Face Recognition summary

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Artificial Intelligence & Information Analysis Lab

Face Recognition

- **Face recognition/identification**
- **Face verification**
- Performance evaluation
- Traditional face recognition
- DNN face recognition
- Facial label propagation

Face Recognition/identification

Problem statement:

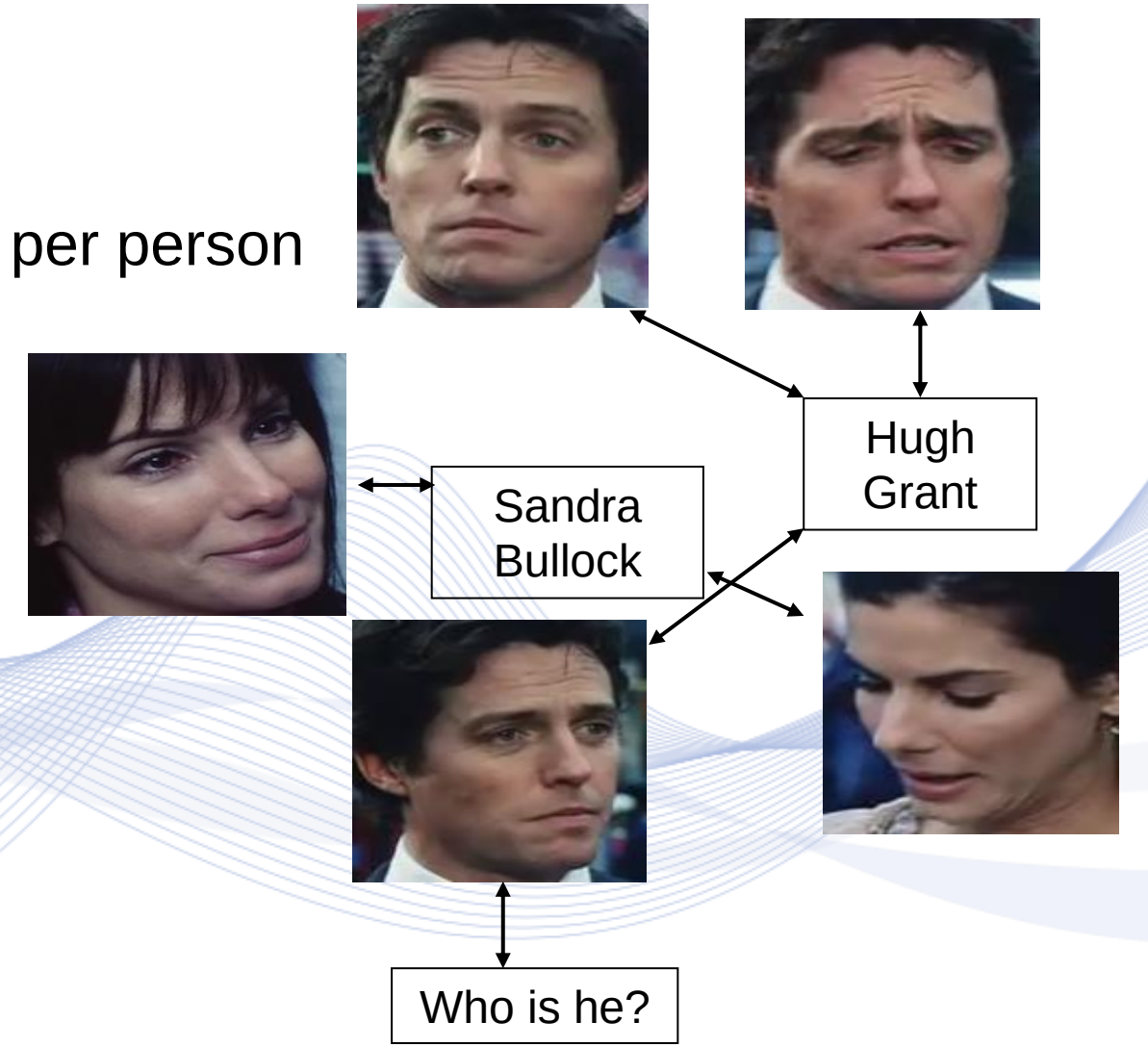
- To identify a face identity
- Input for training: several facial ROIs per person
- Input for inference: a facial ROI
- Inference output: the face id

- Supervised learning
- Applications:

  Biometrics

  Surveillance applications

  Video analytics



Face verification

Problem statement:

