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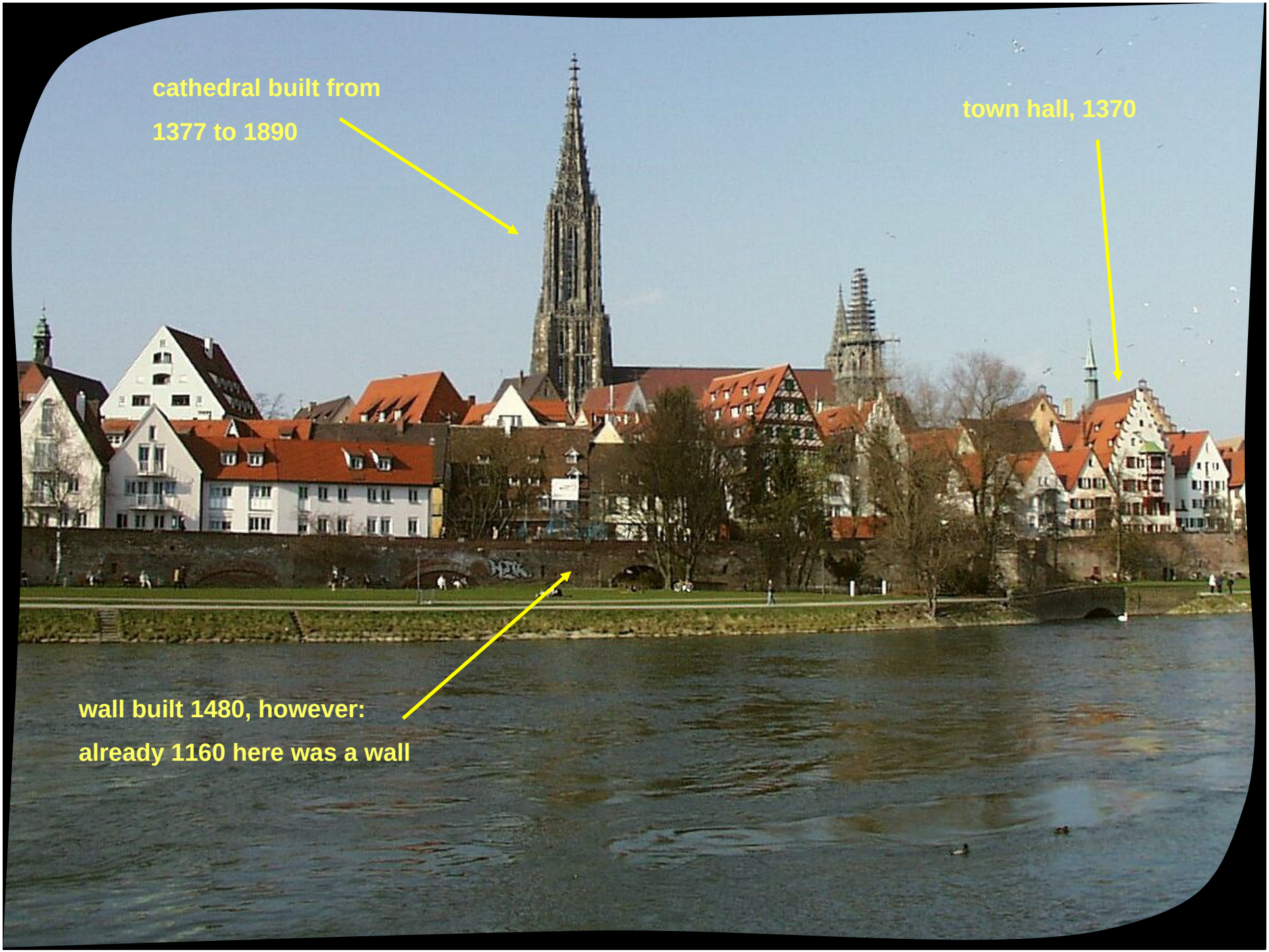
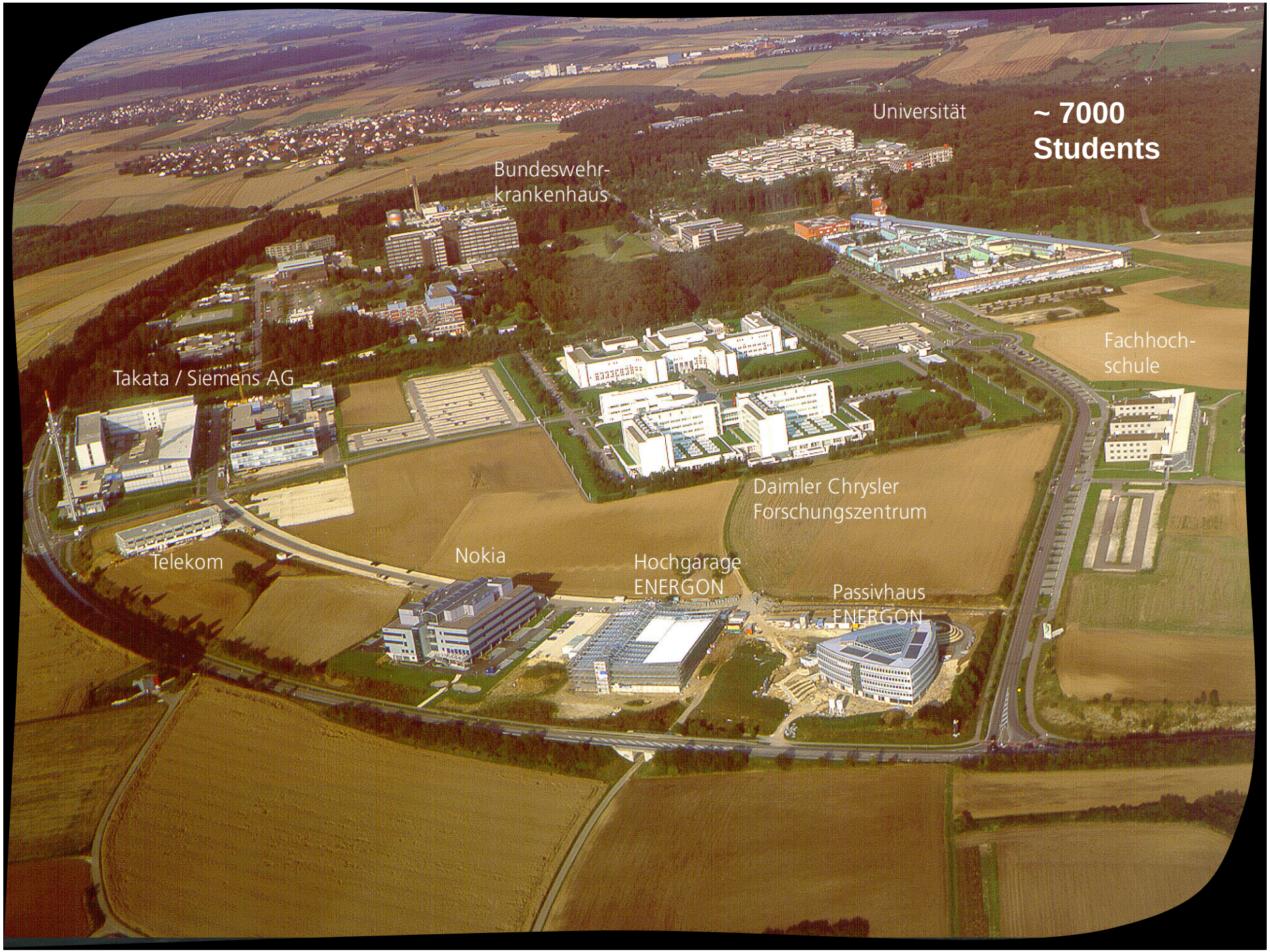

