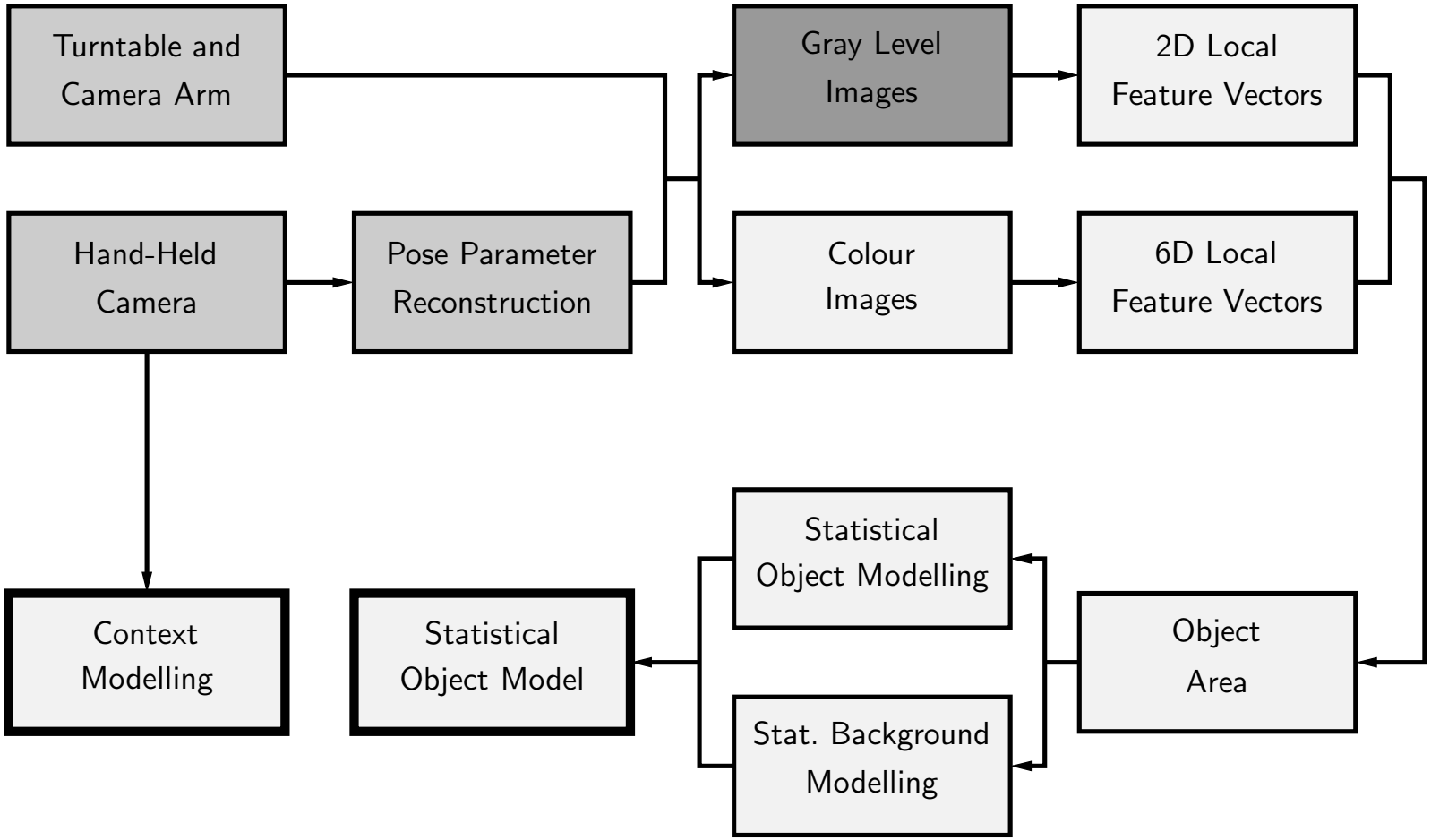
Hand-Held Camera

Object poses $(\phi_\rho, \mathbf{t}_\rho)$ for the training images $\mathbf{f}_\rho$ are unknown.