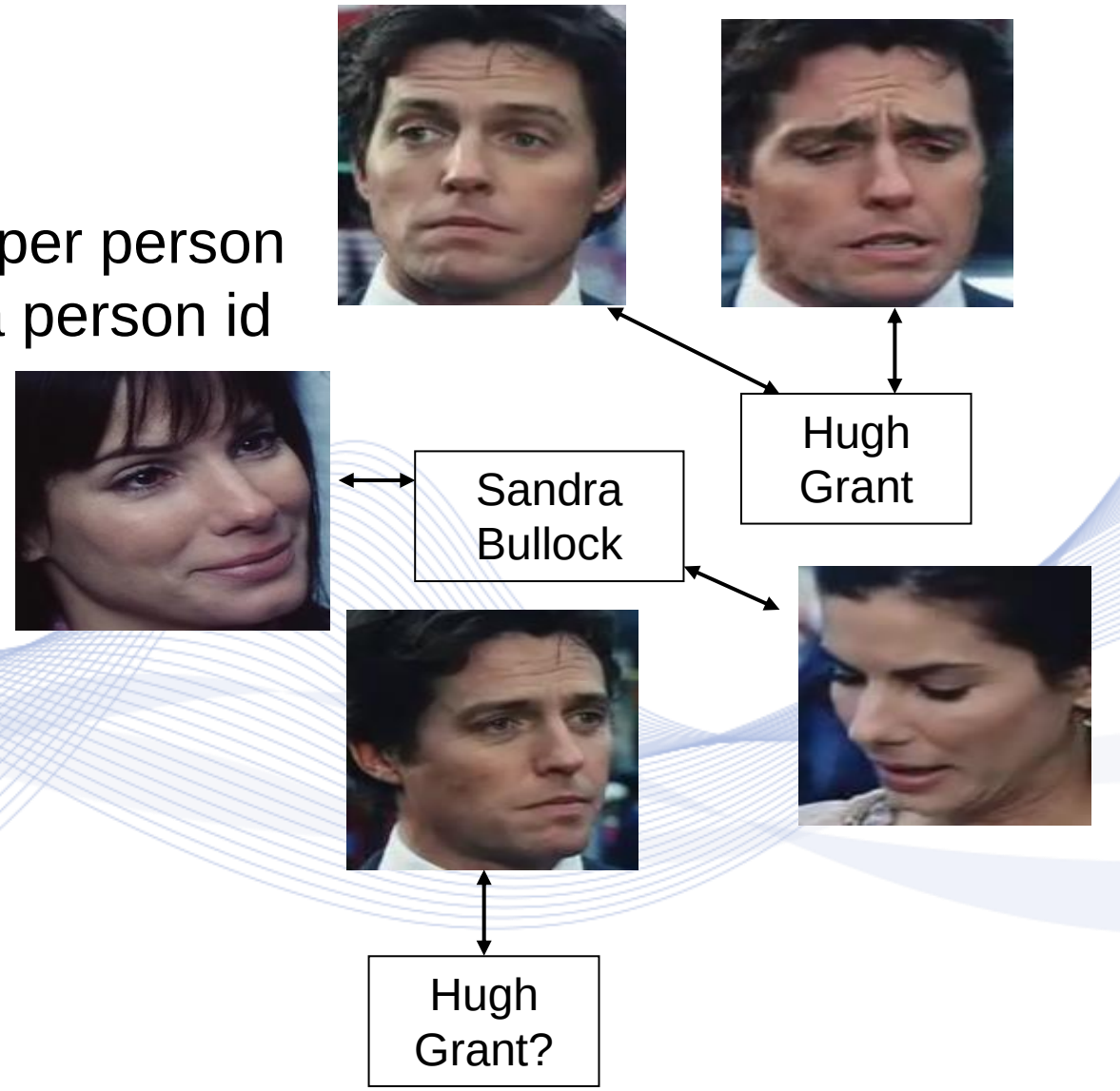
- To verify a face identity
- Input for training: several facial ROIs per person
- Input for inference: a facial ROI and a person id
- Inference output: yes/no

- Supervised learning
- Applications:

  Biometrics

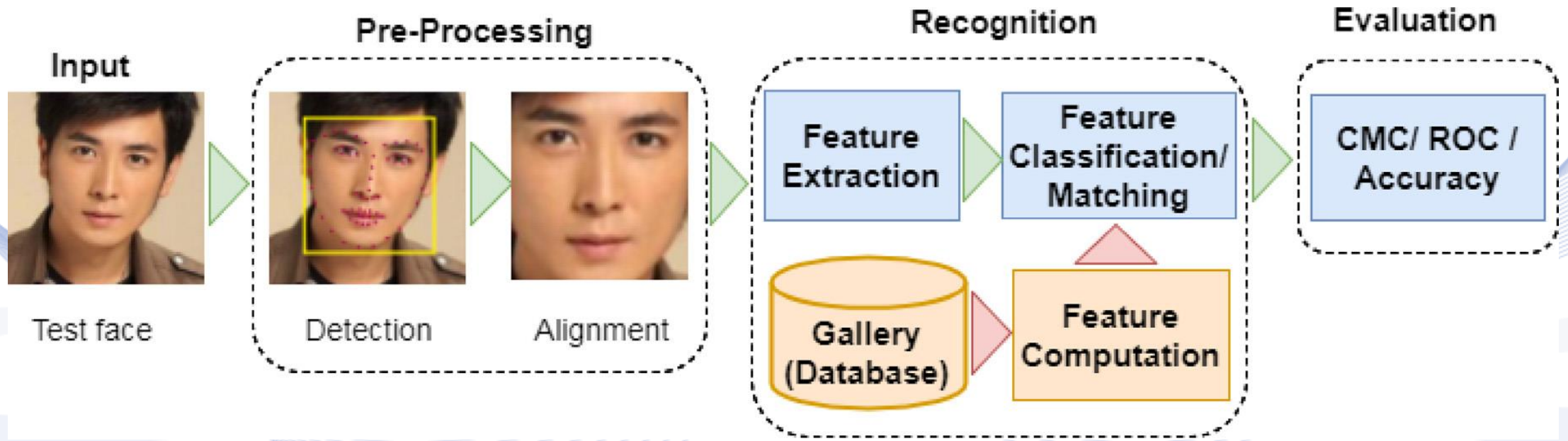
  Surveillance applications

  Video analytics



Face Recognition pipeline

- The basic pipeline that a Face Recognition system use.



