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Practical Issues in Physical Sign Recognition with Mobile Devices

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Introduction

- Background
  - Annotation of physical objects using mobile devices (PERMID 2005)
  - Prototype based on camera phones and 2D barcode (Visual Codes)
  - Can we do it without barcodes, purely based on image matching?
  - Focus on feasibility rather than computer vision
- Outline
  - Sign annotation – use case and motivation
  - Sign recognition based on image matching
  - Comparison of matching algorithms
  - Practical problems

Digital Annotations to Physical Objects

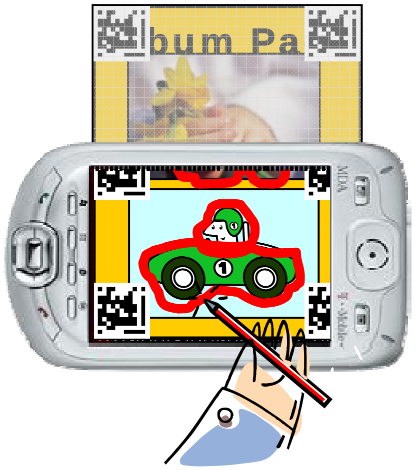
- User-generated digital media linked to physical objects
- Embed digital information into the real world
- Can be shared across space and time
- Can take multiple forms
  - Text, graphics, audio, video, hyperlinks, vCard, vCalendar

Content of Digital Annotations

- What questions do annotations answer?
  - what are similar objects?
  - what are complementary objects?
  - what similar objects are better / worse?
  - who else likes this object?
- Ratings
  - using attributes that are specific for the object class
  - using attributes of a taxonomy or ontology

Techniques for Anchoring Digital Annotations with Physical Objects

- Marker types
  - Numbers (e.g., YellowArrow)
  - Barcodes (e.g., Semapedia)
  - RFID
- Problems
  - Attaching markers is not always feasible
  - Object is not under the annotator‘s control
  - Visual markers are obtrusive
- A different approach…
  - Marker-less annotation
  - Recognize objects based on their unmodified visual appearance



Annotations by Visual Appearance

- Many regular / quadrangular shapes in urban environments
  - street signs, shop signs, indication panels
  - facades of buildings
- Use signs as annotation anchors
  - interactively supported image matching

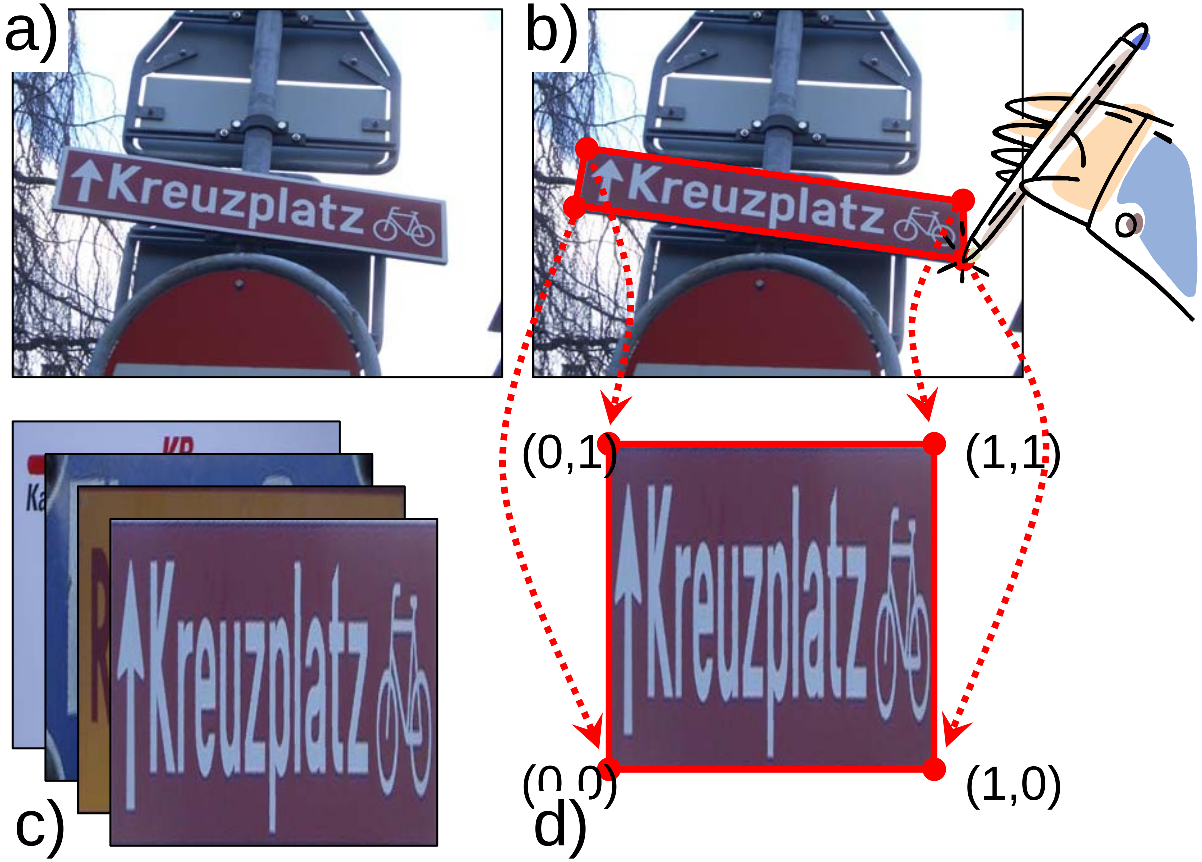
Annotating Signs using Camera Phones with Pen Input