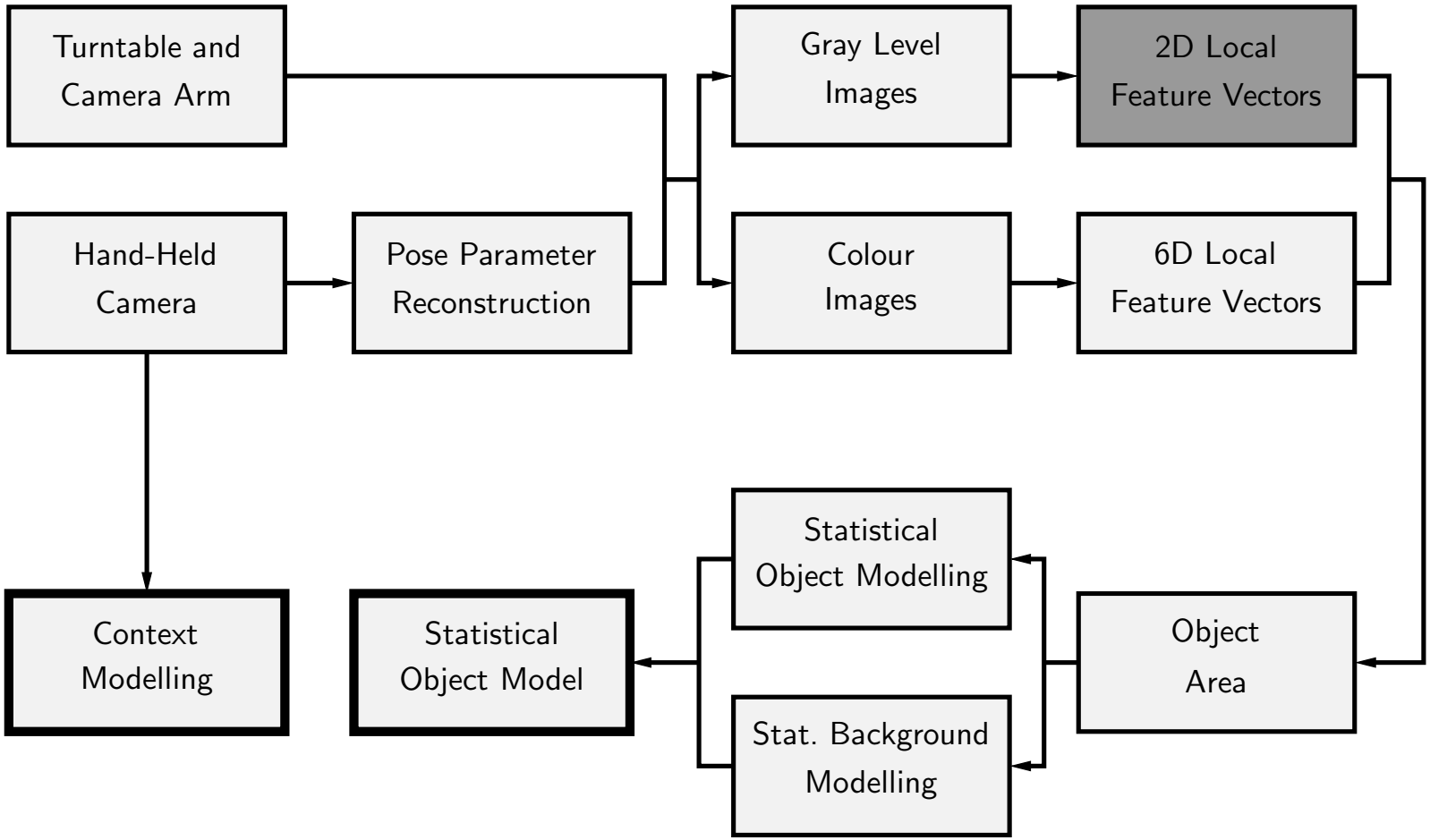
Pose Parameter Reconstruction



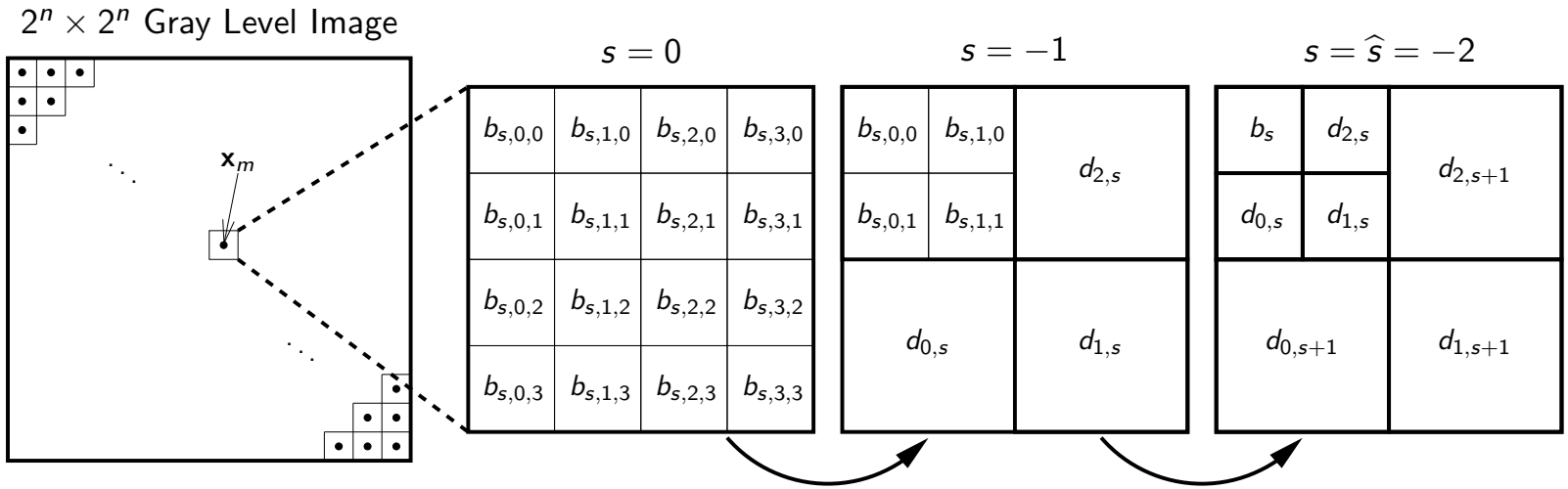
Grey Level Images



2D Local Feature Vectors

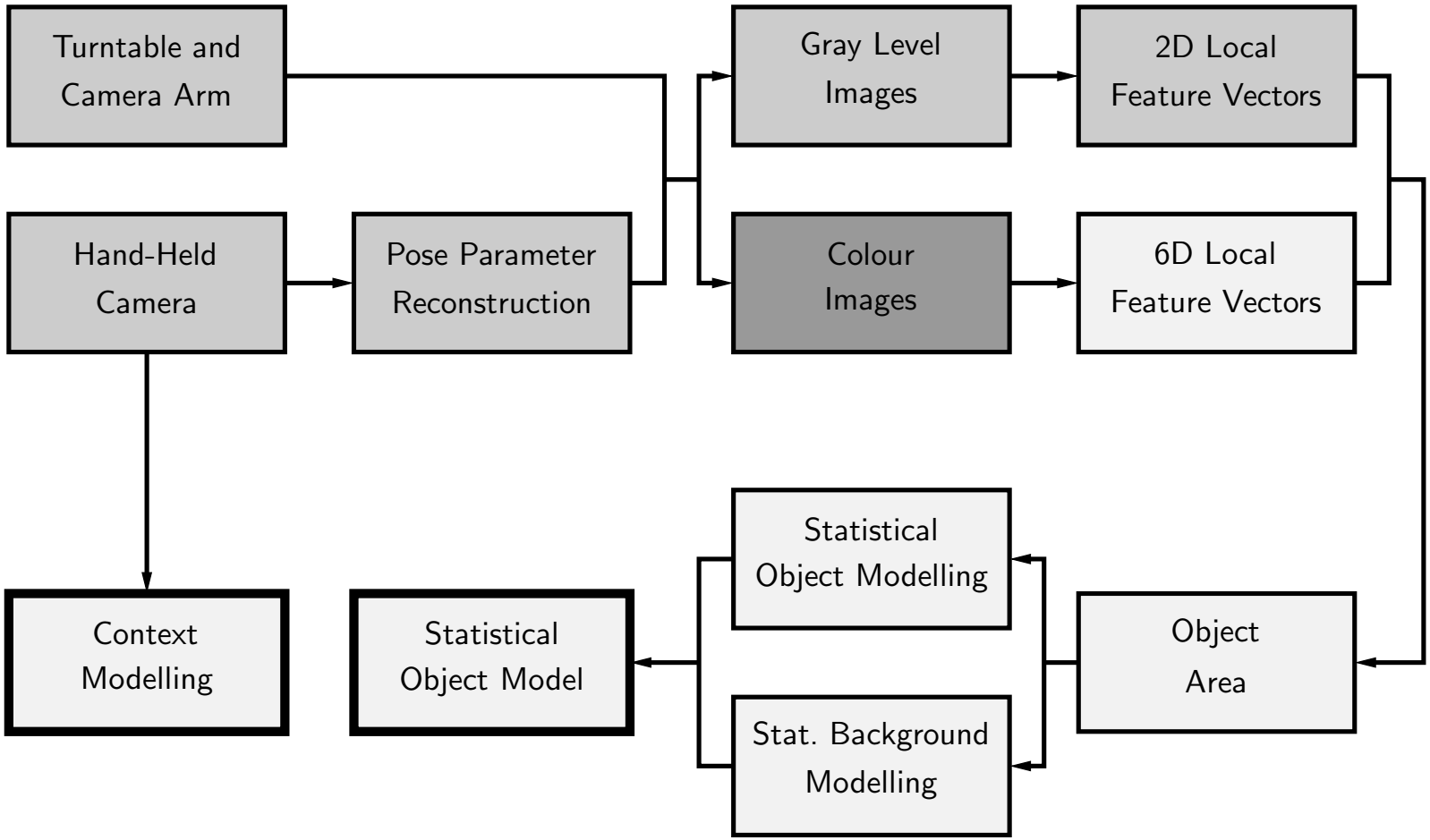


2D Feature Extraction with Wavelet Transform

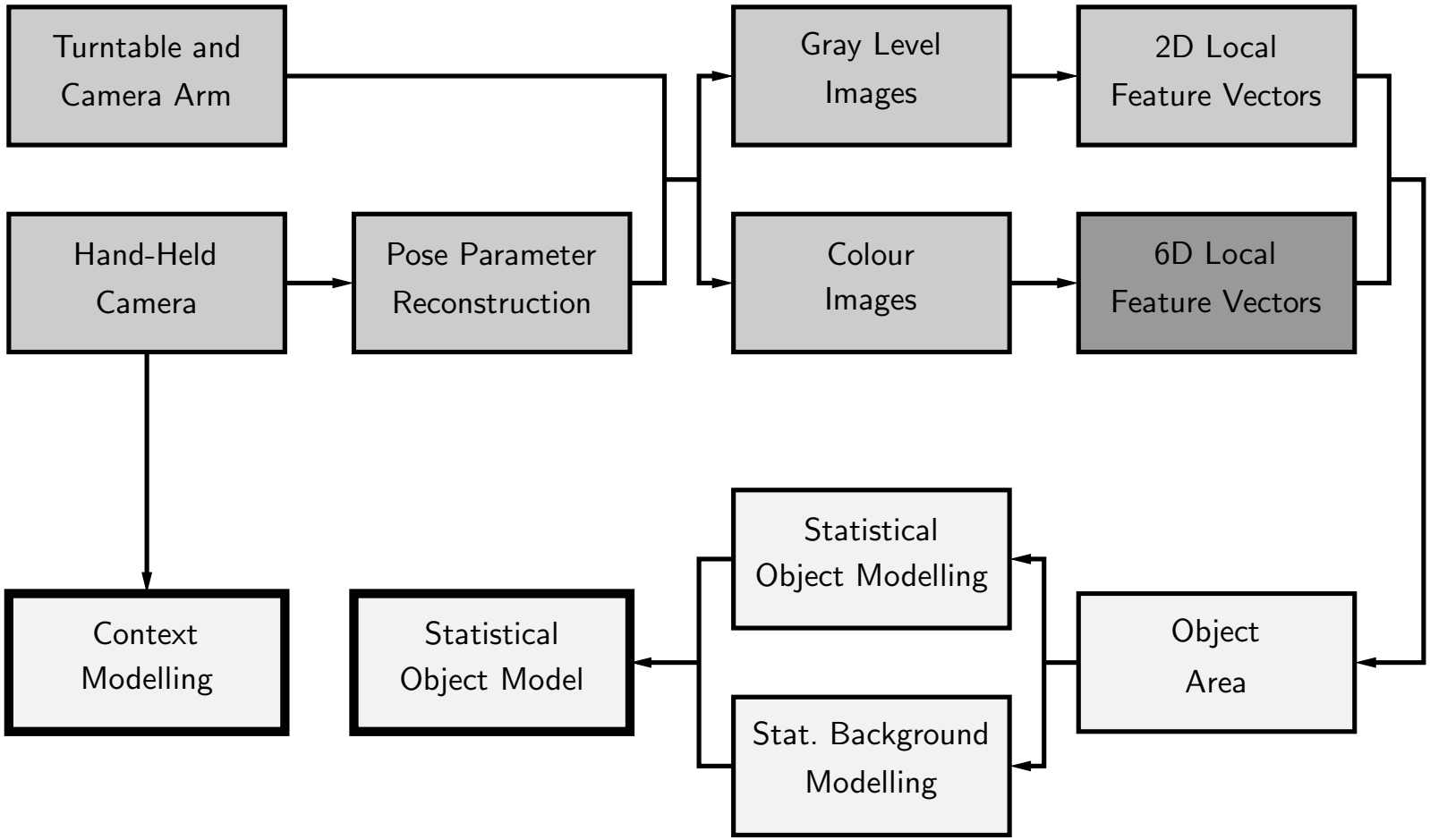


$$\mathbf{c}_m = \mathbf{c}(\mathbf{x}_m) = \begin{pmatrix} c_{m,1} \\ c_{m,2} \end{pmatrix} = \begin{pmatrix} \ln(2^s|b_s|) \\ \ln[2^s(|d_{0,s}| + |d_{1,s}| + |d_{2,s}|)] \end{pmatrix}$$