Face Recognition pipeline

- General face recognition process.

Face Recognition pipeline

In face matching, there are two different tasks:

- Face Verification (FV):
  - One-to-One comparison.
- Face Identification (FI):
  - One-to-Many comparison.

Face Recognition

- Face recognition/identification
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- **Performance evaluation**
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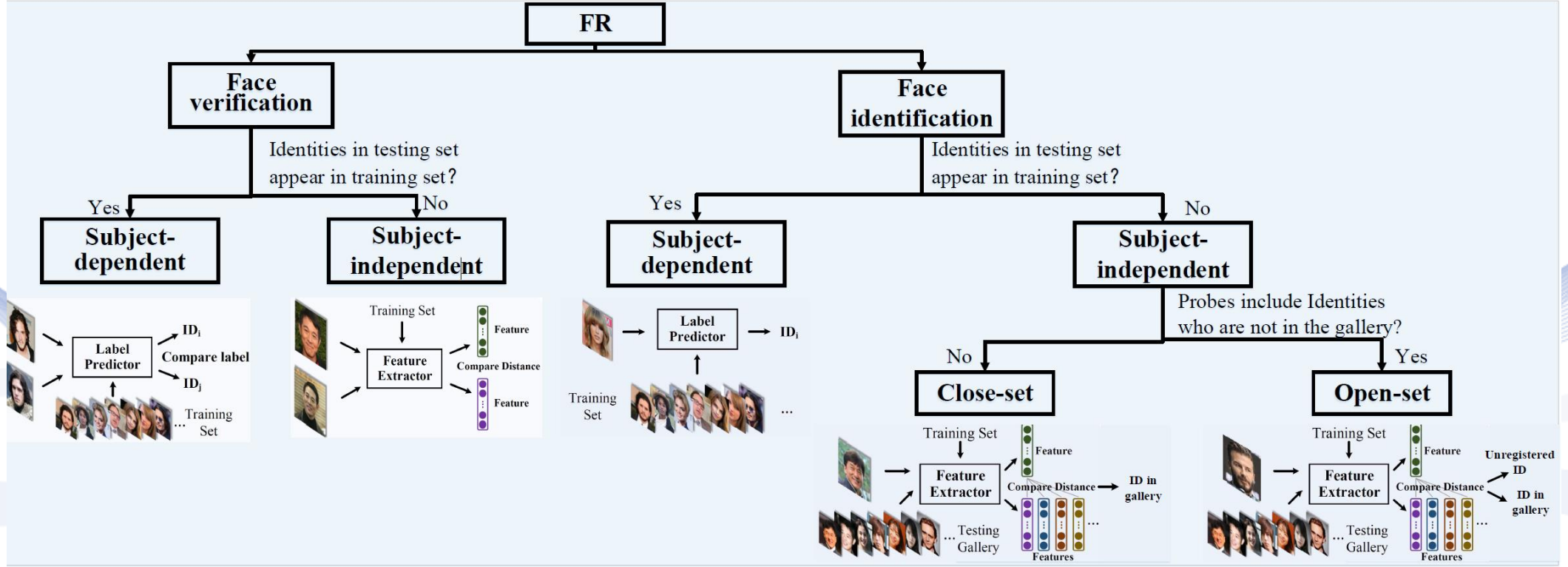
Training protocols and evaluation tasks