cathedral built from
1377 to 1890
town hall, 1370
wall built 1480, however:
already 1160 here was a wall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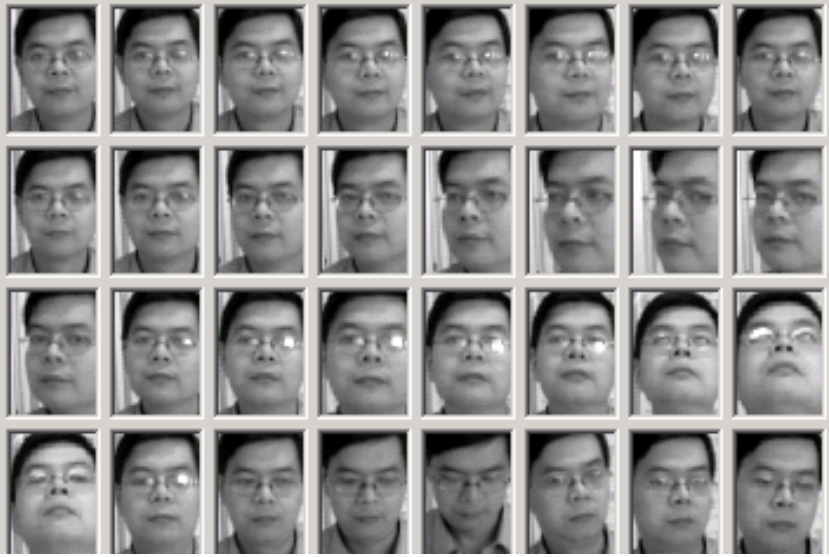


Unsupervised Face Recognition Database

Albrecht L. Rothermel | Sept. 25th, 2007

Distinguished Lecturer Event

Contents

- Introduction
- Face detection
- Face recognition
- Database construction

Introduction

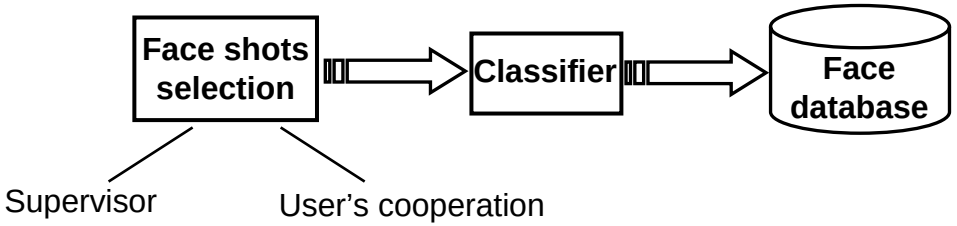
- **Ideal face recognition system**
  - Self-learning – automatic & unsupervised
  - Self-adaptive (aging)
  - Robust: Low FAR (false acceptance rate)
    Low FRR (false rejection rate)
  - Stable
  - Fast & cheap
- **Applications**
  - Home convenience:
    - Speech recognition support
    - Family member favorites memory
    - Movie star search
  - Automotive convenience
  - Frequent customer servicing (shops)
  - Mobile phone control
  - Electronic pets

Introduction

- **Face recognition issues**
  - **Robustness**
    - Pose variation
    - Facial expression changes
    - Aging

pitch yaw roll

  - **Intelligence**
    - Supervised training not applicable

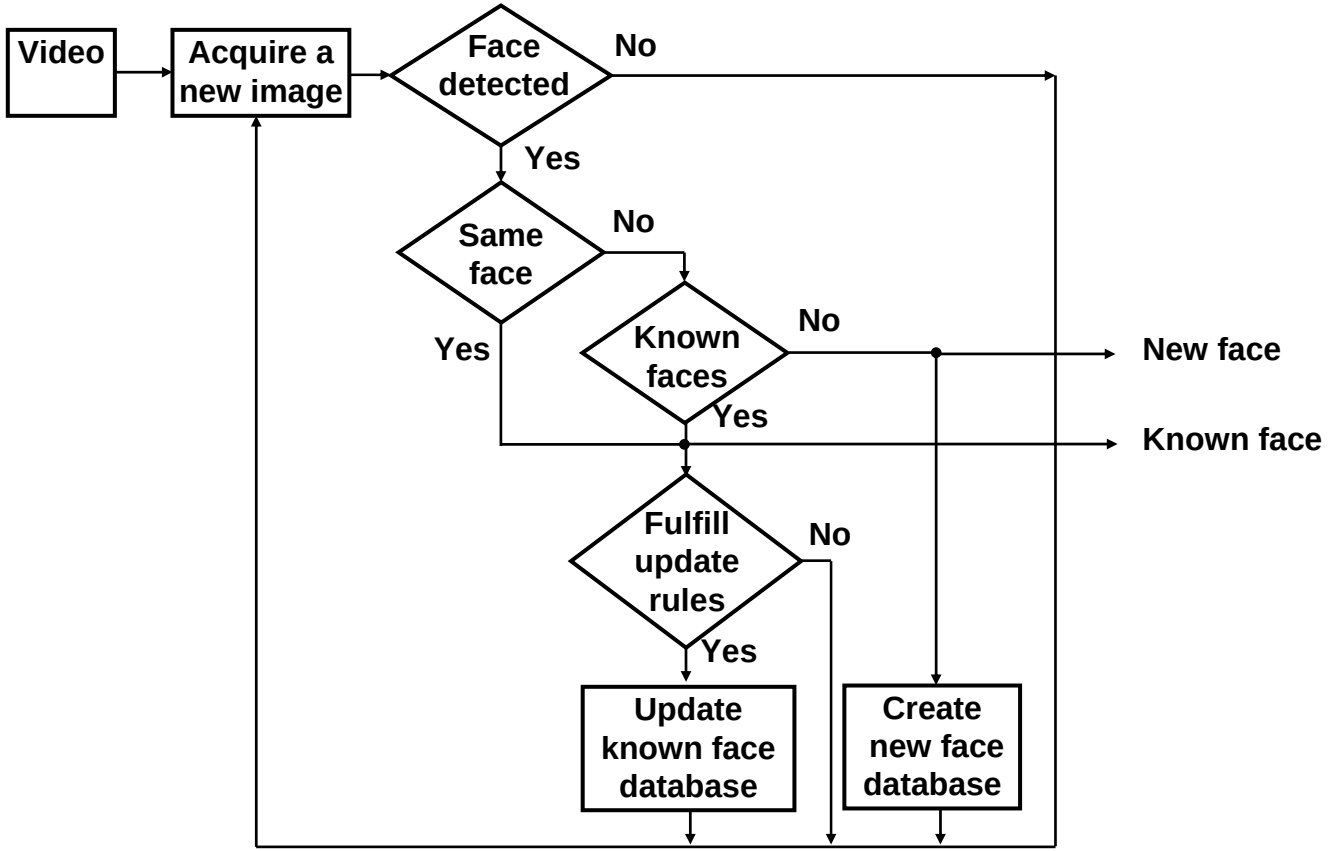


Introduction

- **Automatic system issues**
  - **Face recognition relies on *comparison* with a *face database***
    - Large variety in database required to achieve low FAR
    - When there is a brand new database for a new person, there is no variety
    - No variety in database results in high danger for FAR
    - Only very similar faces can be recognized
    - ***Contradicting requirements!***
  - **Specialized mugshots selection procedure required**
    - Database properties have to be optimized
    - Database build-up procedure has to be secure
    - Appropriate database structure required