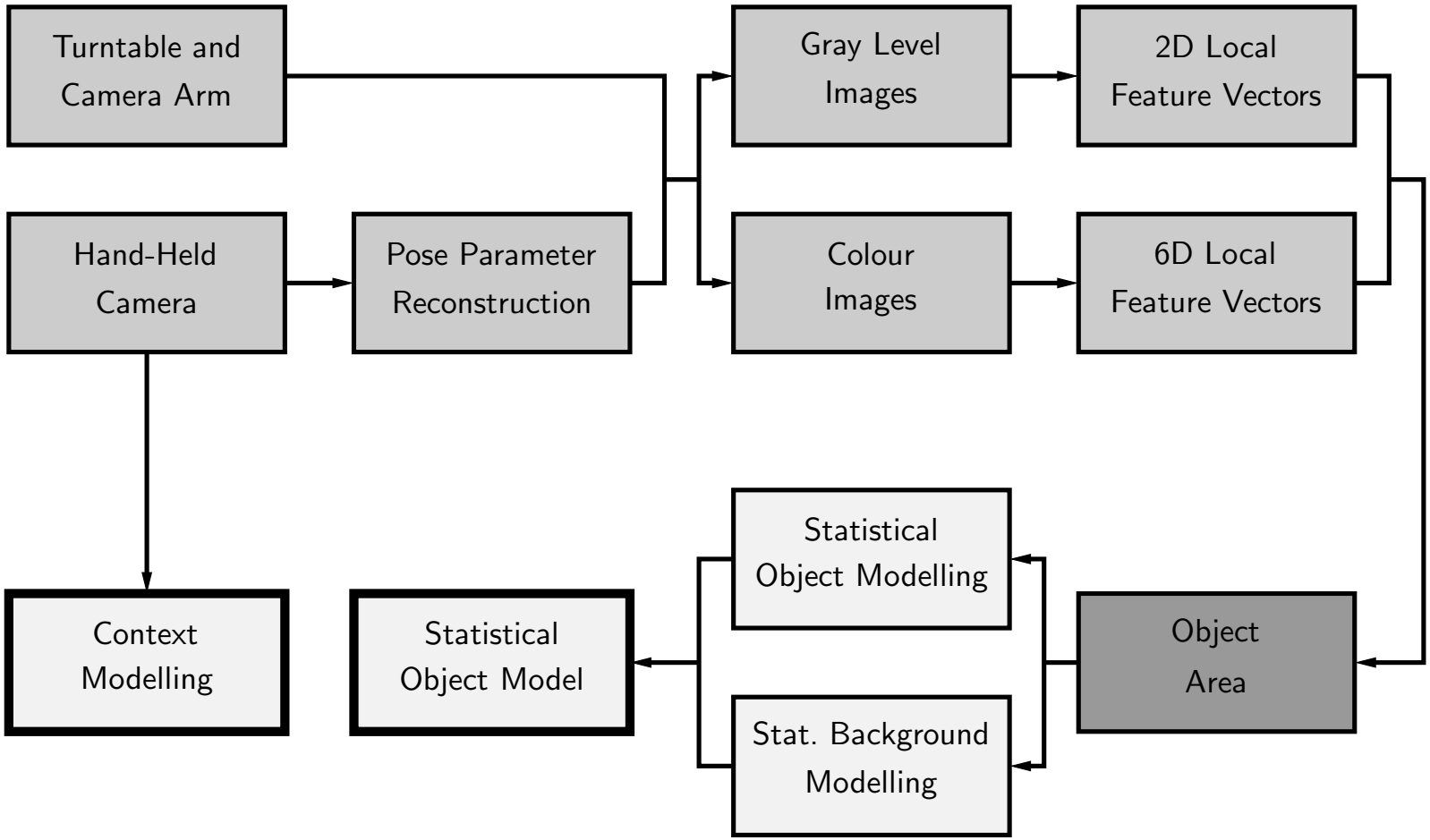
Colour Images



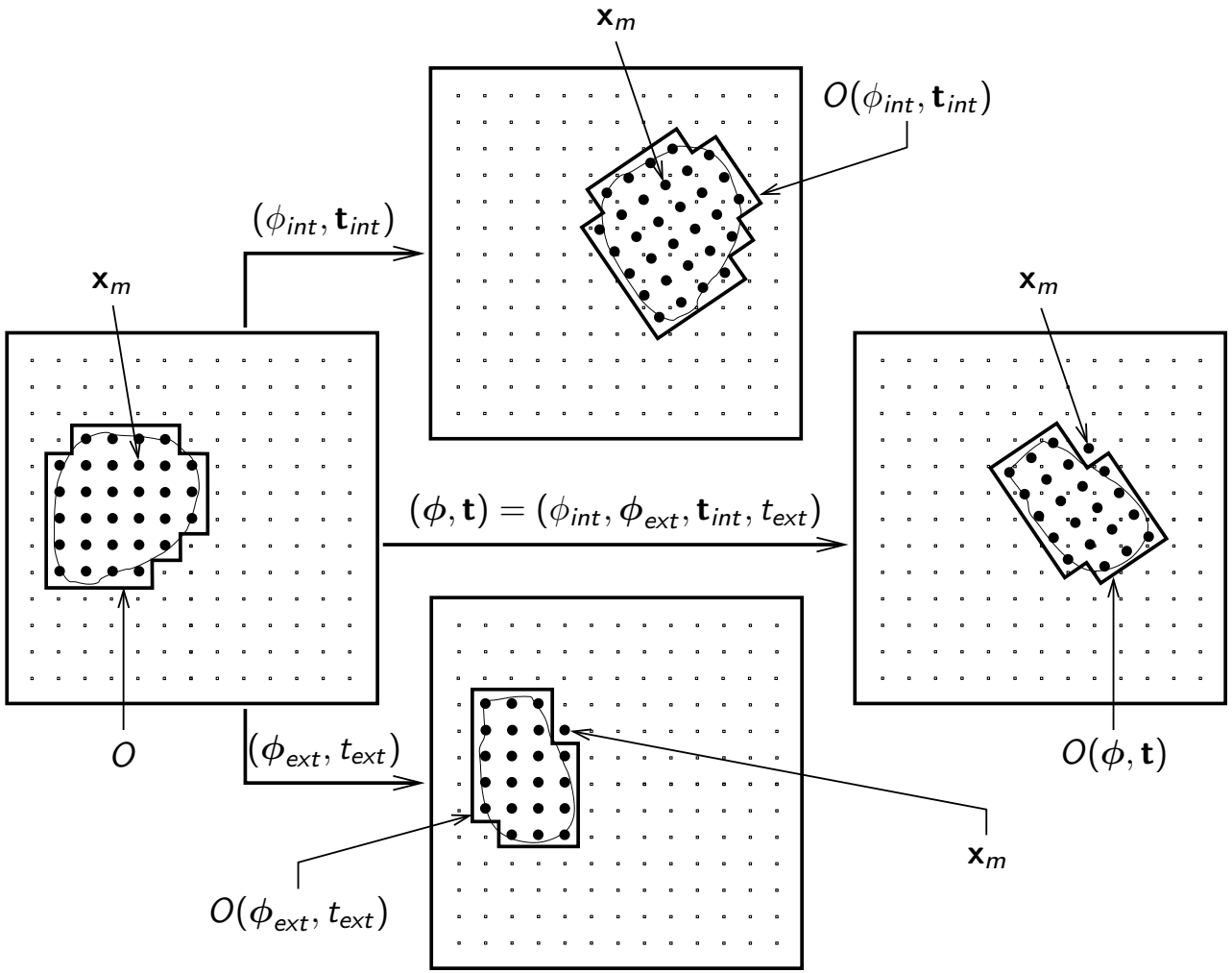
6D Local Feature Vectors



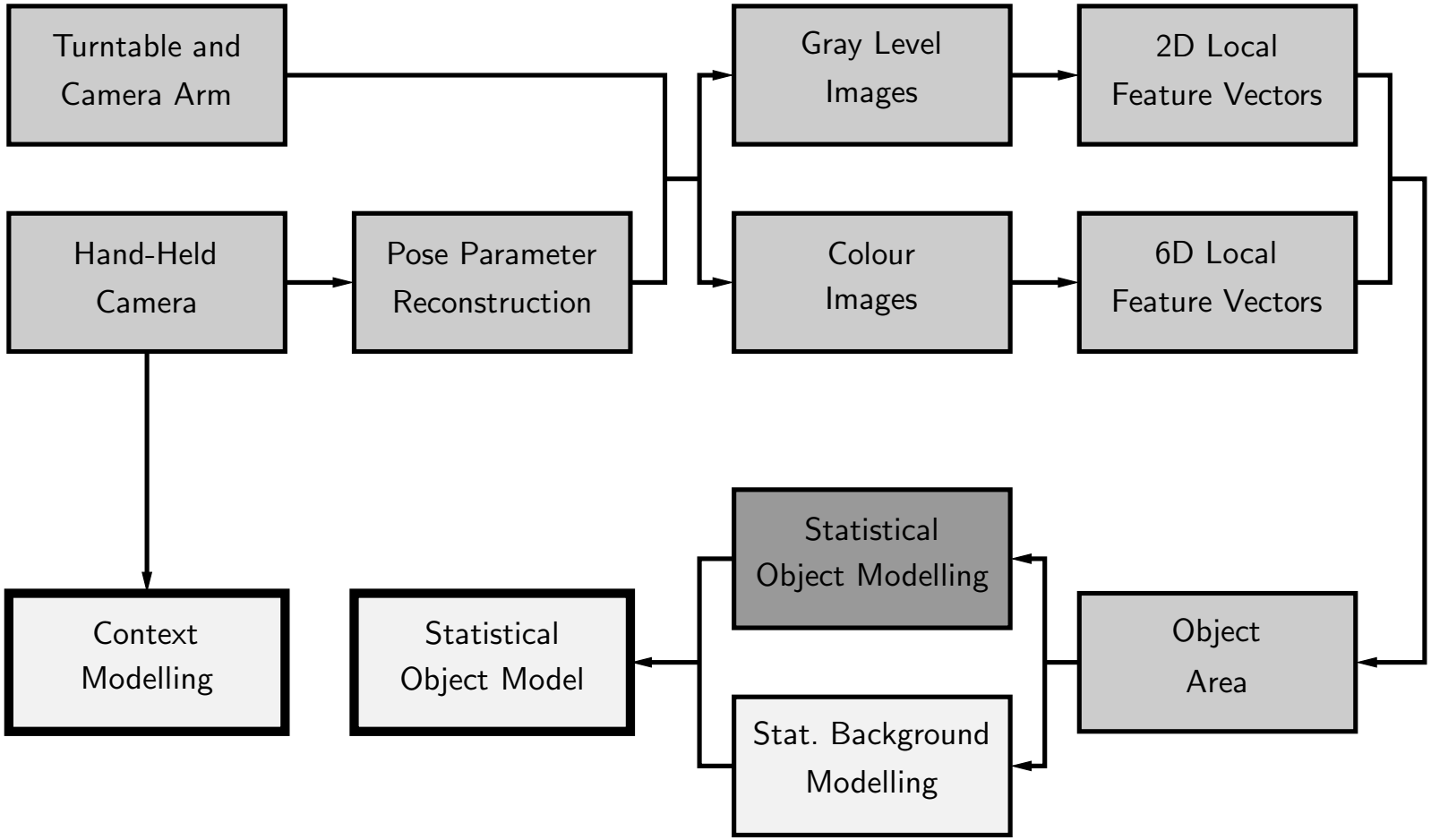
Object Area



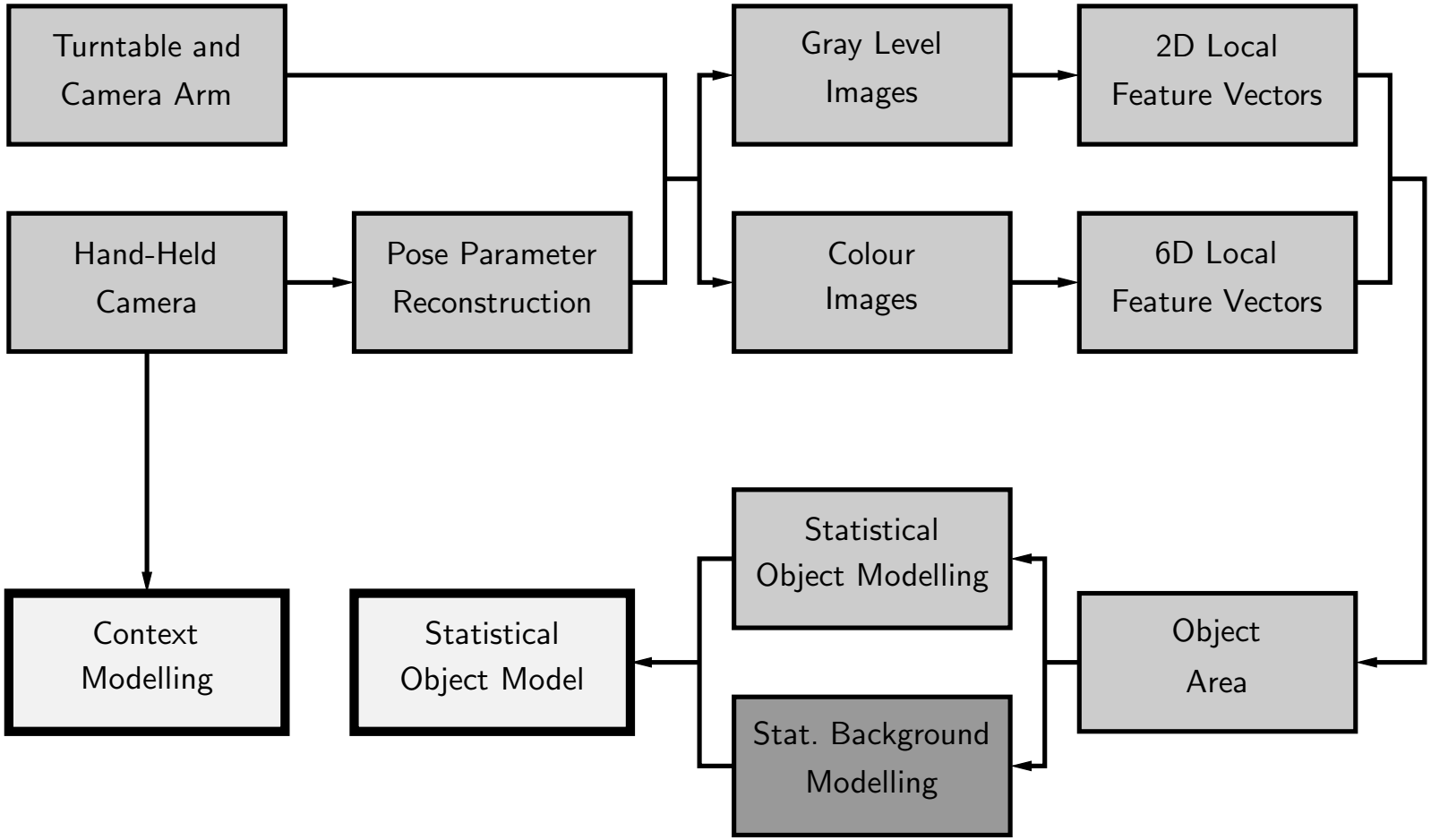
Object Area $O = O(\phi, \mathbf{t})$



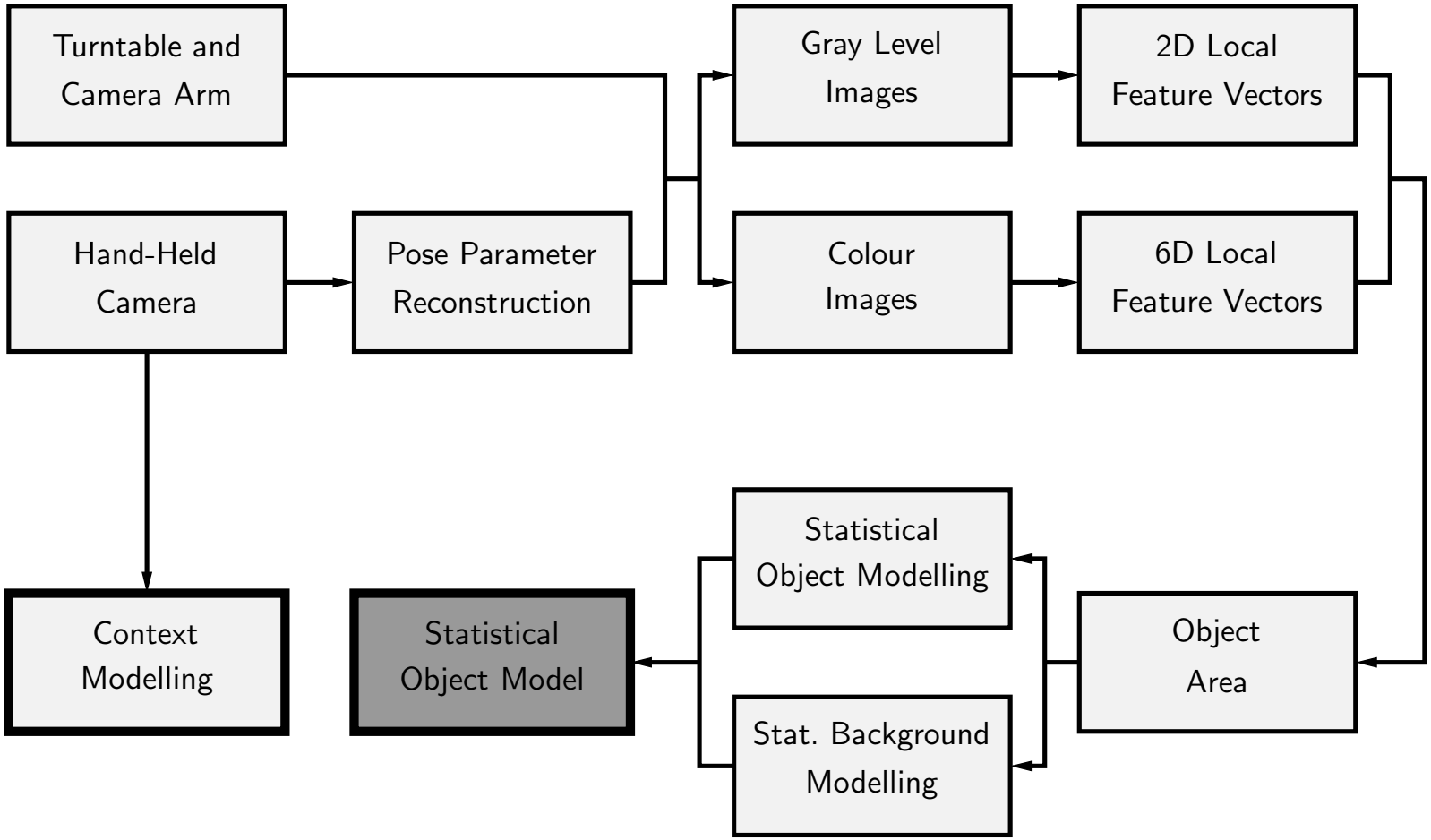