- Face Recognition Protocol and Evaluation Tasks



Training protocols

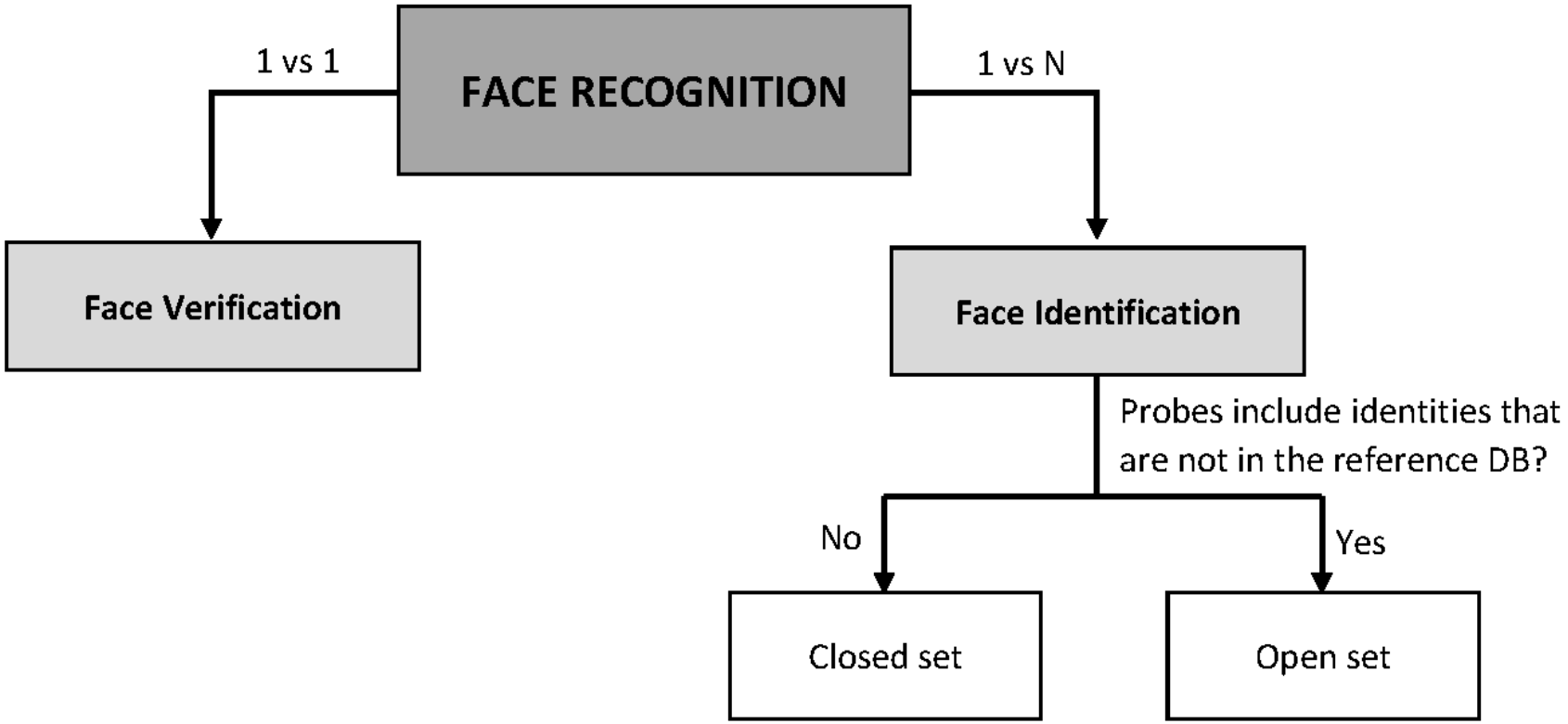
- In terms of training protocol, FR model can be evaluated under settings:
  - Subject-dependent.
  - Subject-independent.
- According to whether testing identities appear in training set or not.

Evaluation tasks

- In terms of testing tasks, the performance of recognition model can be evaluated under settings:
  - Face Verification.
  - Close-set Face Identification.
  - Open-set Face Identification.

Training protocols and evaluation tasks

- Face Verification VS Face Identification



Face Verification Evaluation tasks

- One-to-one comparison.
- Model has to decide whether two face images come from the same person.

Face Verification Performance Metrics

- False Match Rate (FMR):
  - Proportion of non-mated samples (different subject), that are falsely declared as match.
  - True Match Rate (TMR) = 1 - FMR.
- False Non-Match Rate (FNMR):
  - Proportion of mated samples (same subject), that are falsely declare to non-match.
  - True Non-Match Rate (TNMR) = 1 - FNMR.

Face Identification Evaluation tasks

- CLOSED-SET IDENTIFICATION:
  - Input is a face image corresponding to a subject which is known inside the reference database.
  - Find the person within the database.
  - One-to-N comparison, where N is the size of the reference database.

Face Identification Performance Metrics

- CLOSED-SET IDENTIFICATION:
  - Identification rate at rank r:
    - The probability that a transaction by a user enrolled in the system
      - User's true identifier within the top r matches returned.
    - When a single point identification rank is reported, it should be referenced directly to the database size.
      - Example: "The identification rate at rank 1 was 95 % against a database of 250 entries".

Face Identification Evaluation tasks

- OPEN-SET IDENTIFICATION:
  - Input is:
    - Face image corresponding to a subject:
      - Exist.
      - Do not exist in the database.
  - Output is:
    - The identity of the search subject within the database.
    - Or a notification that the person has not been found in the database.

Face Identification Performance Metrics

- OPEN-SET IDENTIFICATION:
  - (True positive) identification rate at rank r:
    - Probability that a transaction by a user enrolled in the system.
      - user's true identifier within the top r matches returned.
  - False-negative identification-error rate (FNIR):
    - Proportion of identification transactions by users enrolled in the system.
      - The user's correct identifier is not included in the candidate list returned.
  - False-positive identification-error rate (FPIR):
    - Proportion of identification transactions by users not enrolled in the system.
      - For which a non-empty list of candidate identifiers is returned.

Face Recognition

- Face recognition/identification
- Face verification
- Performance evaluation
- **Traditional face recognition**
- DNN face recognition
- Facial label propagation

Face Recognition

Two general approaches:

- Traditional methods
  - Subspace methods
  - Elastic graph matching methods.
- DNN face recognition (state of the art)

Face Recognition

Subspace methods

- The original high-dimensional image space is projected onto a low-dimensional one.

- Face recognition according to a simple distance measure in the low dimensional space.

- Subspace methods: **Eigenfaces** (PCA), **Fisherfaces** (LDA), ICA, **NMF, Class Specific NMF (CSNMF)**.

- Main limitation of subspace methods: they require perfect face alignment (registration).

Face Recognition - NMF

- Original facial images are reconstructed using only additive combinations of the resulting basis images.
- Combination weights: coefficients in **H**.

- Consistent with the psychological intuition regarding the objects representation in the human brain (i.e. combining parts to form the whole).

Face Recognition

Elastic graph matching (EGM) methods

- Elastic graph matching is a simplified implementation of the Dynamic Link Architecture (DLA).

- DLA represents an object by a rectangular elastic grid.
- A Gabor wavelet bank response is measured at each grid node.

- Multiscale dilation-erosion at each grid node can be used, leading to Morphological EGM (MEGM).