Introduction: System overview

- **Overview of the proposed system architecture**



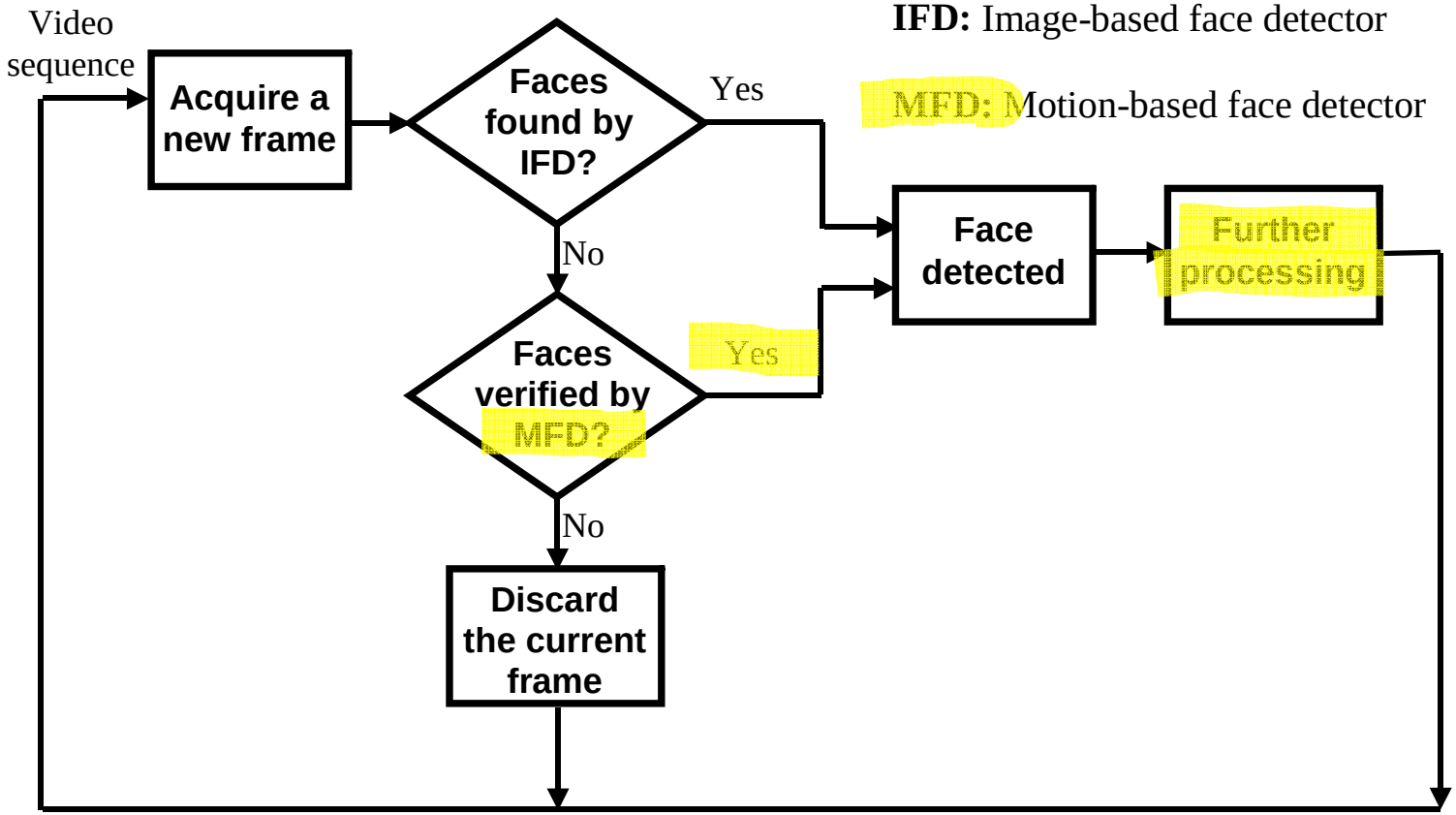
Face Detection: Concepts

Face detection methods:

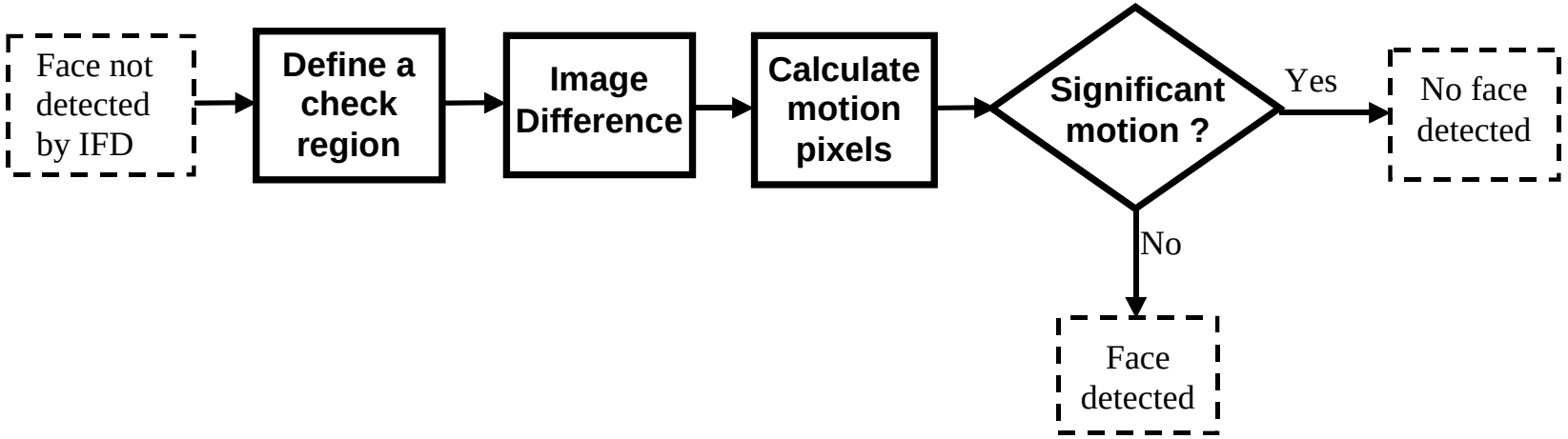
- Image - based
  - Rule - based
    - Facial features
    - Templates
    - Skin colors
  - Learn - based
    - PCA (Principal Component Analysis)
    - Neural Networks
    - SVM (Support Vector Machines)
    - Bayesian
    - SNoW (Sparse Network of Winnows)
    - AdaBoost
    - Metabooting
    - ⋮
- Video - based (temporal information considered)
  (Kalman filters, Hidden Markov models)

Commercial tool FaceVACS®, ranked first in FRVT 2002 (Facial Recognition Vendor Test, www.frvt.org)

Face Detection: Introduction of MFD

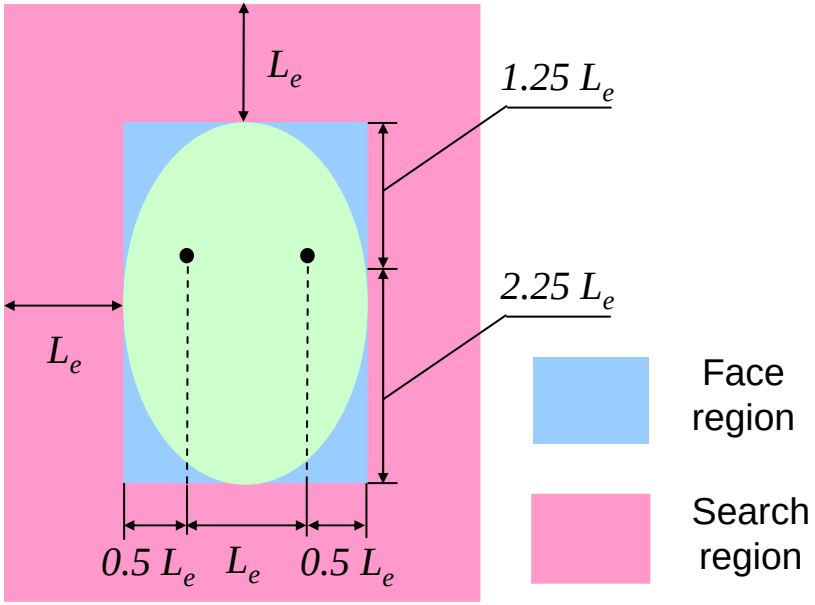


Face Detection: MFD Architecture



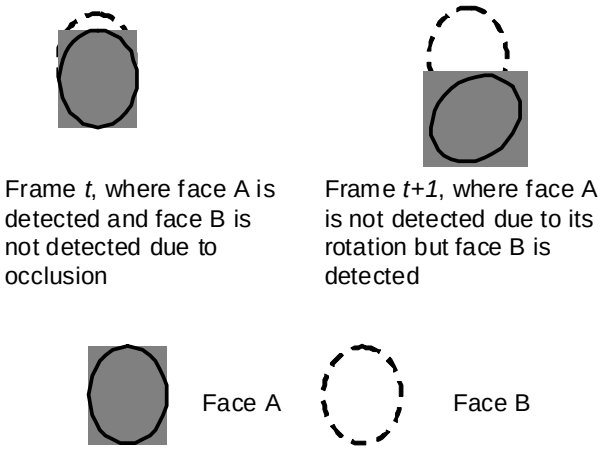
Face Detection: MFD details

- **Combined face detection**
  - Image based face detection
  - Temporal information
- **Assumptions**
  - 10~25 fps
  - 4~5 km/hour
- **Features**
  - Robust against background objects in motion
  - Improving *same face* decision
  - Low computational complexity