Statistical Object Modelling



Statistical Background Modelling



Statistical Object Model

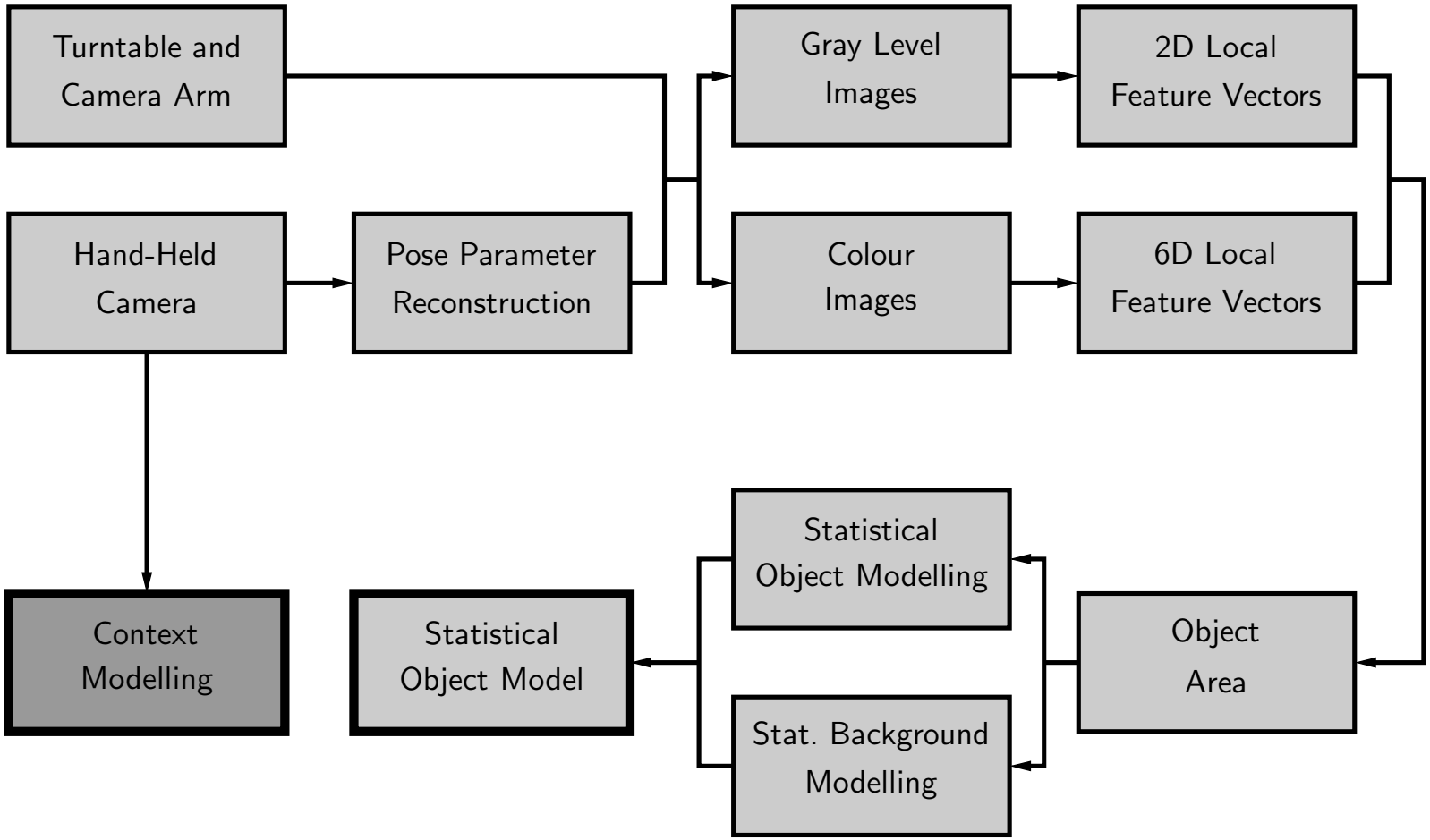


Statistical Object Model - Summary

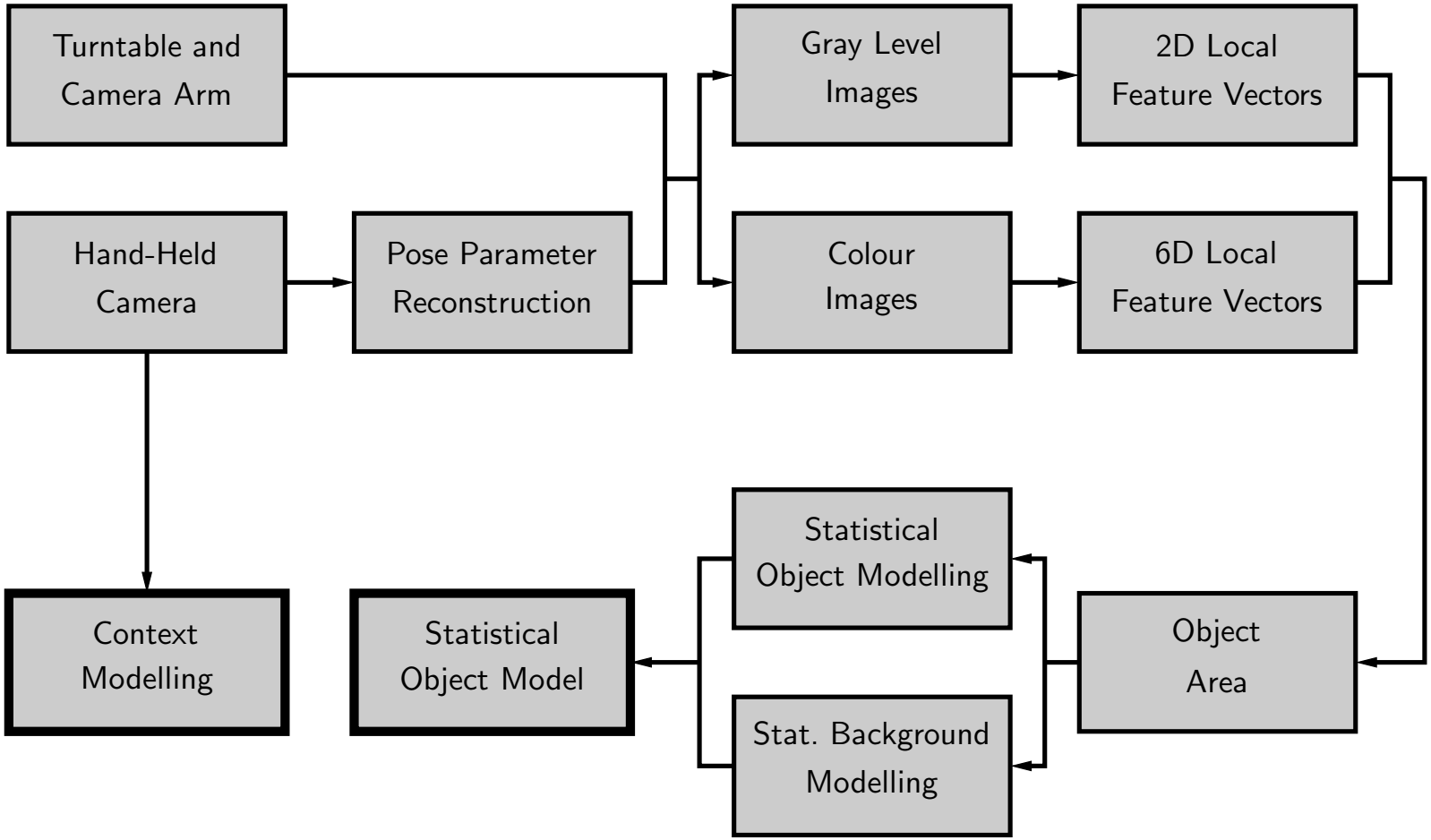
$$\Omega_\kappa \quad \longrightarrow \quad \mathcal{M}_\kappa = \mathcal{M}_\kappa(\boldsymbol{\phi}, \mathbf{t})$$