a) captured photo

b) framing a sign with the pen
- object selection
- segmentation

c) set of templates

d) mapping framed area to unit square ("warping")



Dealing with Distortion

- Perspective distortion of sign in camera image
- Four-point correspondences
- Frame corners correspond to corners of unit square
  - Unique planar homography (projective transformation matrix)
  - Project framed part into unit square
  - Scale unit square to fixed-size request image of 128x128 pixels

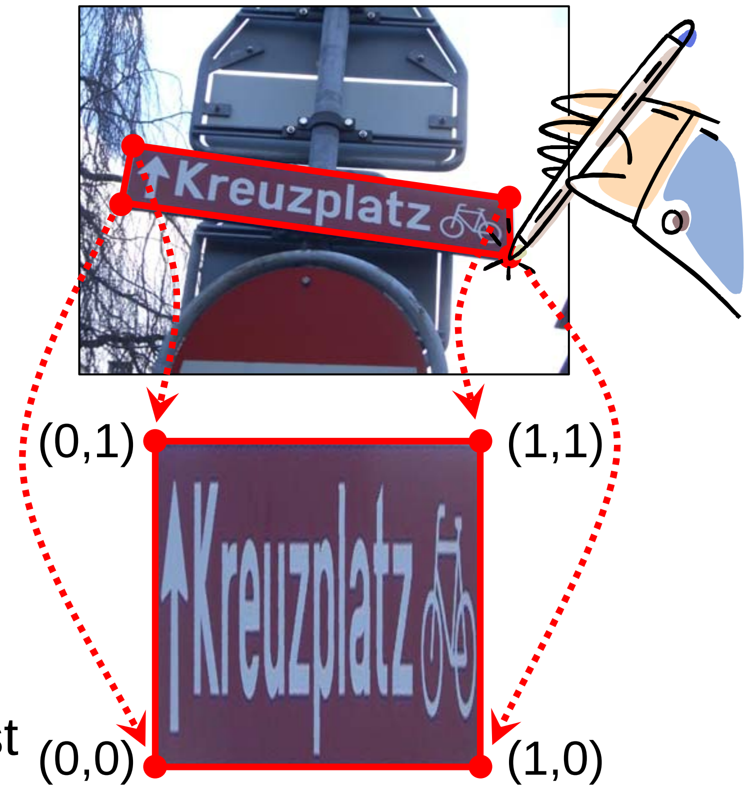


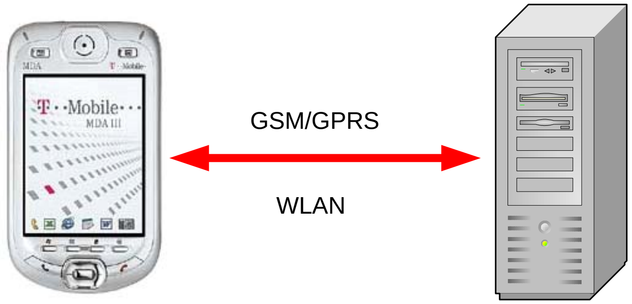
Image Matching

- Request to backend server
  - request image
- Backend server
  - executes matching algorithm
  - stores shared annotations and templates