Face Detection: Critical Case

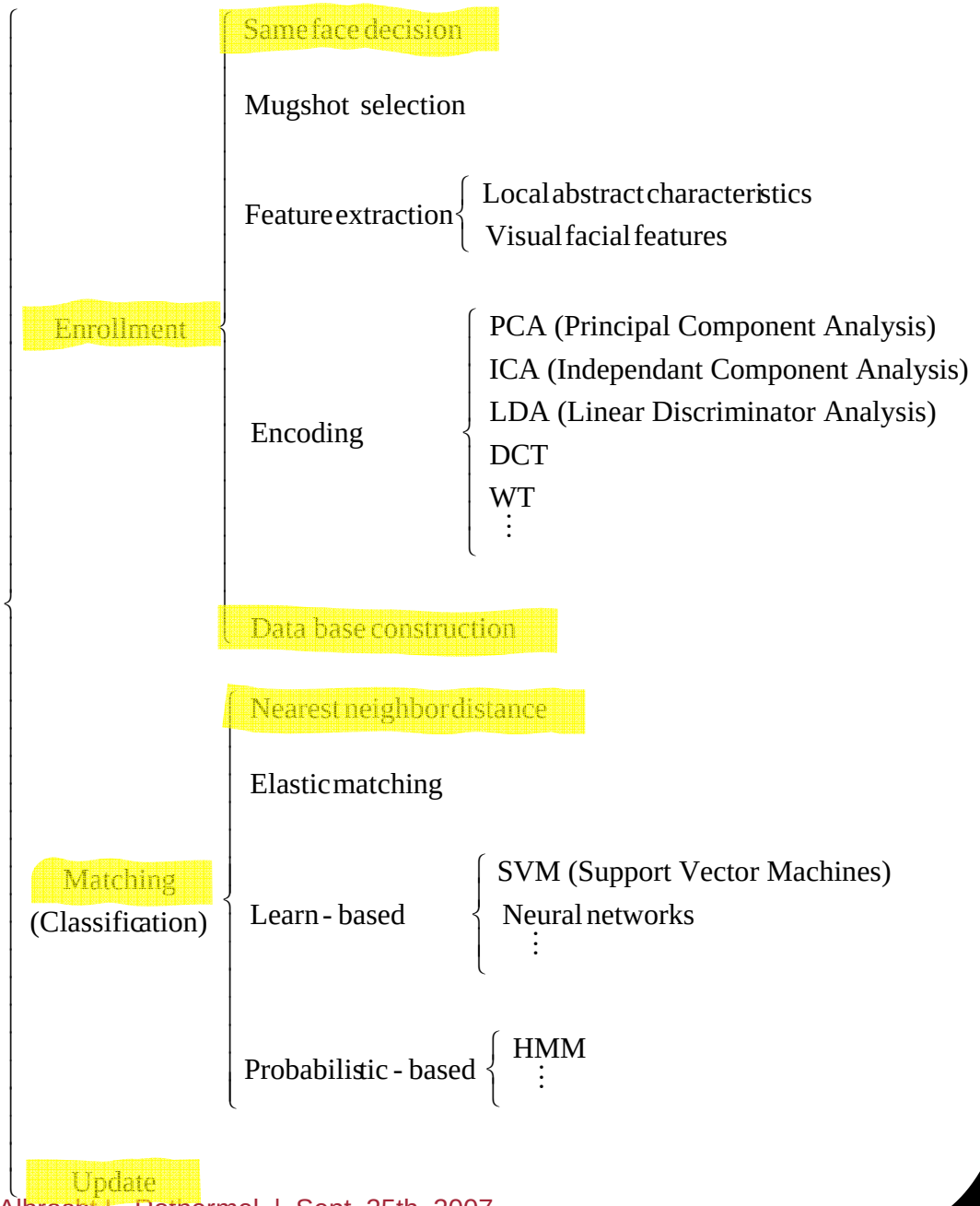
- **Disadvantages for recognition**
  - Problems with occluded faces
  - Problems with sudden person change



  - Has to be taken into account during recognition process

Face Recognition

Face recognition methods and procedures:



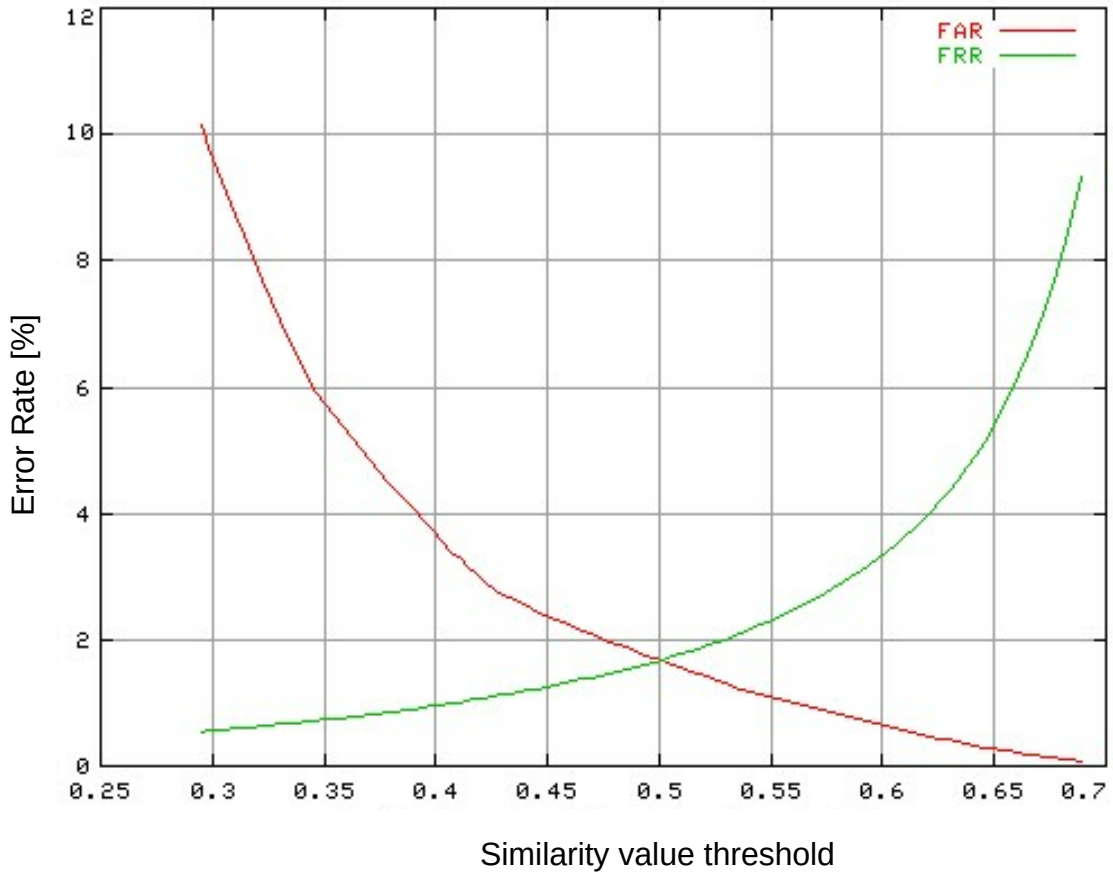
D2

Face Recognition: Similarity Value S_V

- **Face recognition measure in FaceVACS® software: Similarity values S_V**
- **S_V is obtained by comparison of a detected face with all available databases**
- **If S_V large enough for a particular database, detected face belongs to that database and is *recognized***