1. Object Area $O_\kappa = O_\kappa(\boldsymbol{\phi}, \mathbf{t})$
2. Densities for Object Features $p(\mathbf{c}_m) = p(\mathbf{c}_m | \boldsymbol{\mu}_m, \boldsymbol{\sigma}_m, \boldsymbol{\phi}, \mathbf{t})$
3. Densities for Background Features $p(\mathbf{c}_m) = p_b$

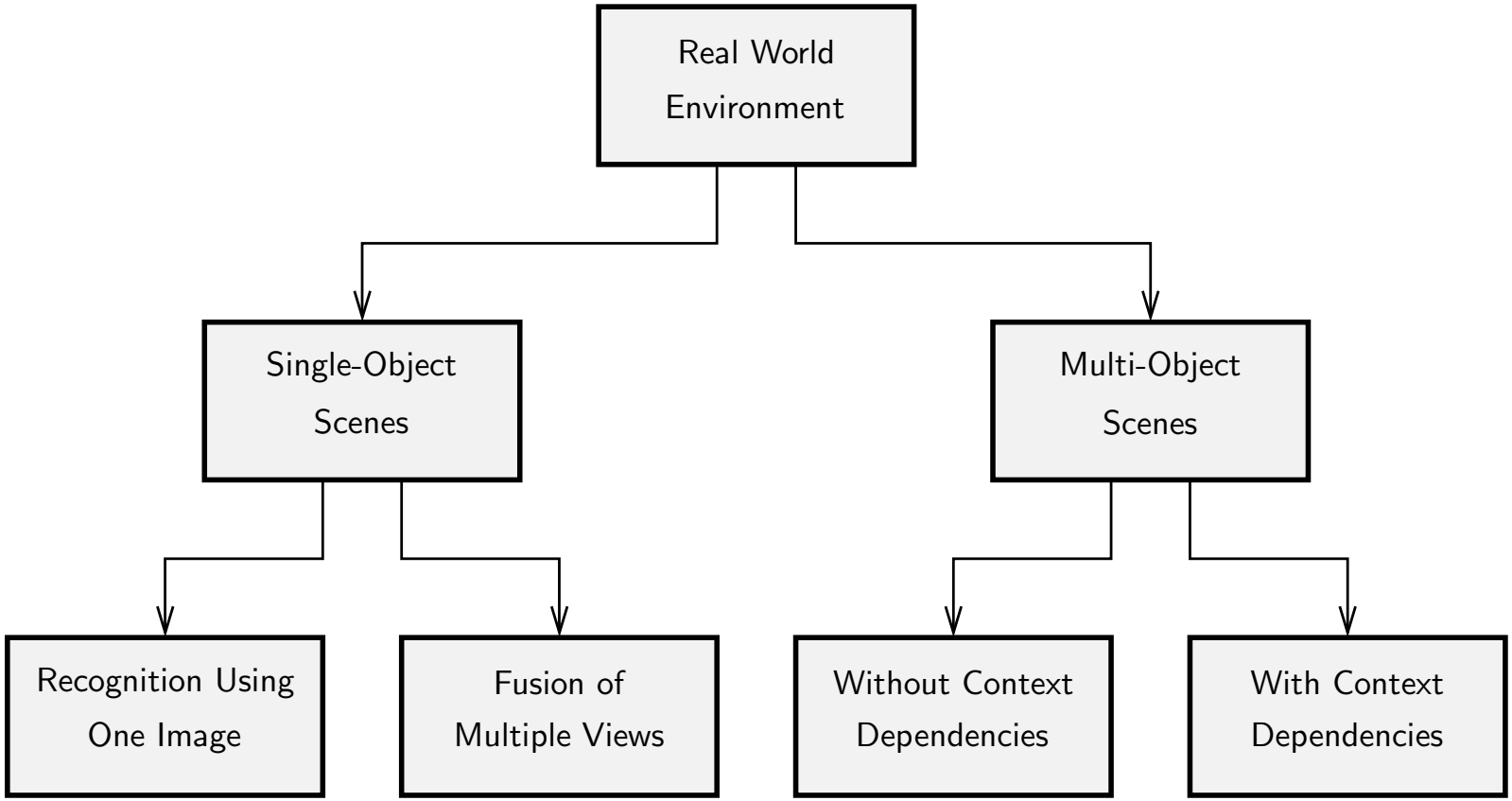
Context Modelling



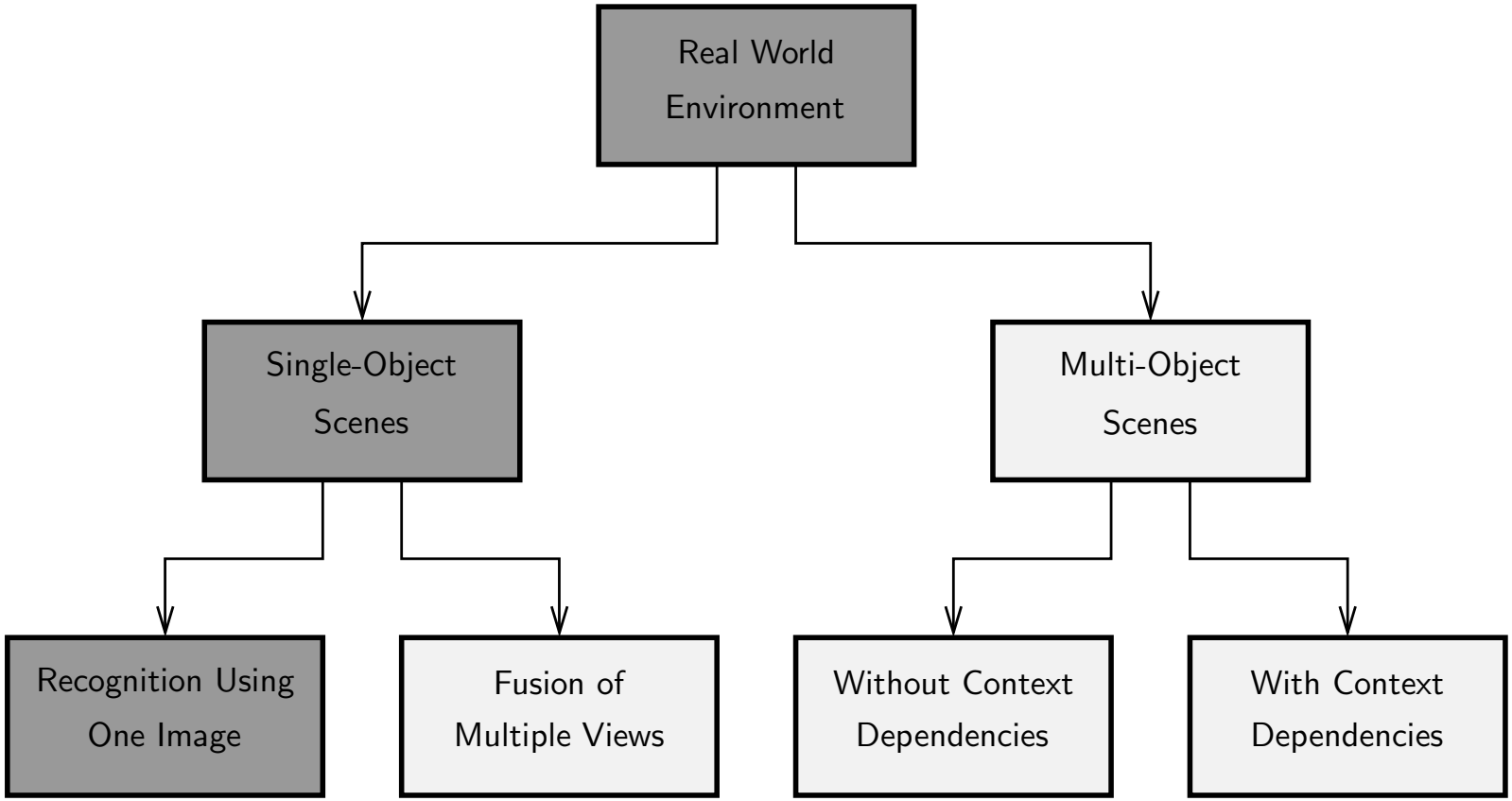
Training Phase Completed



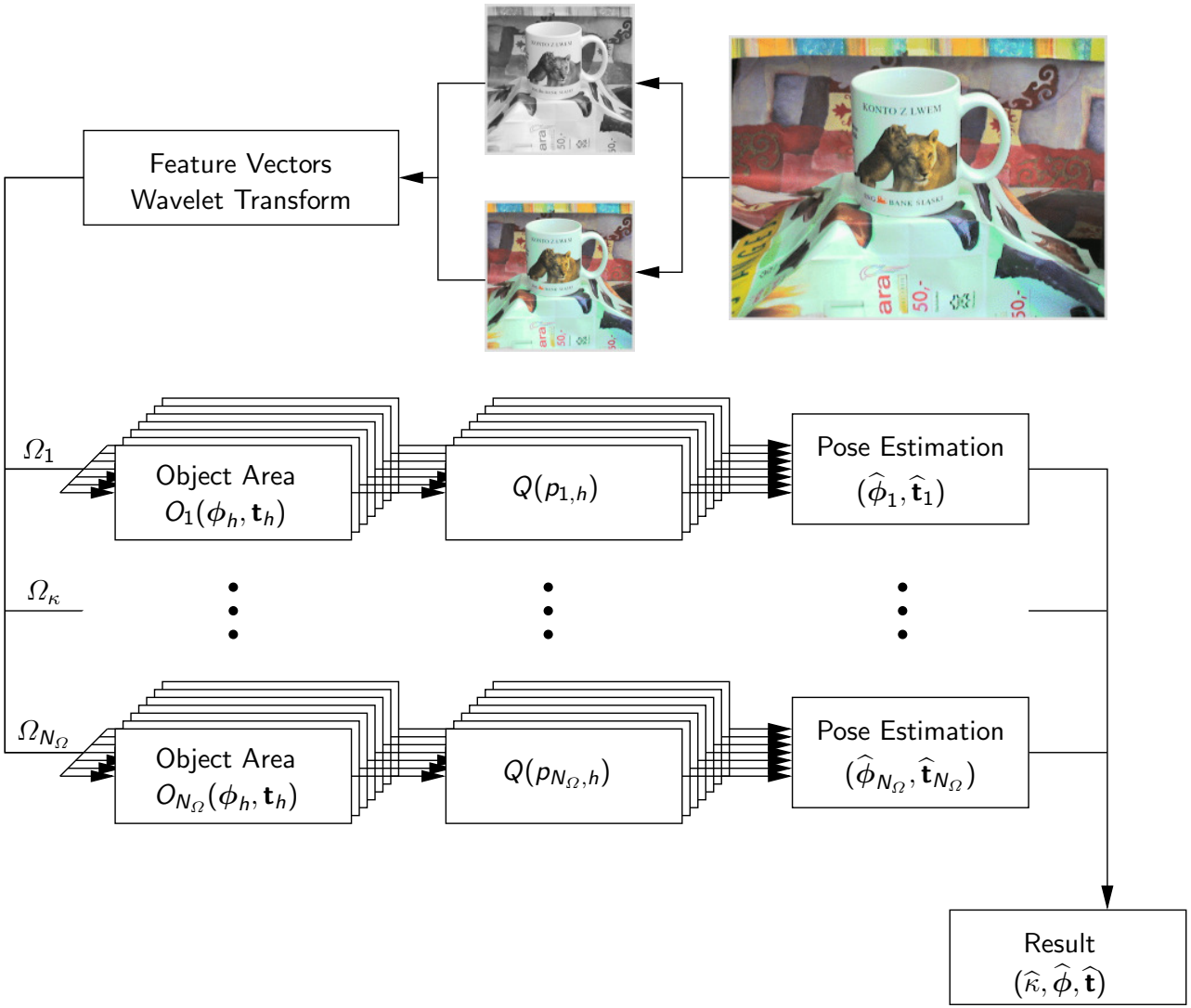
Recognition Phase



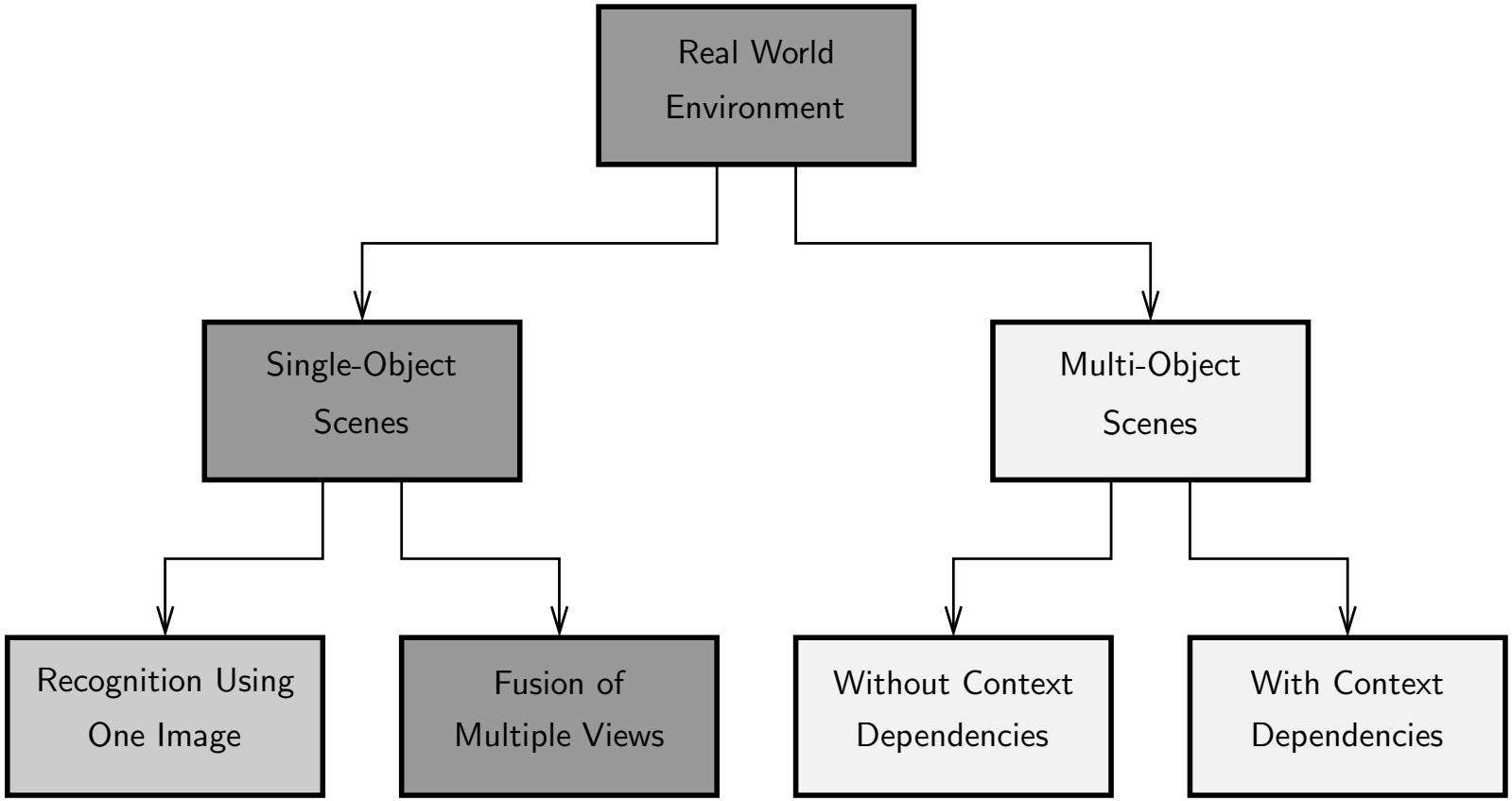
Single-Object, One Image



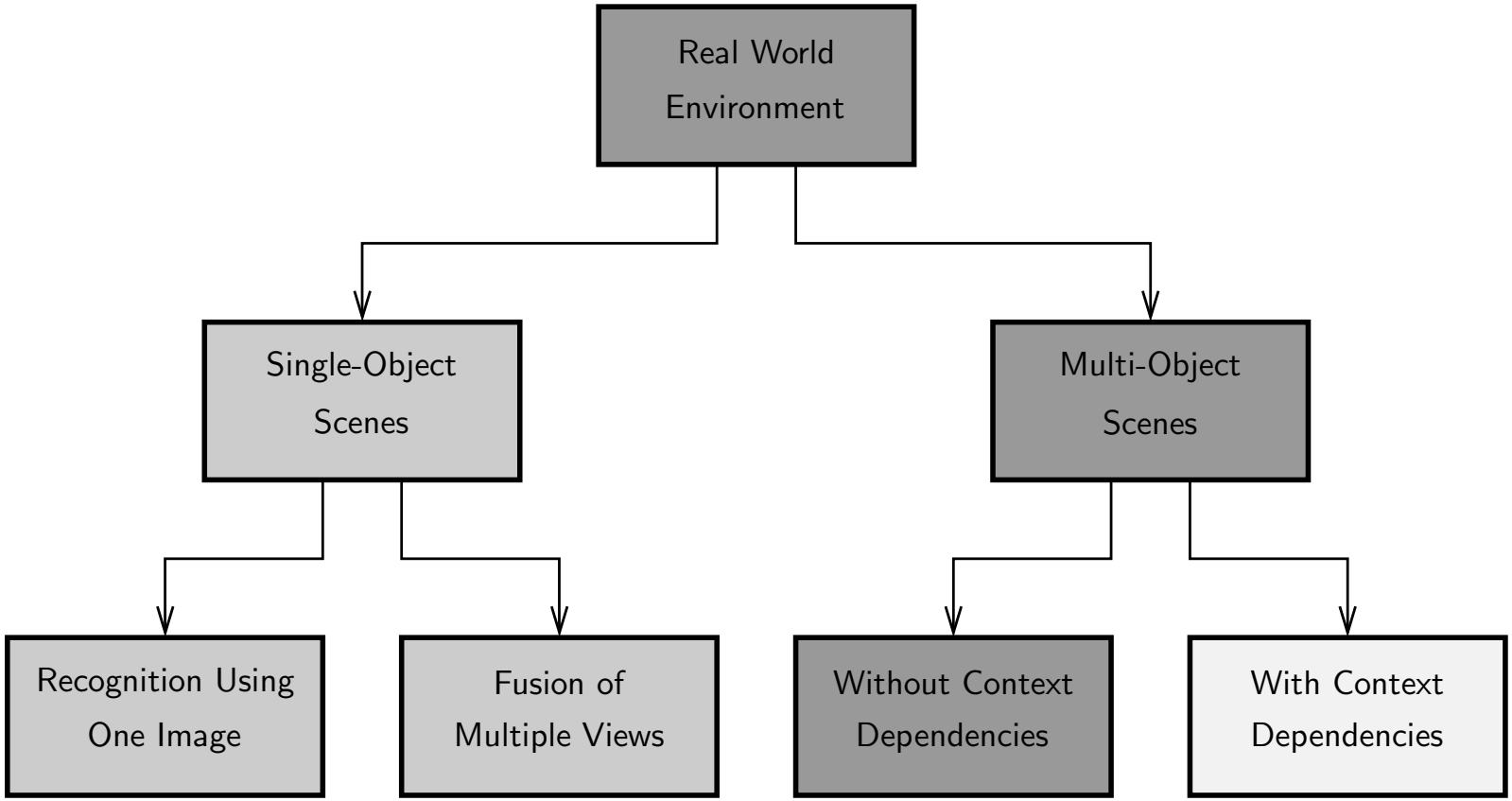
Classification and Localisation Algorithm