Face Recognition

Output of normalized multi-scale dilation-erosion for nine scales.

Face Recognition

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Deep Face Recognition/Verification

- Introduction [1][2][3][4][5]
- Traditional Face Recognition System [2]
- Deep Face Recognition pipeline [1][2][4]
- Deep Learning Models [1][3][4]
- Face Recognition Scenes [1]
- Face Recognition Problems [4]

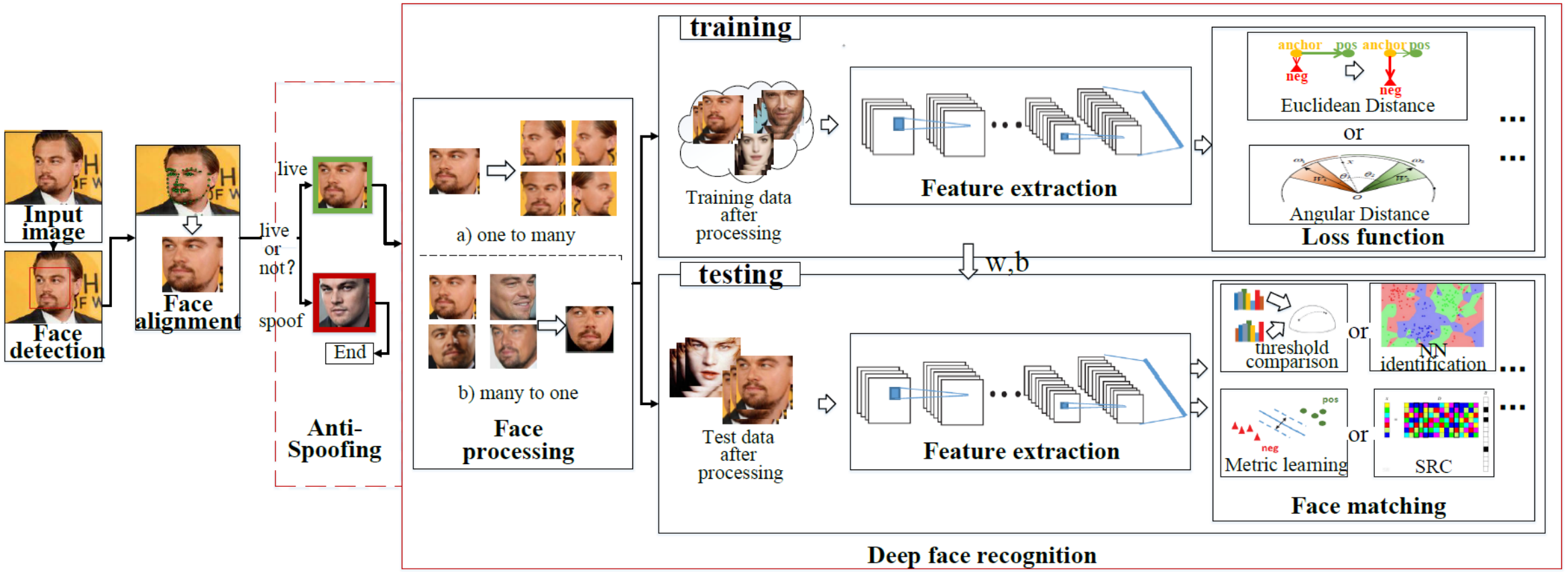
Deep Face Recognition/Verification

- Face recognition is a visual pattern recognition problem:
  - The face/3D-object that is subject to varying:
    - Illumination
    - Pose
    - Expression
    - Other factors that need to be identified based on acquired 2D images.
- Deep Neural Networks have advantages over traditional algorithms (Eigenfaces, Fisherfaces, Bayesian, SVM, etc).
  - Learning ability, generalization and robustness

Deep Face Recognition/Verification

- The main difference between traditional face recognition systems and deep-based approaches lies in the feature extraction algorithm:
  - Features extracted in traditional systems:
    - Are hand-crafted.
  - Features extracted by the deep-based approaches:
    - Learned by the neural network based on a pool of data subjects which is used to train a network based on a specific loss function.

Deep Face Recognition pipeline



Deep Face Recognition pipeline

- Deep FR system with face detector and alignment:
  - First, a face detector is used to localize faces.
  - Second, the faces are aligned to normalized canonical coordinates.
  - Third, the FR module is implemented.