Request image

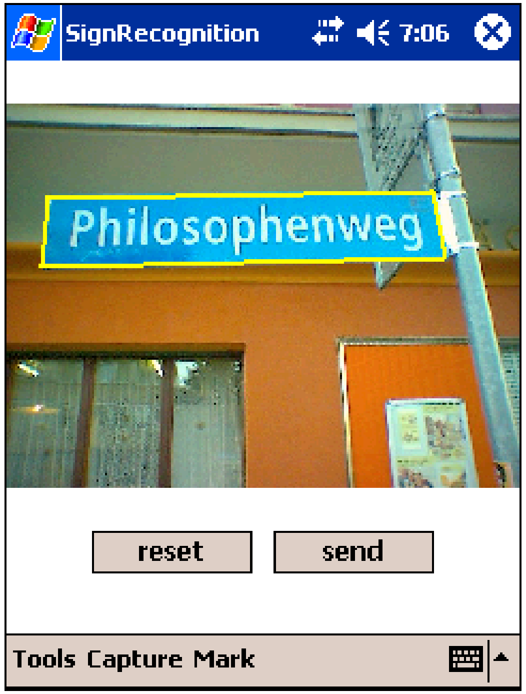
Set of templates

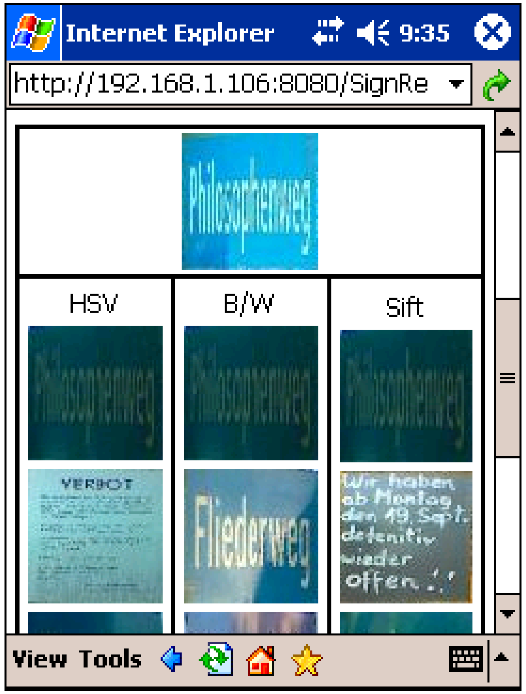
Prototype System

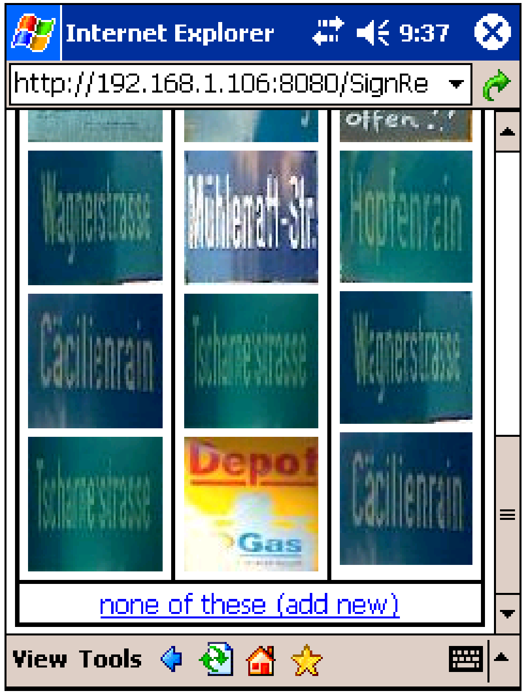


- Smartphone (T-Mobile MDA III)
  - Windows Mobile 2003
  - Pen-based input
  - Camera: 640 x 480 pixels, no optical zoom, relatively poor image quality
  - Software: Visual C++ application and web browser
- Server with Servlets and MySQL db to store templates and annotations
- Four different algorithms for image matching:
  - HSV
  - Black / White
  - SIFT (Scale Invariant Feature Transform)
  - (Wavelet)

Annotation Process







- Warped image is compared with each template
- Five best matches are presented to user as candidates
- User selects correct sign or decides to add warped image as template