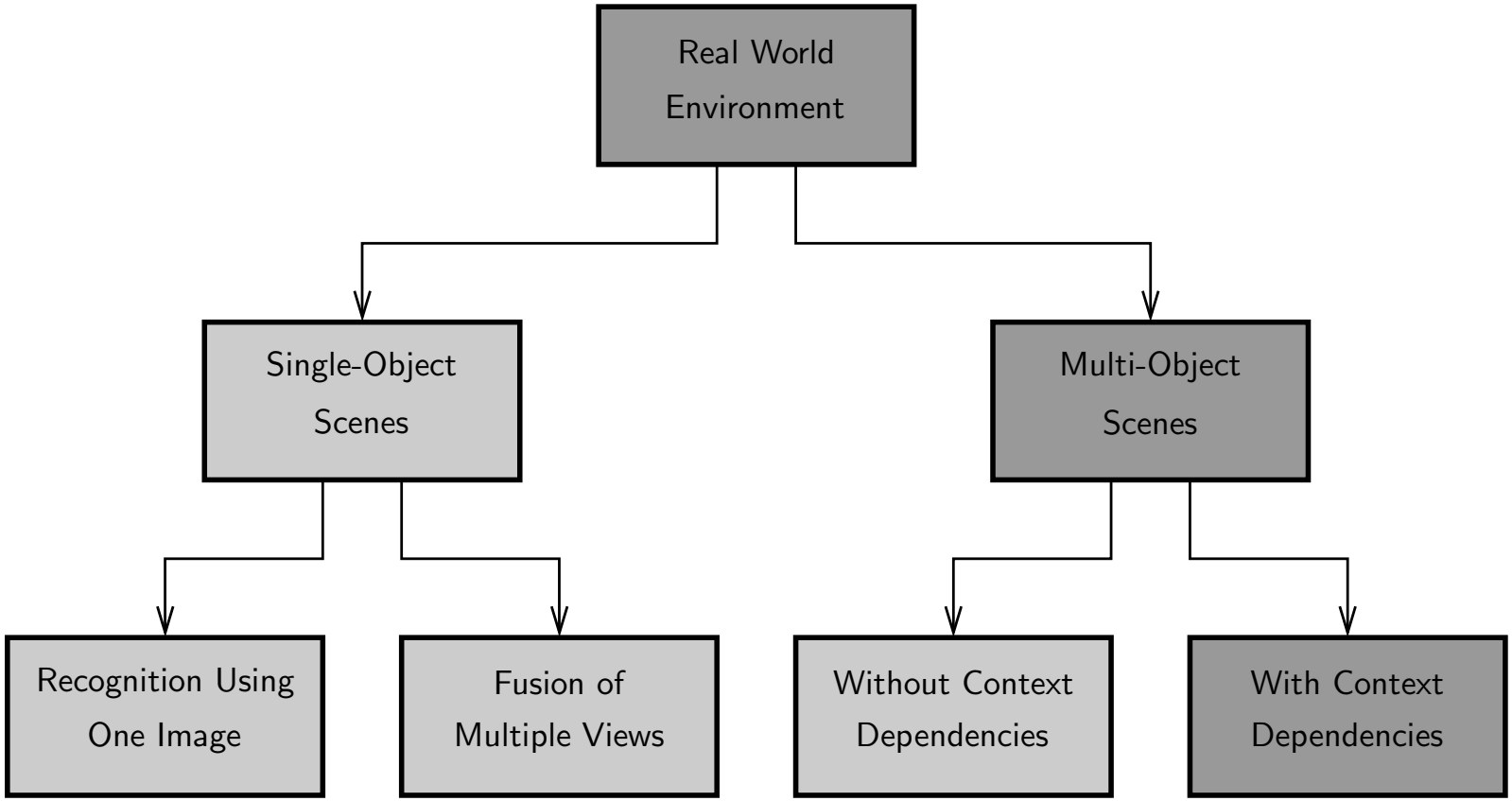
Single-Object, Multiple Views



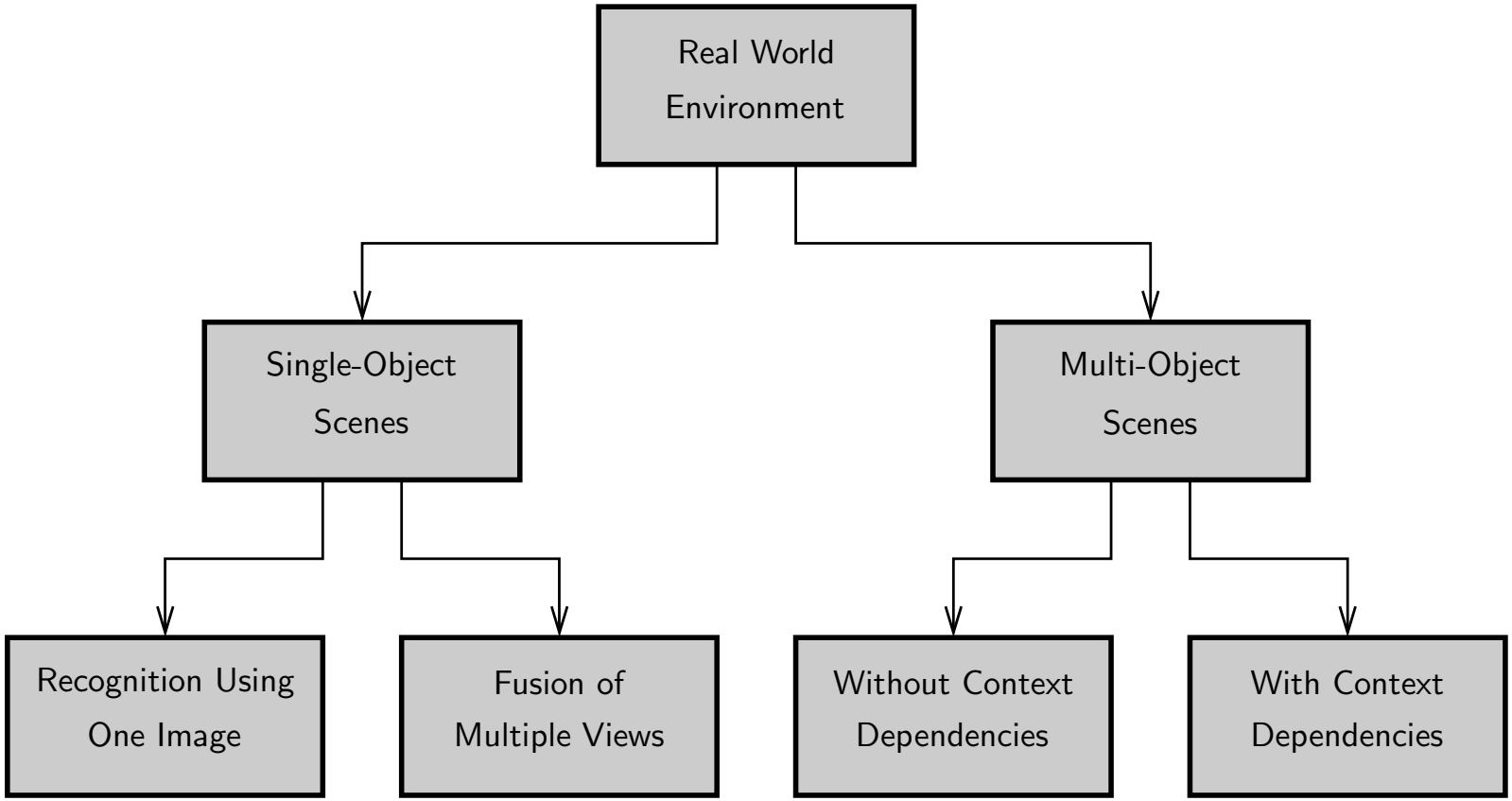
Multi-Object Scenes without Context



Multi-Object Scenes with Context



Recognition Phase Completed



Experiments and Results

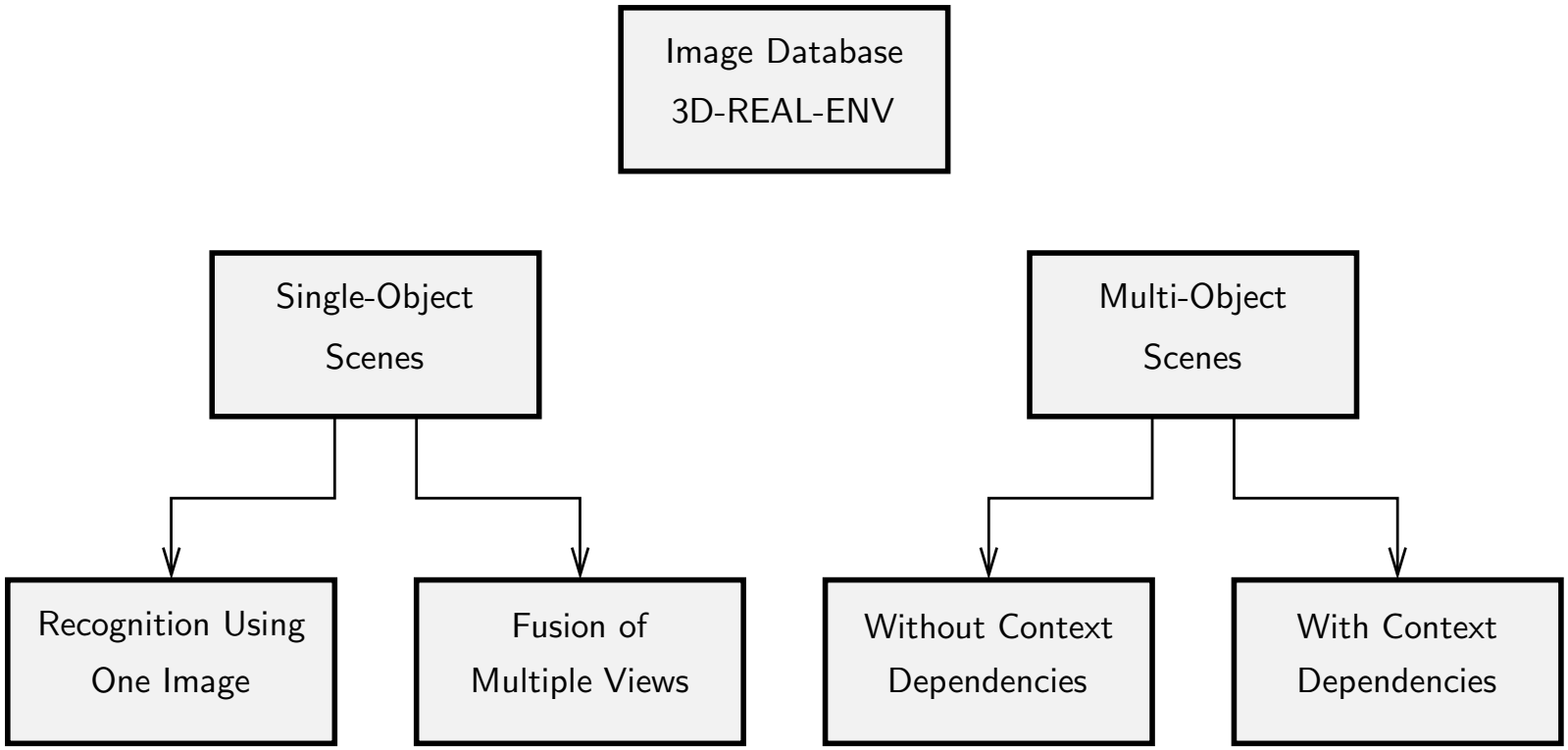
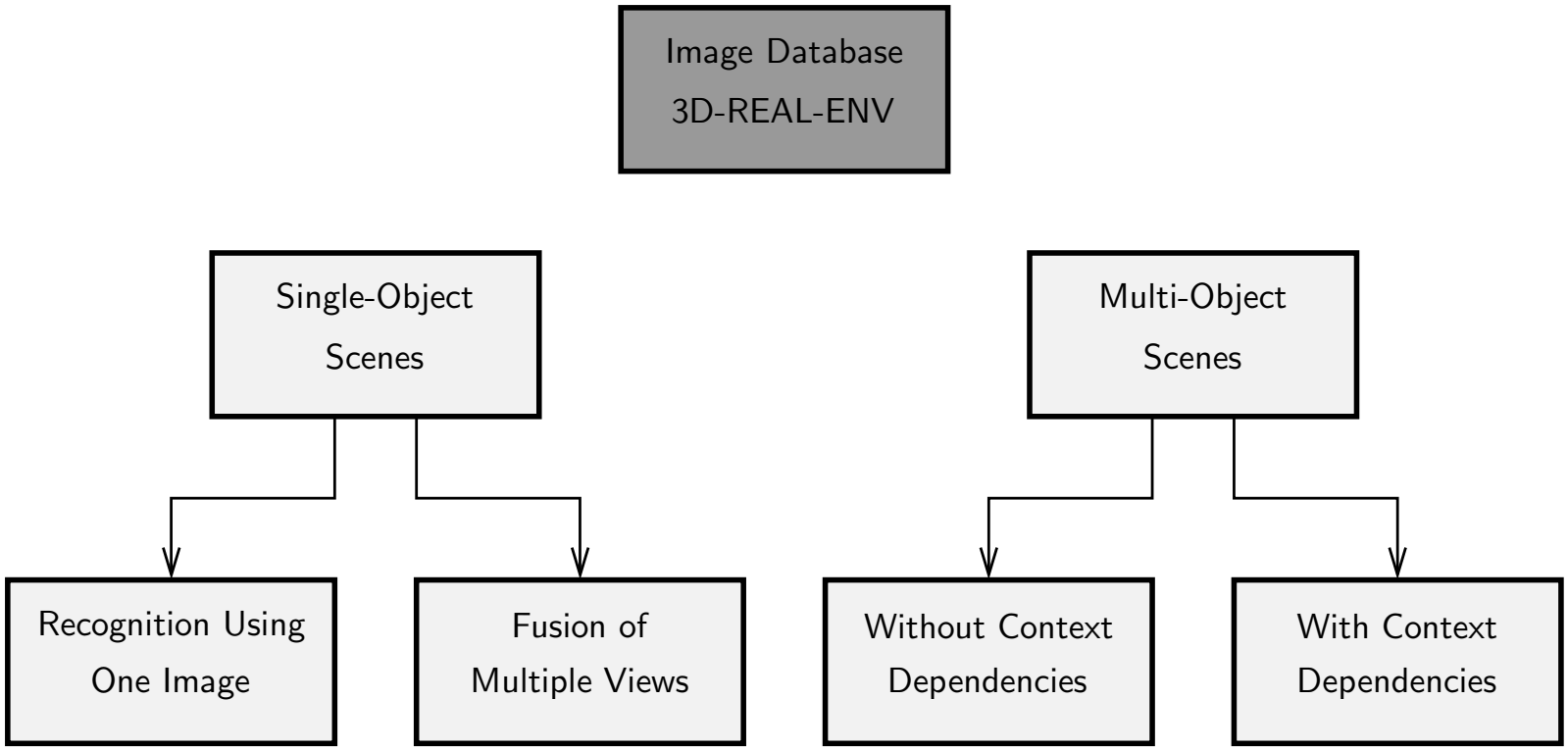
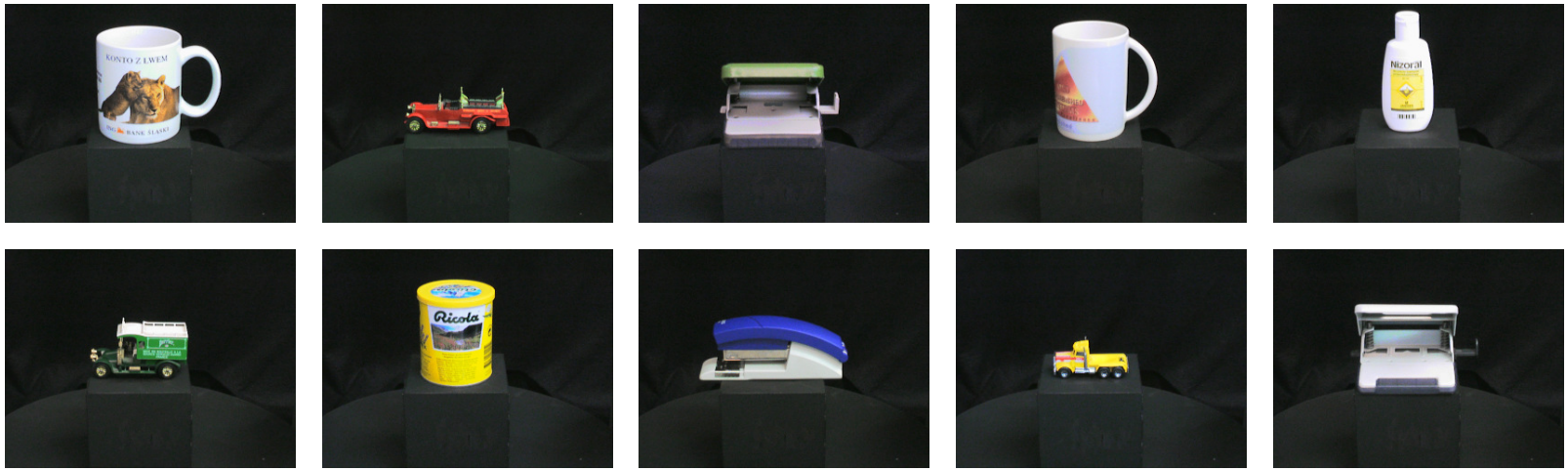


Image Database 3D-REAL-ENV



Training Images

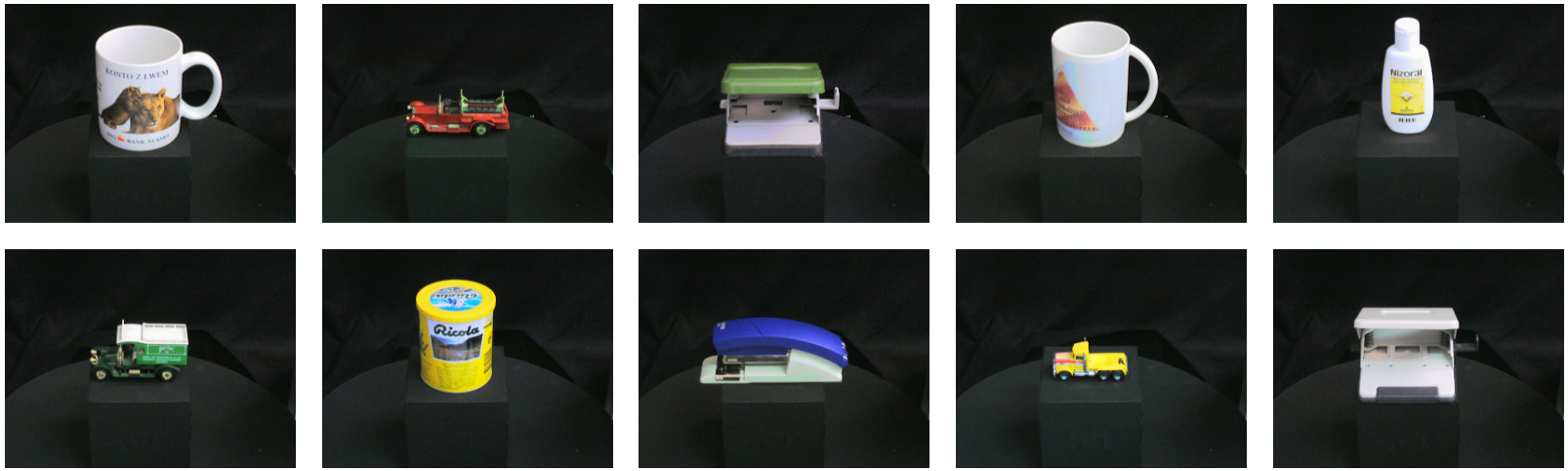


1680 Training Viewpoints, 33600 Images

$$\phi_{x,\rho} = (0.0^\circ, 4.5^\circ, 9.0^\circ, \ldots, 85.5^\circ, 90.0^\circ)$$

$$\phi_{y,\rho} = (0.0^\circ, 4.5^\circ, 9.0^\circ, \ldots, 351.0^\circ, 355.5^\circ)$$