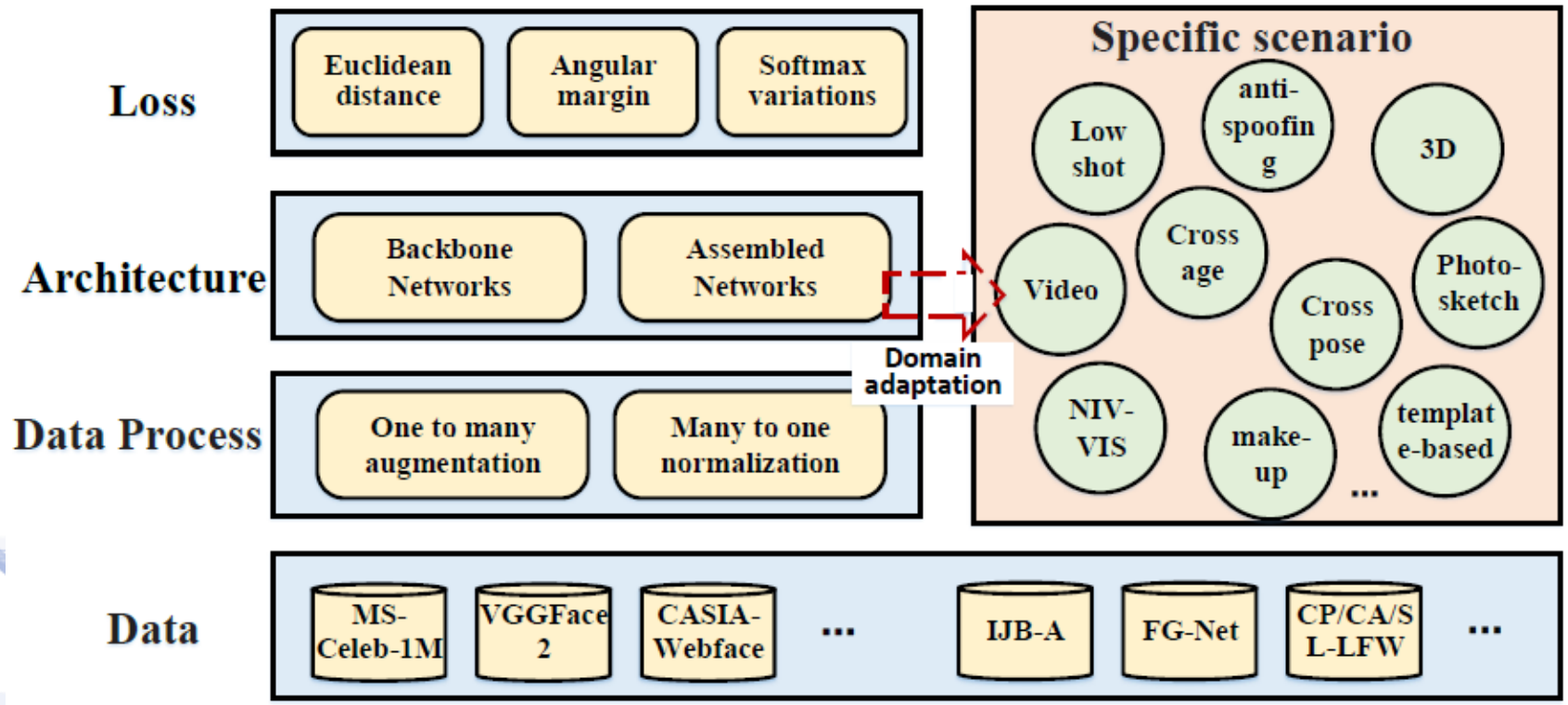
Deep Face Recognition pipeline

- Deep FR module in general:
  - Face anti-spoofing recognizes whether the face is live or spoofed.
  - Face processing is used to handle recognition difficulty before training and testing.
  - Different architectures & loss functions are used to extract discriminative deep feature when training.
  - Face matching methods are used to do feature classification when the deep feature of testing data are extracted.

Deep learning models

- Convolutional neural networks (CNNs).
- Auto encoder (AE).
- Restricted Boltzmann machine (RBM), Deep Belief networks (DBNs), Deep Boltzmann machines (DBMs).
- Generative Adversarial Networks (GANs).
- Hybrid architectures.

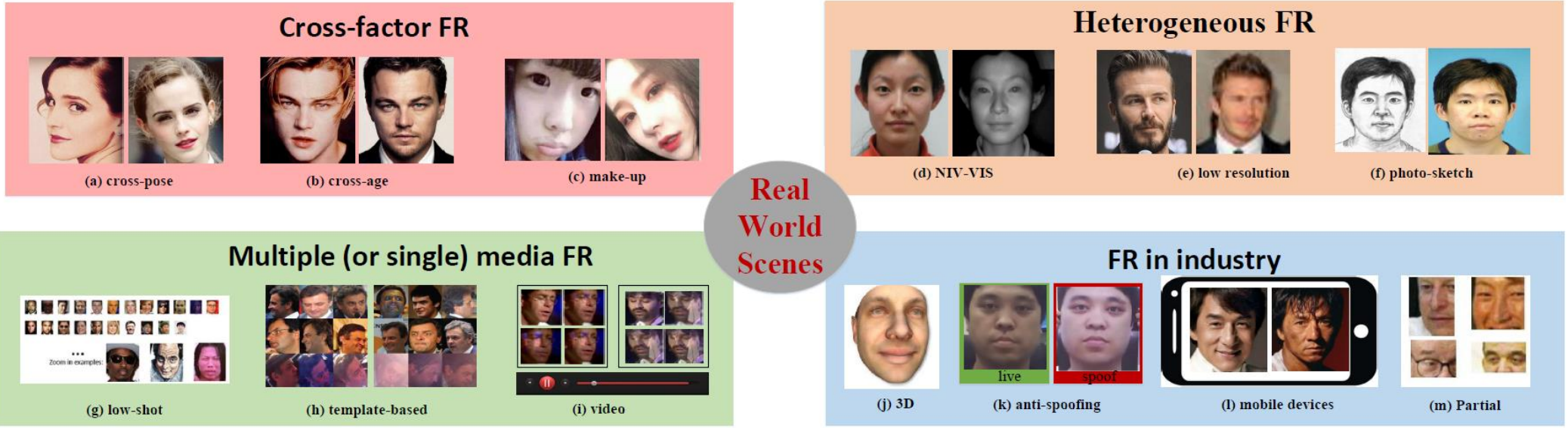
Modules of FR and commonly used Methods



Deep Face Recognition Scenes

- Real World Scenes:
  - Cross-factor FR.
  - Heterogenous FR.
  - Multiple (or single) media FR.
  - FR in industry.