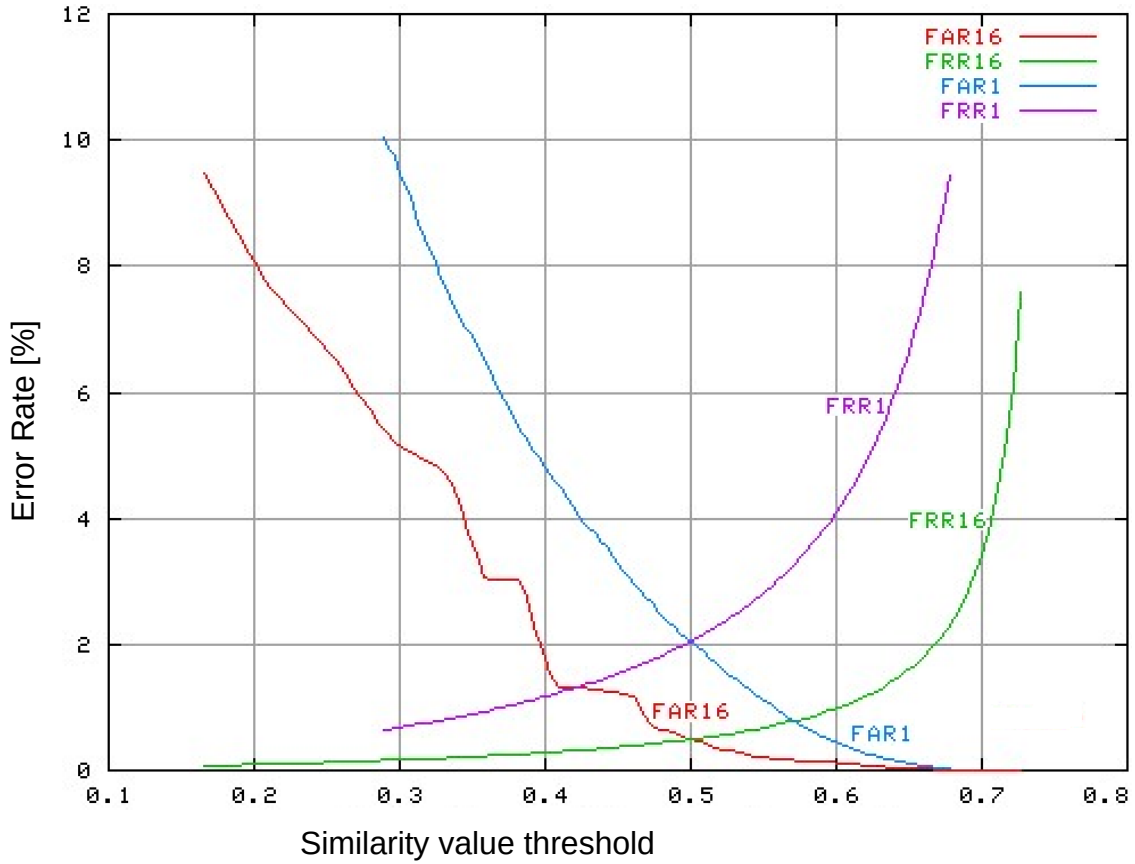
Face Recognition

- **FAR and FRR vs. similarity value S_V for FaceVACS® software**



Face Recognition

- **Influence of data base quality**



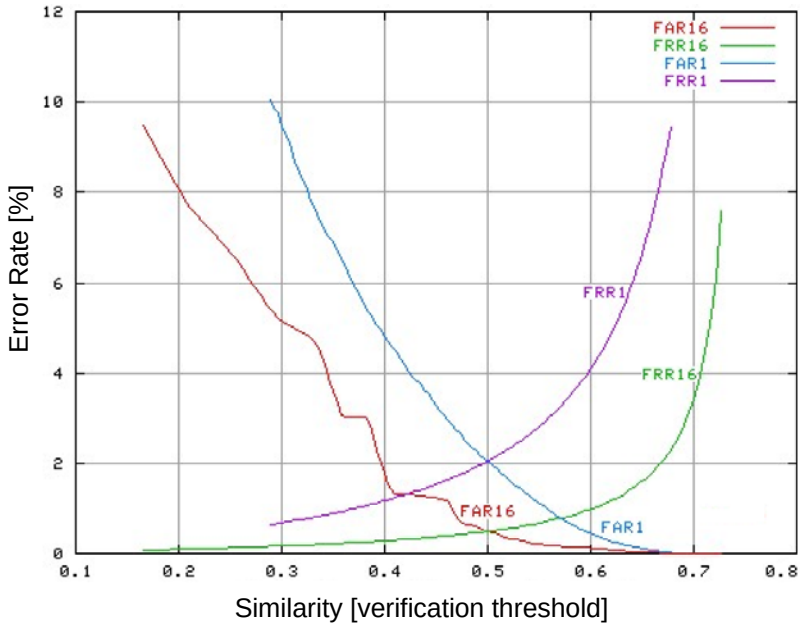
FAR/FRR 16 curves are very similar to FAR/FRR 8 curves

Face Recognition: Known Face Decision

Face Recognition: If $S_V > AST$

- **Similarity threshold is adaptive to number of enrolled faces images**

$$AST = S_{V0} + a \bullet i, \quad (i = 0, 1, 2, ..., N_{\max}, 0 < a < 1)$$



Implementation: 0.55 < *AST* < 0.65

Face Recognition: Introduction of Temporal filtering

Combined Face Recognition Algorithms

- **Temporal filtering to suppress individual false recognitions (mainly improves FAR)**

$$\sum_{i=1}^{n} A_i \bullet S_{v,\,i} > m \bullet AST$$

Face Recognition: Introduction of Temporal filtering

Combined Face Recognition Algorithms

- Another example for temporal filtering benefit

Person 1's frame images	Person 1—image1 	Person 1—image2 	Person 1—image3 	Person 1—image4 	Person 1—image5 	Person 1—image6 	Person 1—image7 	Person 1—image8 	Person 1—image9 
Person 2's database 	0.72	0.59	0.65	0.51	0.11	0.08	0.65	0.39	0.50
Average	0.47								

Face Recognition: Combined Algoithm

- **Combined same face decision algorithm**

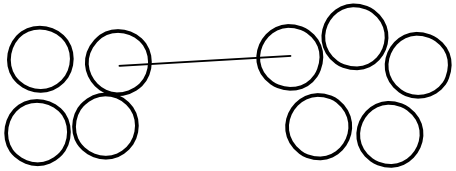
Case categories	I	II	III	IV	V	VI		
Image-based face detection	0	1	1	1	0	1	0	0
Temporal-based face detection	0	0	0	1	1	1	0	1
Recognition after temporal filtering	0	0	1	1	0	0	1	1
Same face	No	No	Yes	Yes	Yes/No	Yes/No	No decision	

Database Construction

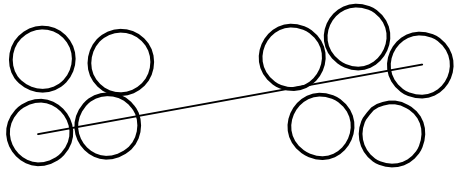
- **Database features**
  - **Purity** — no face shot from any other person allowed
  - **Variety** — only various enough face shots enrolled
  - **Rapidity** — a rapid growth at the beginning
  - **Updatability** — keeping update with recent views of each person
  - **Uniqueness** — only one single database for one person
- **Construction & update rules**
  - Introducing *AUT (Adaptive Updating Th)*, decreasing with database growing until saturation
  - If $AST < S_v < AUT$, then enroll into database
  - If database complete, and if $Date(I_{live}) - Date(I_{old}) > T_{th}$, then enroll
  - To merge similar databases, *MSV (Mutual Similarity Value)* proposed (not yet implemented)