Test Images HomBack

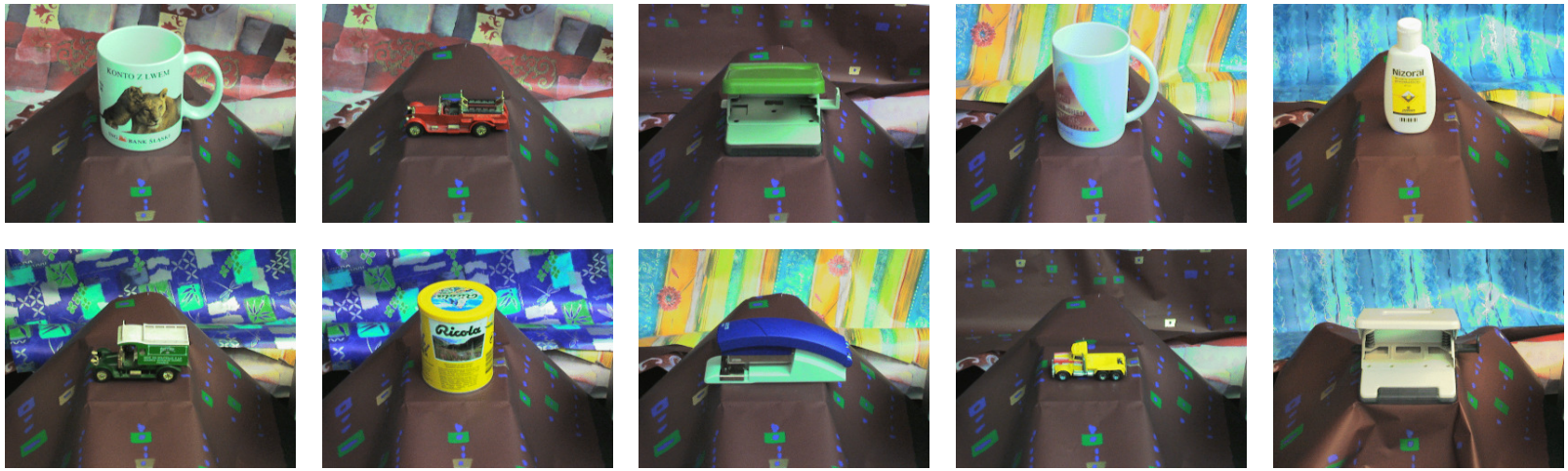


288 Test Viewpoints, 2880 Images

$$\phi_{x,\tau} = (0.00°, 11.25°, 22.50°, \ldots, 78.75°, 90.00°)$$

$$\phi_{y,\tau} = (0.00°, 11.25°, 22.50°, \ldots, 337.50°, 348.25°)$$

Test Images LessHetBack



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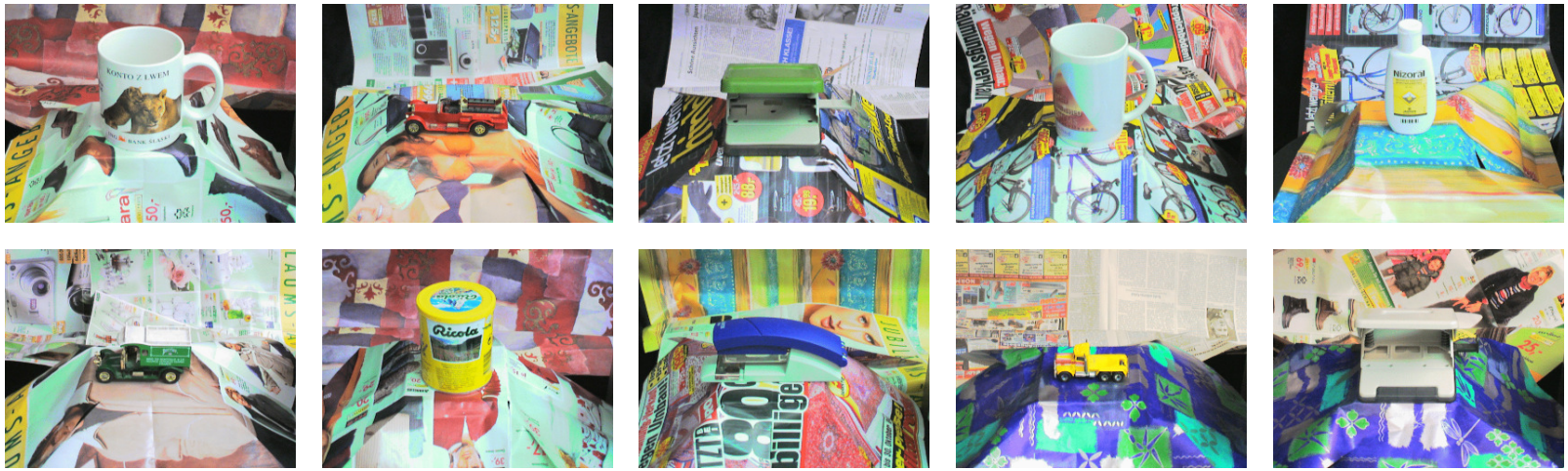
Test Images MoreHetBack



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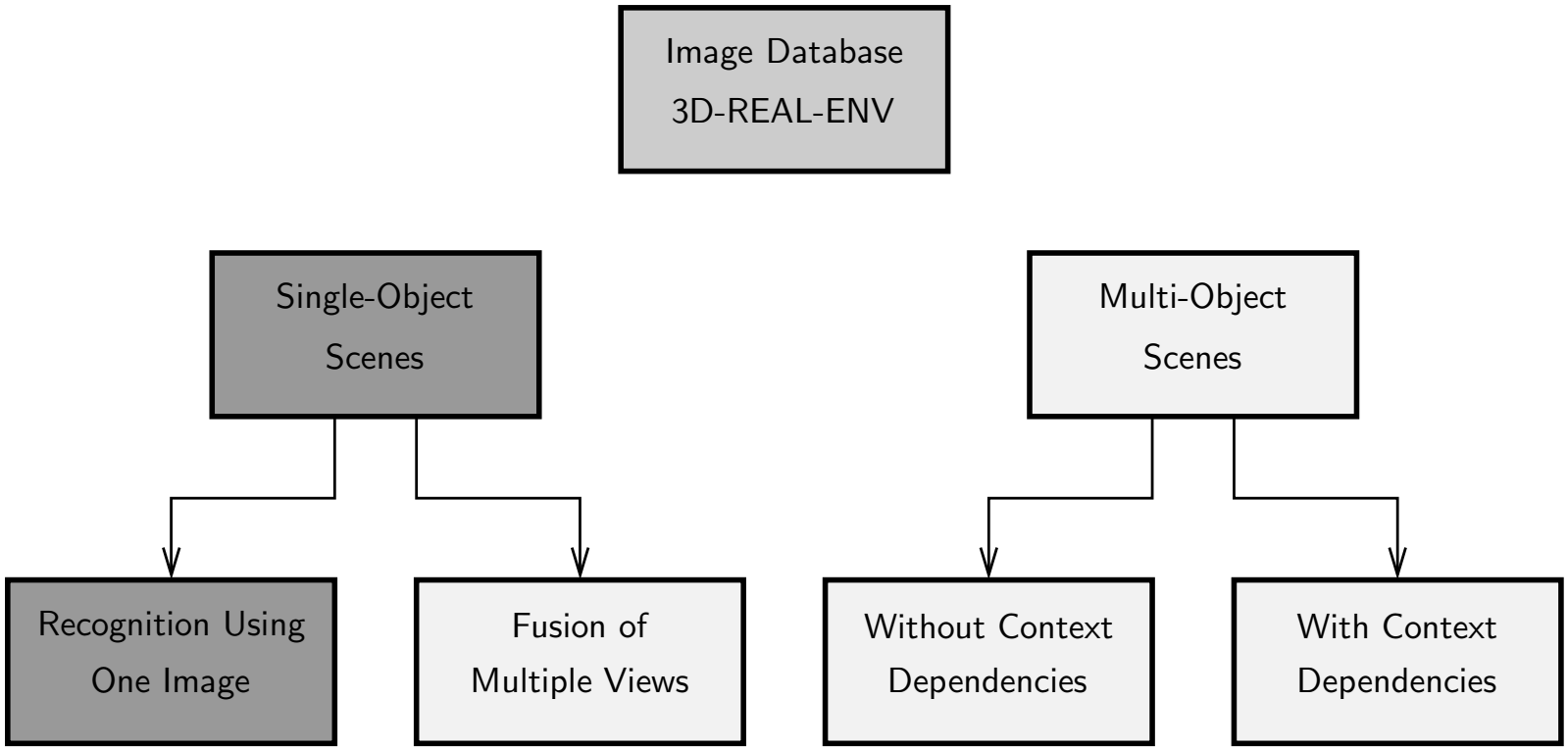
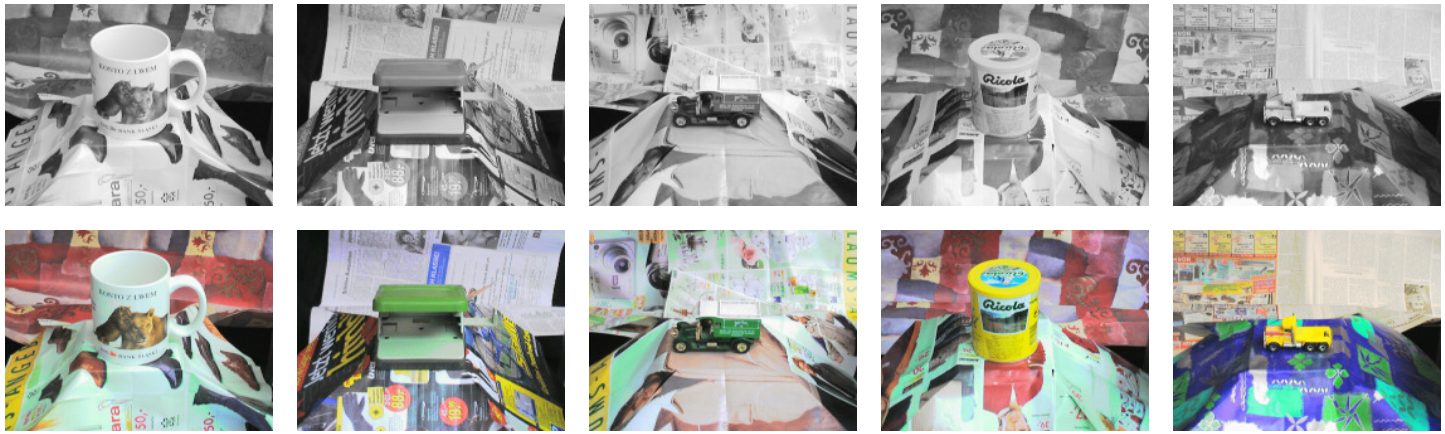
$$\phi_{y,\tau} = (0.00°, 11.25°, 22.50°, \ldots, 337.50°, 348.75°)$$