Deep Face Recognition Scenes



Deep Face Recognition Scenes

- Cross-factor FR:
  - Cross-Pose Face Recognition.
  - Cross-Age Face Recognition.
  - Makeup Face Recognition.

Deep Face Recognition Scenes

- Heterogenous FR:
  - NIR-VIS Face Recognition.
  - Low-Resolution Face Recognition.
  - Photo-Sketch Face Recognition.

Deep Face Recognition Scenes

- Multiple (or single) media FR:
  - Low-Shot Face Recognition.
  - Set/Template-Based Face Recognition.
  - Video Face Recognition.

Deep Face Recognition Scenes

- FR in industry:
  - 3D Face Recognition.
  - Partial Face Recognition.
  - Face Anti-attack.
  - Face Recognition for Mobile Devices.

Face Recognition Problems

- Still image-based face recognition (SIFR).
- Video-based face recognition (VFR).
- Heterogeneous face recognition (HFR).
- Image set-based face recognition (ISFR).
- Hard mining.
- Closed-set vs. open-set face recognition.

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- **Facial label propagation**

Facial label propagation

Problem statement:

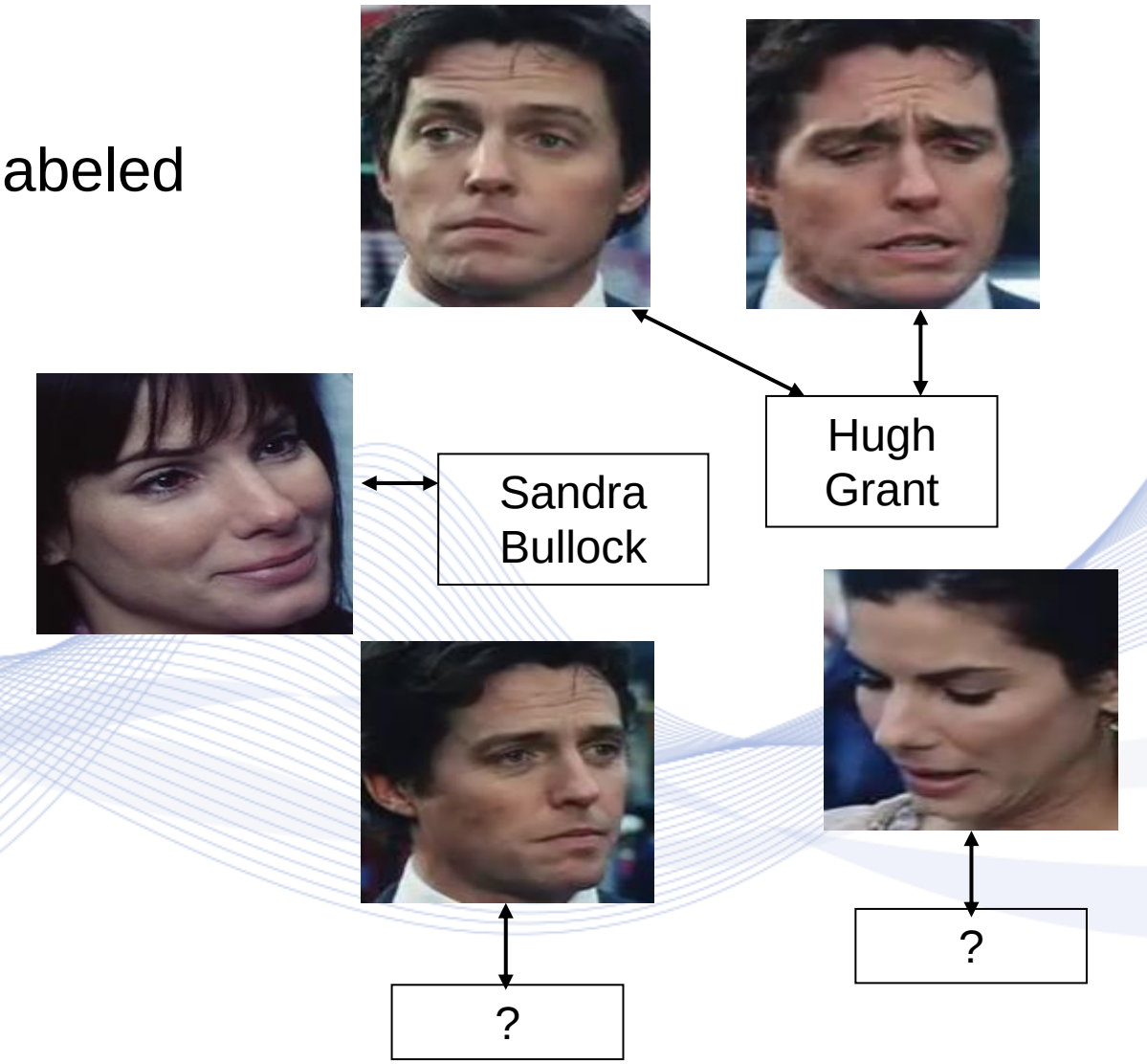
- To transfer labels from labeled to unlabeled facial images
- Input: a) labeled facial ROIs,
  b) unlabeled facial ROIs
- Output: facial image labels