Database Construction

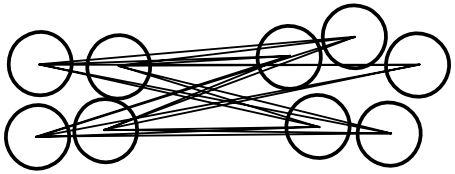
- **Database features**



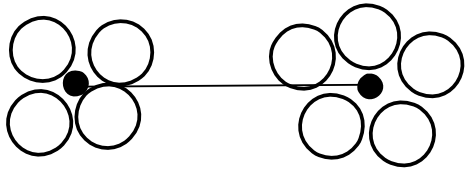
a) Minimum distance



b) Maximum distance



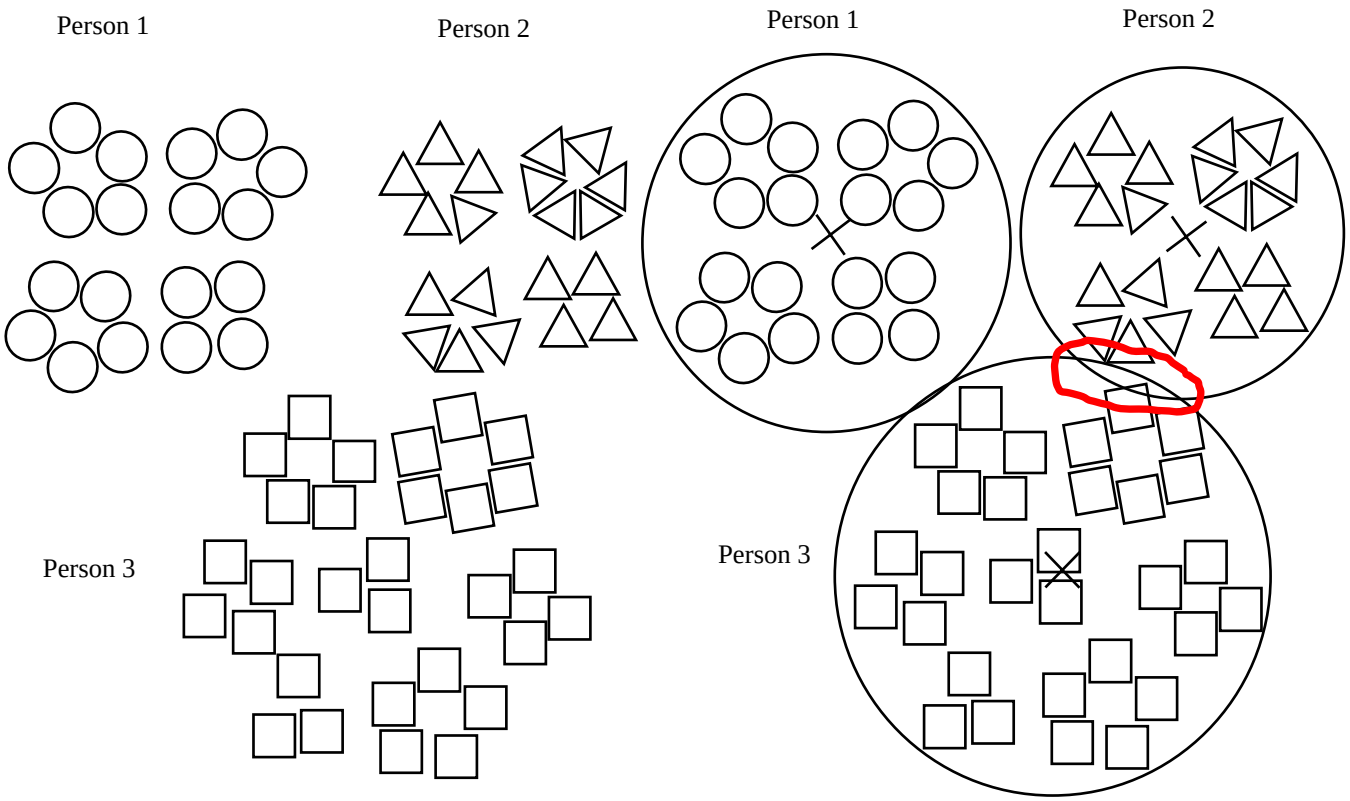
c) Average distance



d) Center distance

Database Construction

- **Database features**

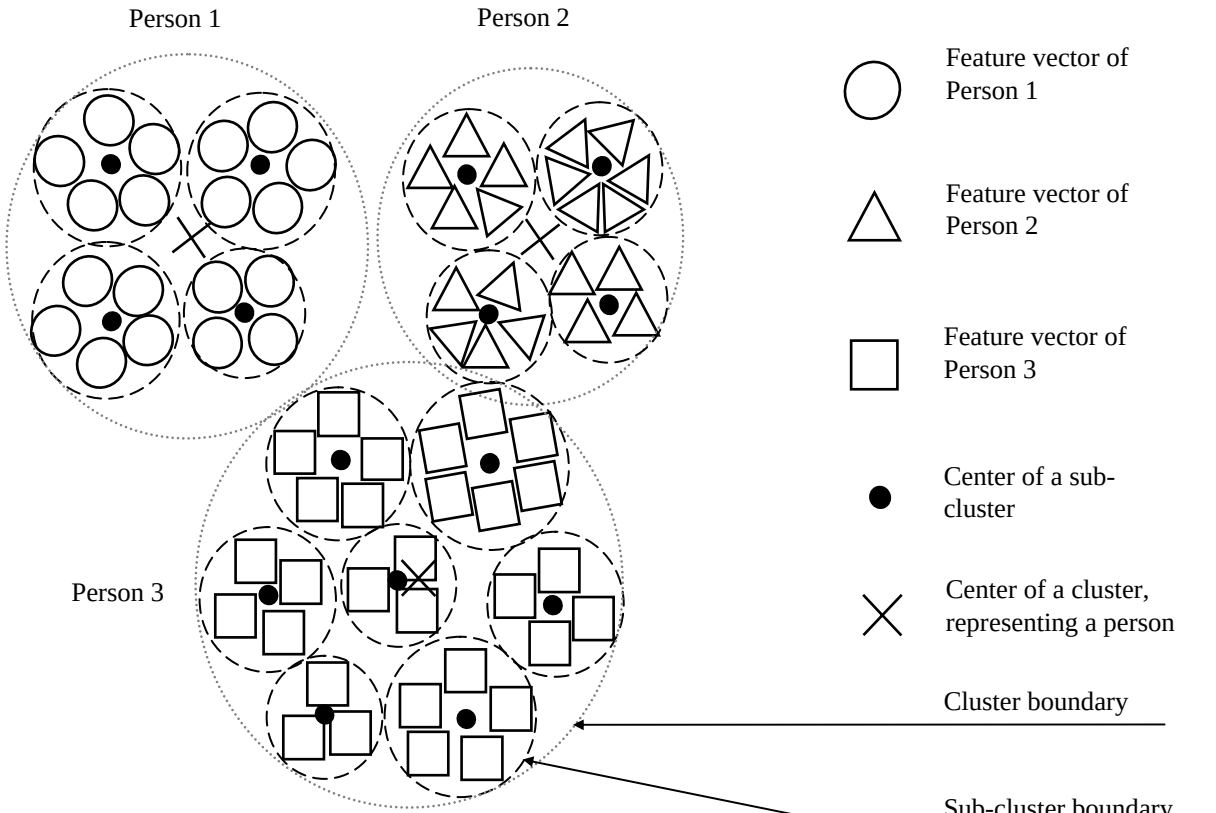


(a) original data without clustering

(b) partitioning clustering method

Database Construction: Improvement of Boundary Overlap

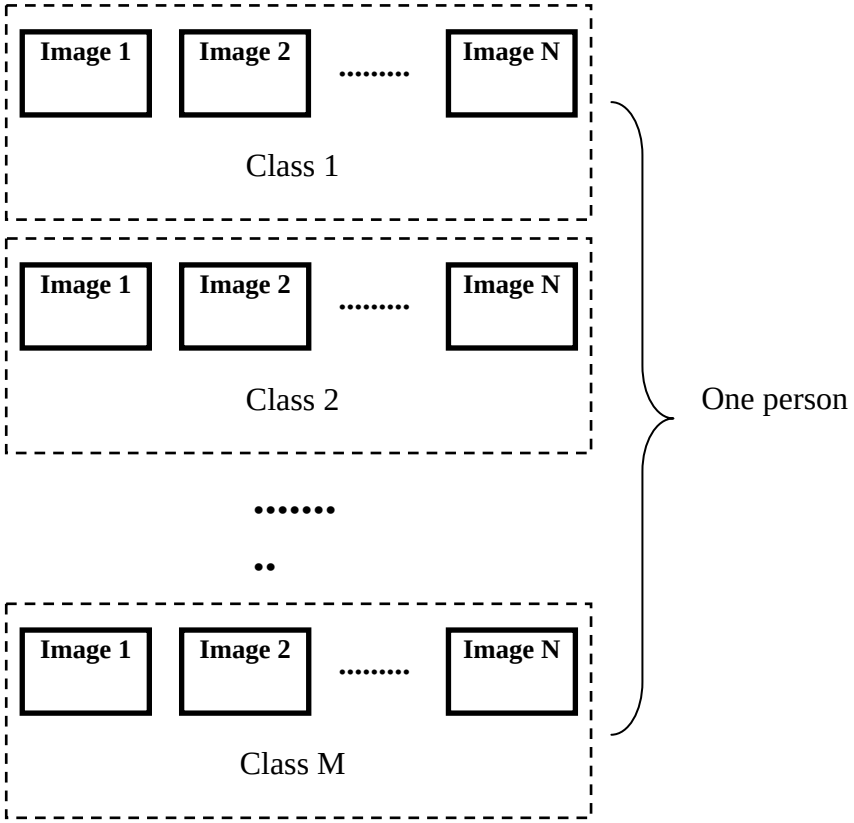
- **Database features**



(c) An improved clustering method

Database Construction

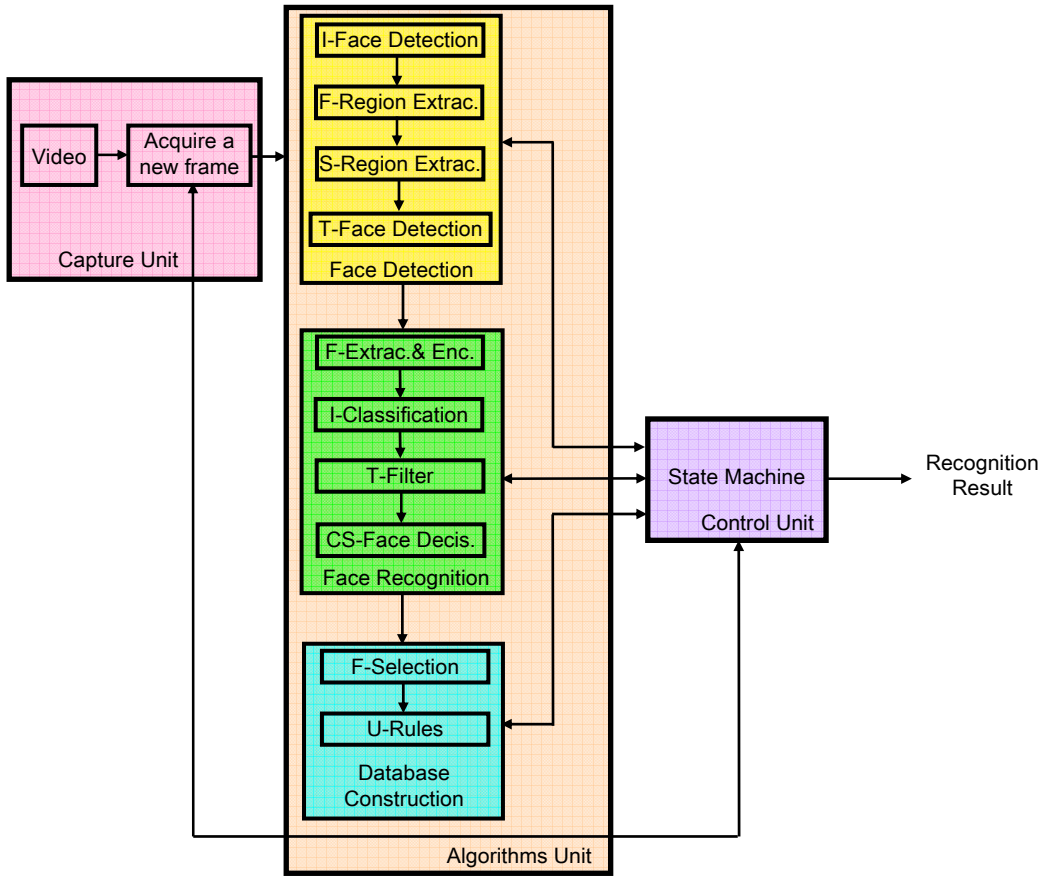
- **Database features**



Structure of one person's database (Experiments suggest 6 < M < 12