Single-Object, One Image

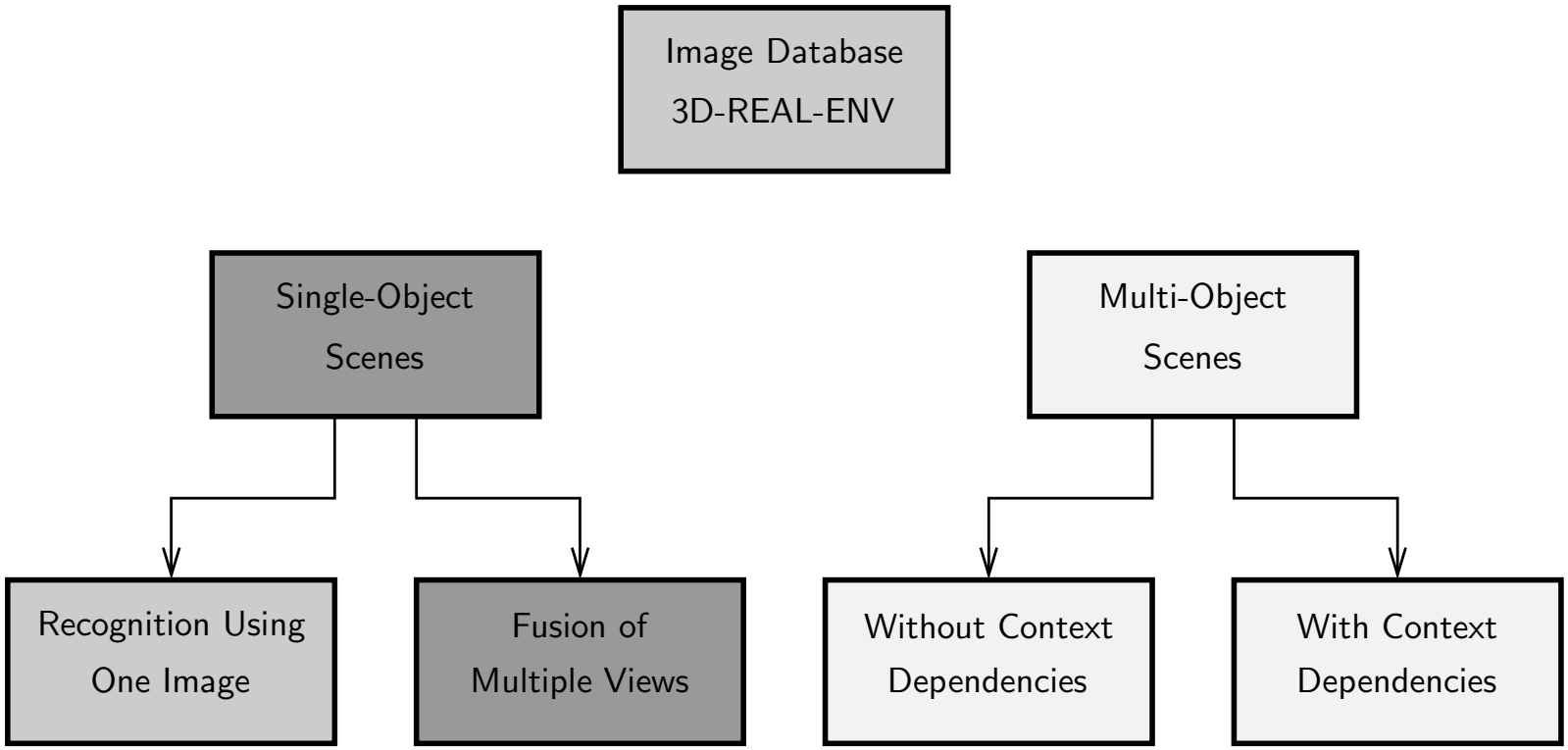


Classification and Localisation Rates

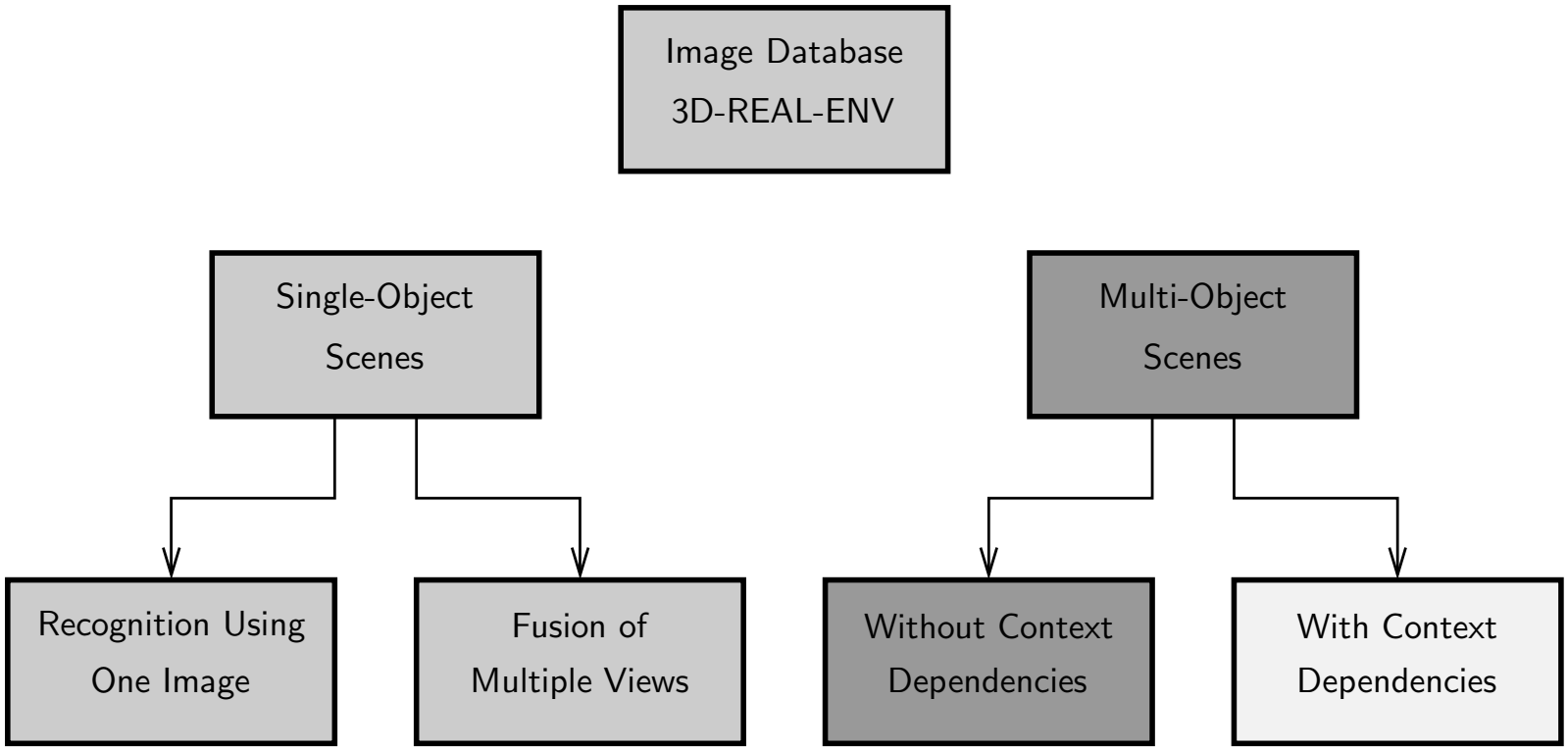
Distance of Training Views 4.5°	Classification			Localisation		
	Hom. Back.	Less Het. Back.	More Het. Back.	Hom. Back.	Less Het. Back.	More Het. Back.
Gray Level	100%	92.2%	54.1%	99.1%	80.9%	69.0%
Colour	100%	88.0%	82.3%	98.5%	77.8%	73.6%



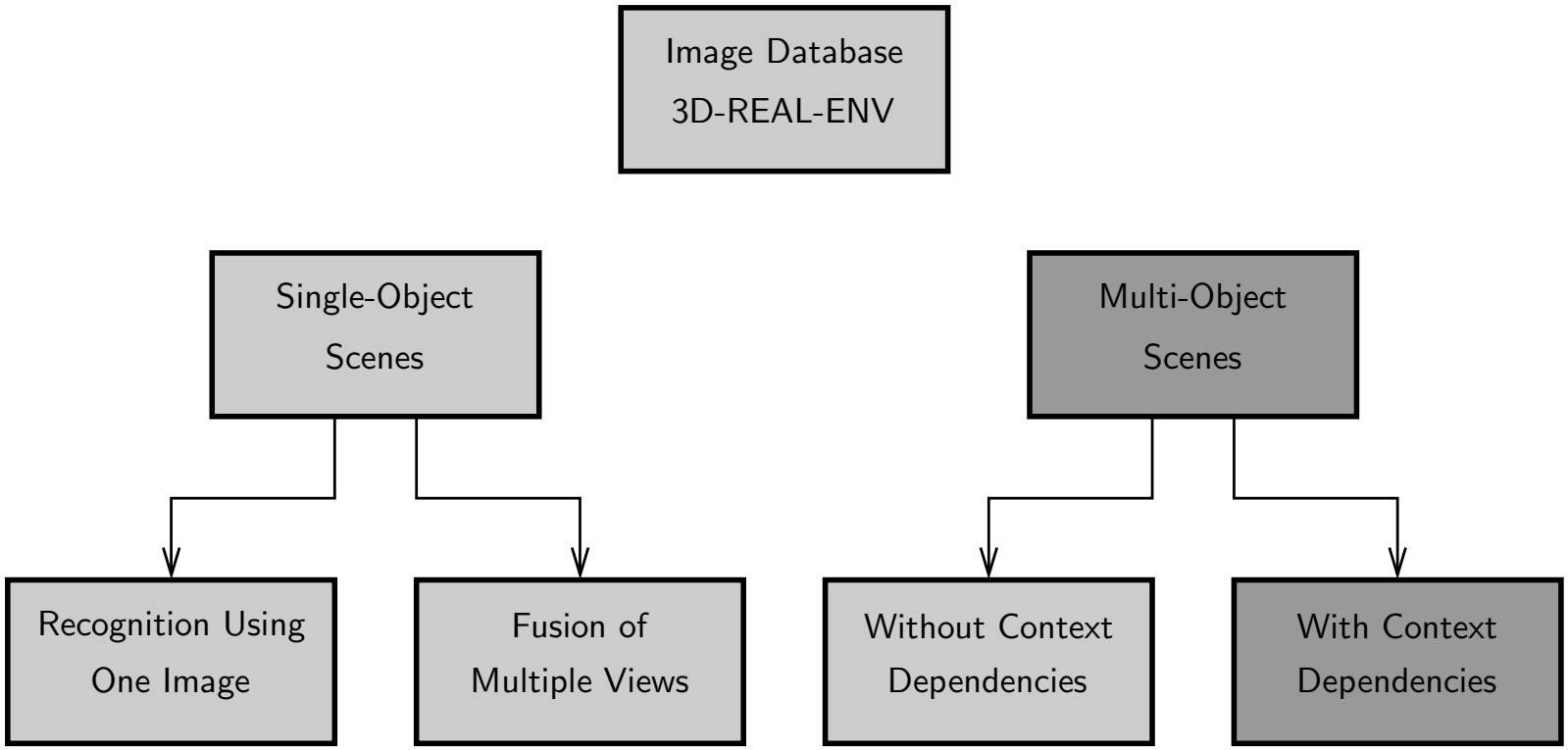
Single-Object, Multiple Views



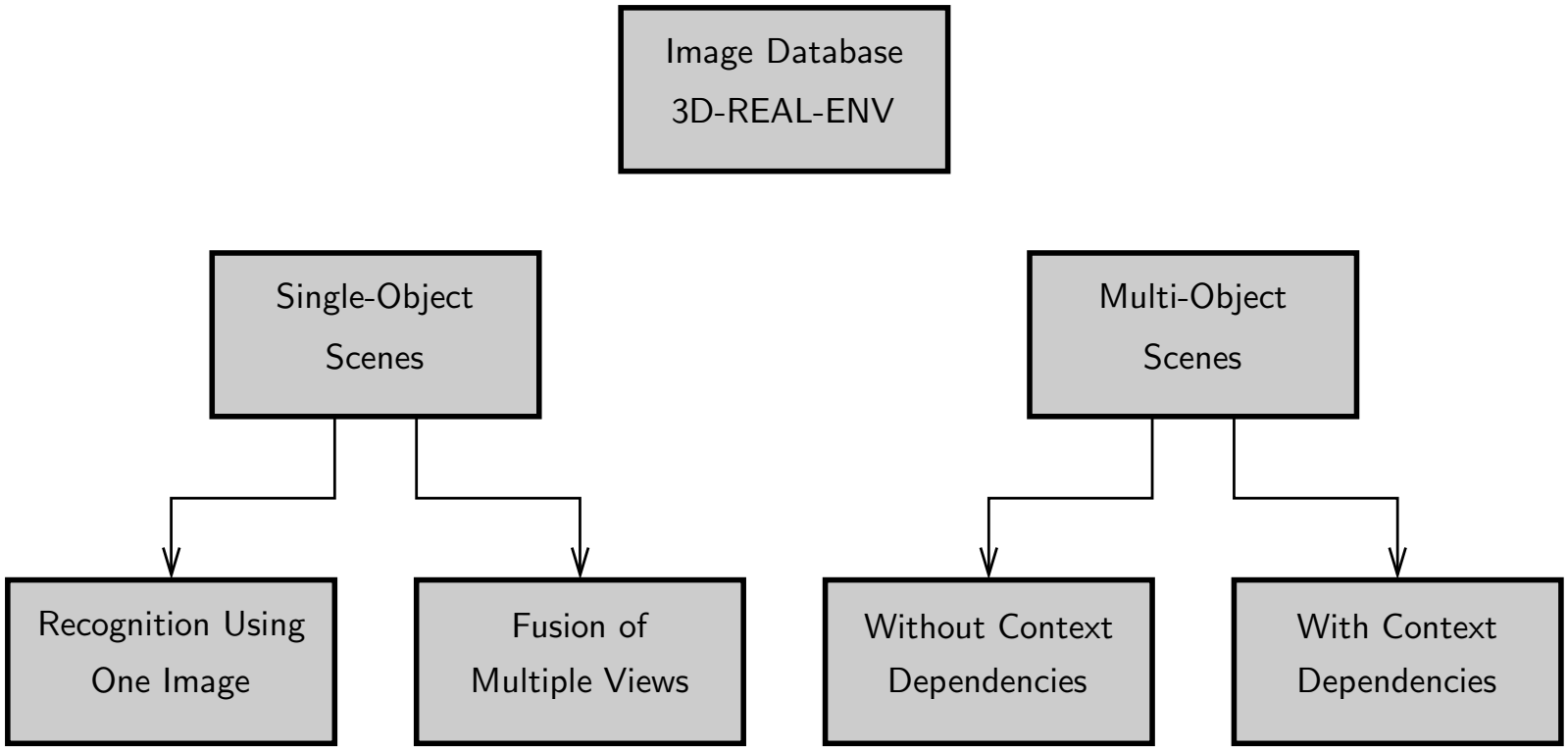
Multi-Object, Without Context



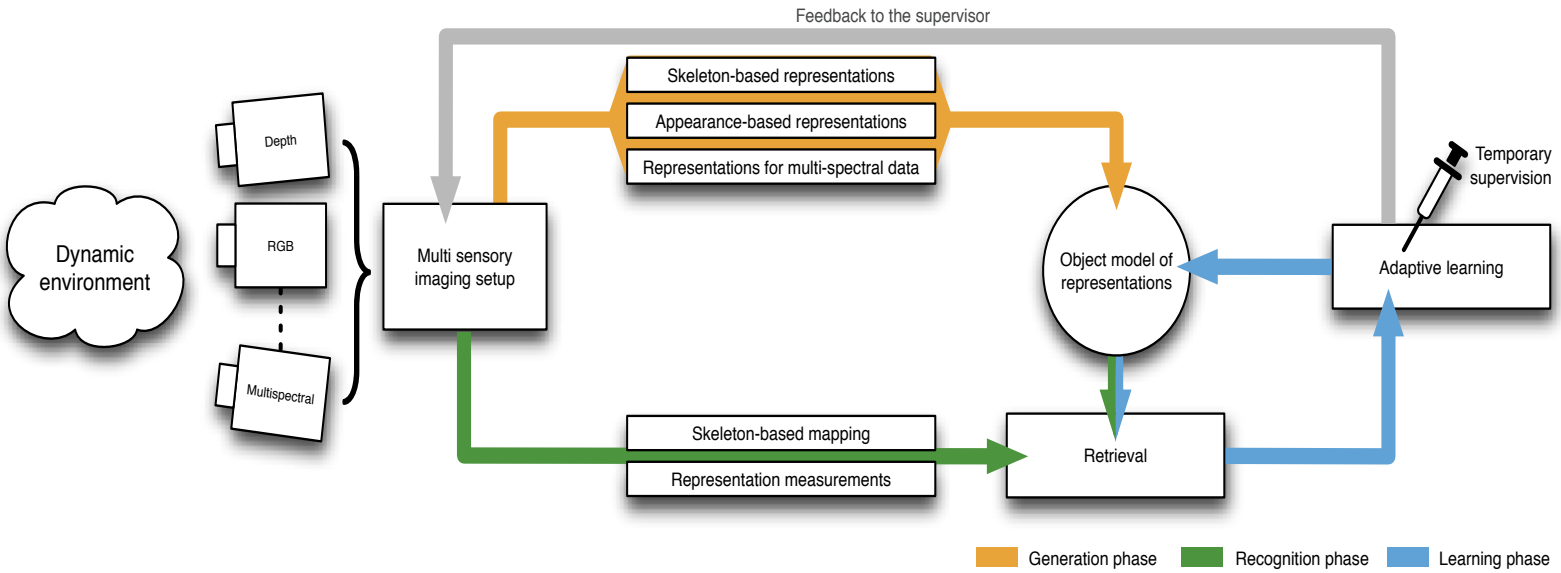
Multi-Object, With Context



Evaluation Completed



Adaptive Learning for Object Recognition



Overview

Adaptivity and Background Knowledge

Object Recognition

Start:	A System for Appearance-Based Statistical Object Recognition Including Colour and Context Modelling
Vision:	Adaptive Learning of Context for Object Recognition

Multimedia Retrieval

Start:	Multimedia Content Management and Retrieval System
Vision:	Adaptive Learning of User Preferences based on Relevance Feedback

Image Understanding

Start:	Spacial Reasoning for Image Classification
Vision:	Integration of High-Level Background Knowledge from Ontologies into Low-Level Image Processing

Existing Collaborations

Object Recognition

- Prof. Kropatsch, Vienna University of Technology
- Prof. Latecki, Temple University of Philadelphia
- Prof. Paulus, University of Koblenz-Landau
- Prof. Pizlo, Purdue University, West Lafayette

Multimedia Retrieval

- Prof. Izquierdo, Queen Mary University of London
- Prof. Rüger, Open University
- Prof. Uehara, Kobe University

Image Understanding

- Prof. Haas, Joanneum Research in Graz
- Prof. Staab, University of Koblenz-Landau

New Research Field - Biometry

Driver Condition Monitoring with Smartphones

- Assessment of Smartphone Sensors for Driver Condition Monitoring
- Driver Profile Learning from Multimodal Smartphone Sensory Data
- Runtime Automatic Driver Condition Recognition
- New Promising Collaboration with Prof. Krajewski, University of Wuppertal

Human Identification using Palm-Vein Images

- Robust Sensory Setup for Acquisition
- Graph-Based Matching for Similarity Measure