Image Matching Algorithms

- HSV
  - Sum of pixel-by-pixel differences of hue value of request image and templates
- B/W
  - Correlation coefficient between monochrome request and template images
- Wavelet
  - Jacobs et al., 1995 – Java implementation based on Eikon engine
  - Signature for each image
- SIFT (Scale Invariant Feature Transform)
  - Lowe, 1999
  - Extraction of stable features (insensitive to changes in viewpoint)
  - Euclidian distance between feature vectors

Eperimental Setup

- Initialization: database with 95 template images of different objects
  - Street signs
  - Building facades
  - Company logos
  - Posters
- Evaluation: second snapshot for every object in database
  - Different perspective, lighting, and distance
  - For each matching algorithm: select 5 most similar templates from database
- Recognition successful if correct object is among the top 5 hits returned by algorithm

Results: Overview

Algorithm	HSV	Wavelet	B/W	SIFT
# snapshots	95	95	95	95
# recognized	81	69	86	89
% recognized	85.3%	72.6%	90.5%	93.7%
mean rank	1.54	1.62	1.37	1.37
% rank 1	74.1%	76.8%	86.1%	77.5%

- SIFT‘s offers the best recognition rate
- Despite their simplicity, HSV and B/W perform relatively well
- Wavelet algorithm seems less suitable
- Recognized objects are usually ranked first or second in the candidate list

Results: Street Signs

- Street signs are special
  - Omnipresent
  - Similar appearance
  - Material very susceptible to reflections and glare

Results: Street Signs

Without street signs

Algorithm	HSV	Wavelet	B/W	SIFT
# snapshots	83	83	83	83
# recognized	72	65	75	78
% recognized	86.8%	78.3%	90.4%	94.0%
% gained / lost	+1.5%	+5.7%	-0.2%	+0.3%

Street signs only

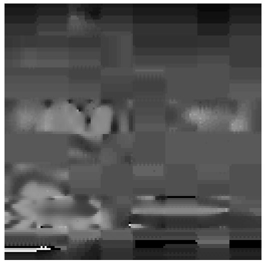
Algorithm	HSV	Wavelet	B/W	SIFT
# snapshots	12	12	12	12
# recognized	9	4	11	11
% recognized	75.0%	33.3%	91.7%	91.7%
% gained / lost	-10.3%	-39.3%	+1.1%	-2.0%

Recognition Problems

- Subtle features
  - Few distinguishable features after warping
  - Negative impact of small tanslations on pixel-based algorithms

Original

Warped



Hue

Black / White

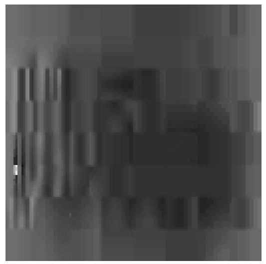
Recognition Problems

- Large width and small height
  - Warping changes aspect ratio leading to few clear features

Original

Warped

Hue



Black / White

Recognition Problems

- Perspective
  - Only problematic with pixel-based algorithms, not with SIFT

Recognition Problems

- Blurred images
  - Mainly problematic for SIFT
  - Minor issue as blur can be corrected by user

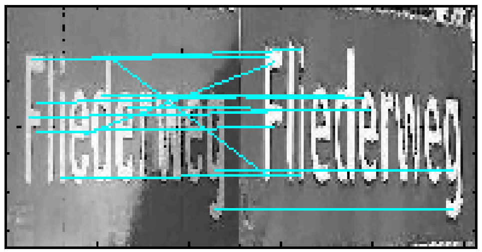
- Reflections
  - Reflecting surfaces introduce spurious features

- Non-rectangular objects
  - Not a problem for SIFT

Recognition Problems

- Lighting conditions
  - Colors changes (problematic for HSV) and reflections (problematic for B/W)

Original | Warped | Hue | Black / White



Summary

- Sign recognition works well with very simple pixel-based algorithms and best with SIFT
- Corner marking can be done accurately
- Corner marking could be omitted with SIFT
  - User still needs to select object to annotate
  - Pen input required
- Possibilities for improvement:
  - Limit search space by considering context parameters (cell id, time, weather conditions)
  - Use of more suitable data structures

Thank you!

Questions?

www.vs.inf.ethz.ch

Camera Phones with Pen Input for Generating Digital Annotations to Real-World Objects

- Interaction possibilities of camera phones with pen input
- Techniques for anchoring digital annotations with physical objects
  - Visual codes for annotations of items in printed photos
  - Suitability of camera phones as annotation devices
  - Annotation of signs using four-point correspondences