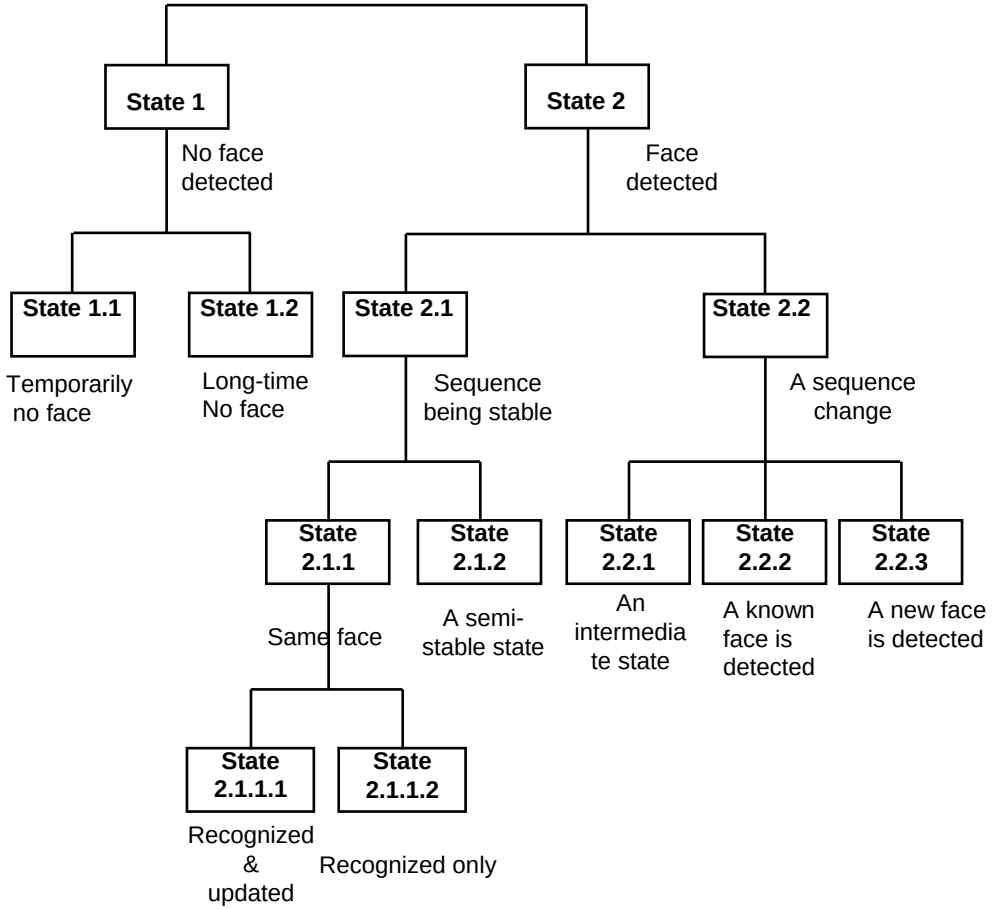
Implementation, System overview

- **Overview of the proposed system architecture**



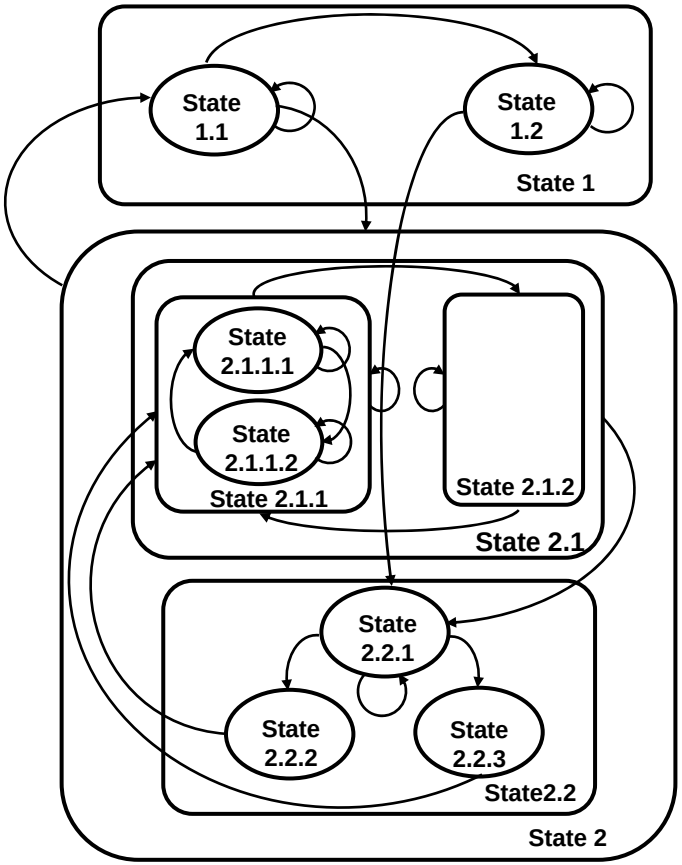
Implementation

- **All possible states for the whole procedure**



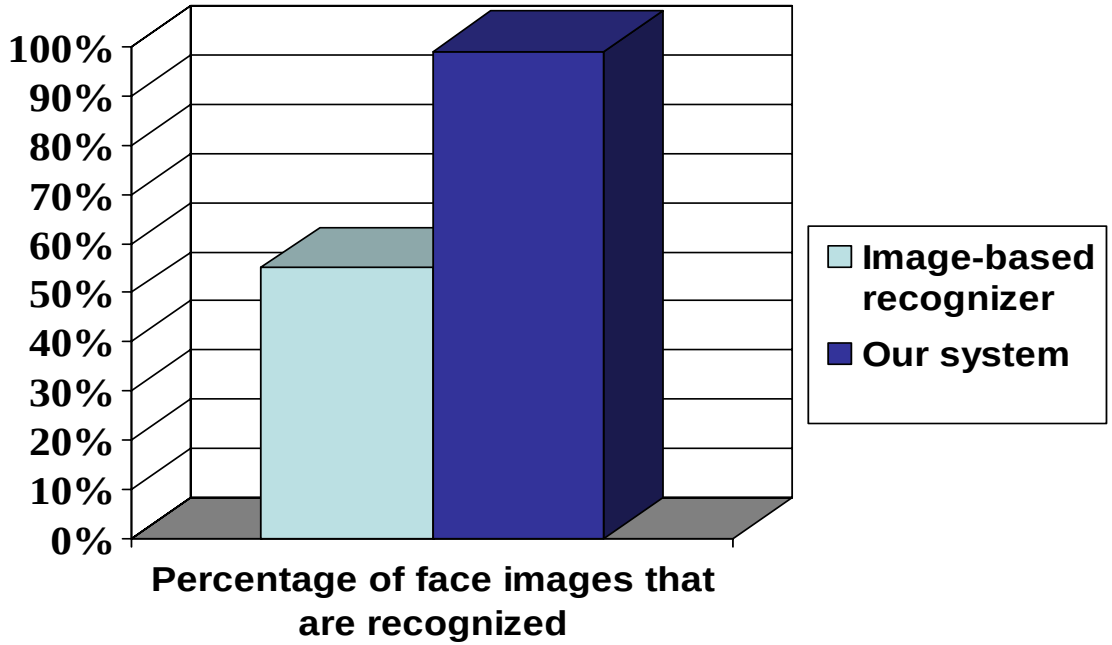
Implementation, State Machine

- **Hierarchical state machine and the transitions**



Performance

- Improvement of FRR



Performance

- **Improvement of FRR**

	Face detection rate under different parameters (in percentage of the whole sequence number)				
	Head pose (Figure 8.1)	Facial Expression (Figure 8.2)	Scale (Figure 8.4)	Luminance (Figure 8.5)	Motion Blurs and Occlusion (Figure 8.6)
IFD alone	45%	41.5%	58.2%	100%	69%
Our detector	93%	100%	98.2%	100%	98.8%

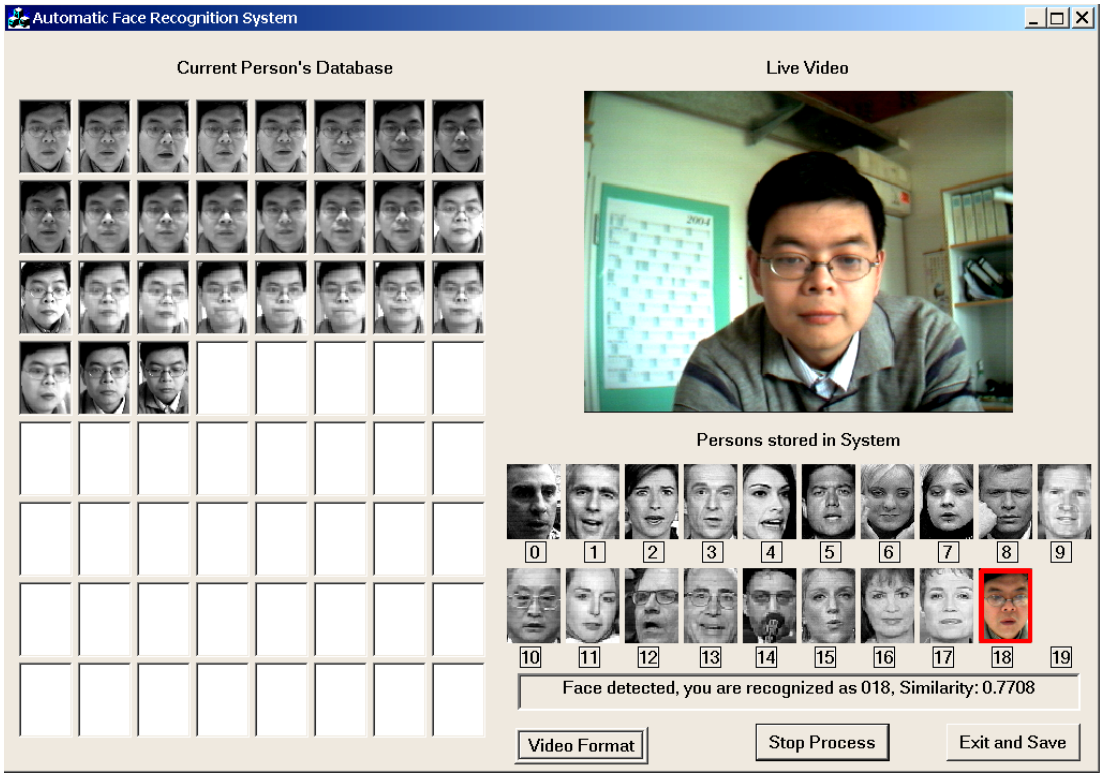
Offline Examples

- **System running offline — one typical example**
  - Sequence 1: one person with 3D head motion
  - Sequence 2: three people freely moving with occlusion
  - Sequence 3: different webcams, aging, without glasses, completely different background and lighting conditions



Demo-System

- **System running live**



Summary & outlook

- **Summary**
  - Contributions
    - Novel combined detection & recognition algorithms
    - Adaptive database construction algorithms
    - State-machine
  - Intelligent self-learning system
- **Future research directions**
  - Multiple face detector
  - Improvement of database redundancy
  - Hardware implementation