- Semi-supervised learning
- Applications:

  Biometrics

  Surveillance applications

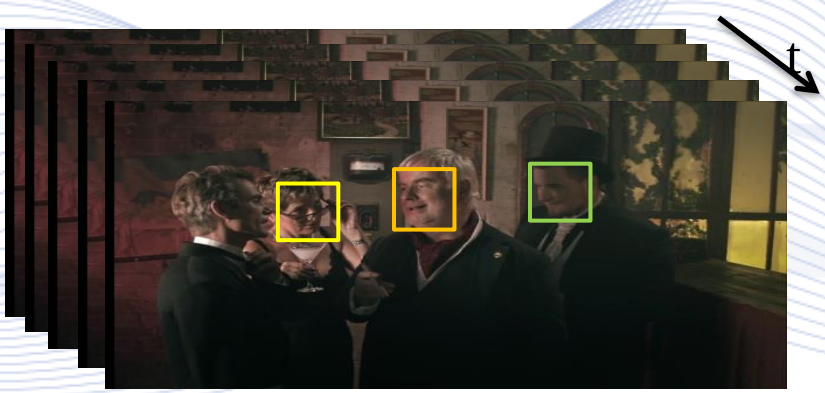
  Video analytics



Label propagation on facial videos

Problem description:

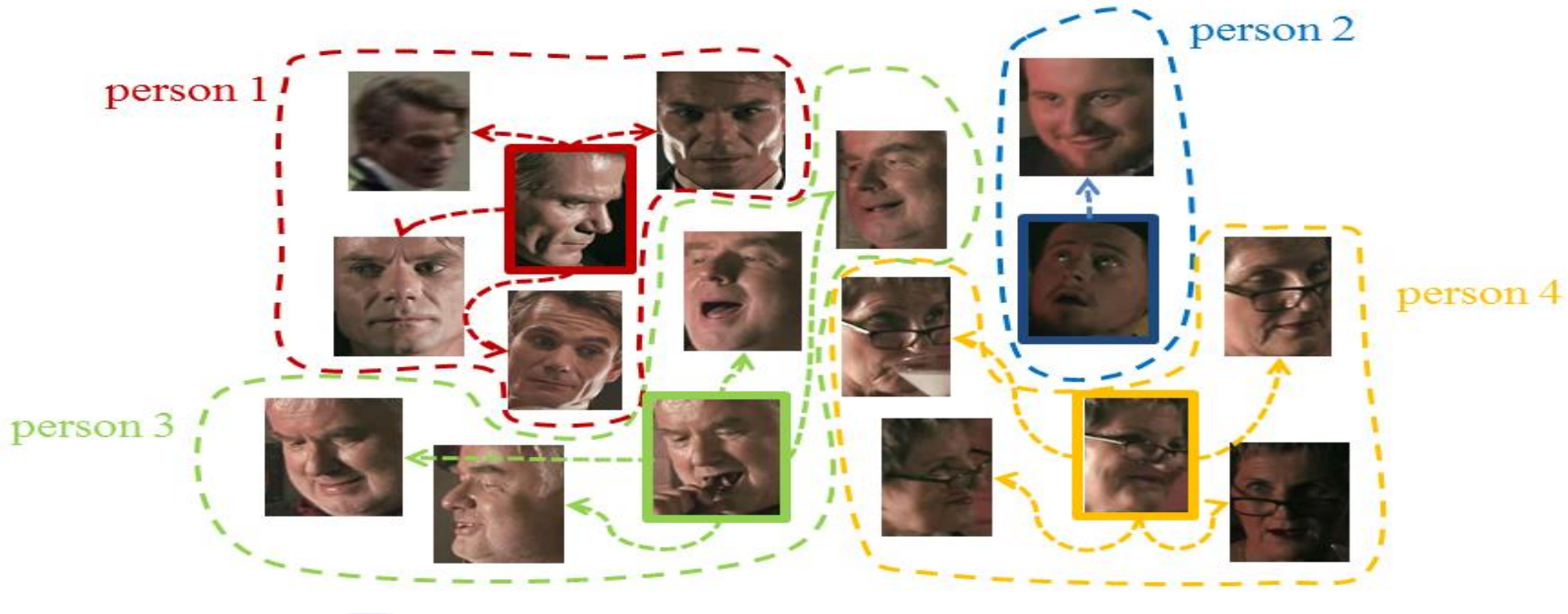
- Person identity label propagation on stereo facial images, starting from a small set of data with known label.
- The facial images are automatically extracted from the video by performing automatic face detection and tracking to the left and right video channel



Facial video.

Label propagation on facial videos

- Label propagation is a label diffusion process from a small set of labeled data $X_L = \{x_i\}_{i=1}^{n_l}$ to a larger set of unlabeled data $X_U = \{x_i\}_{i=1}^{n_u}$



Label propagation on facial videos

- In cases where the data can be represented in more than one feature spaces, one graph can be constructed for each representation method.

- The fusion of multiple data representations can be performed:
  - at the graph construction level (early fusion).
  - at the decision taking level (late fusion).

- The performance of label propagation algorithms depends highly on
  - The data representation method (the data graph construction);
  - The selection of the initially labeled data set.

Bibliography

[PIT2021] I. Pitas, “Computer vision”, Createspace/Amazon, in press.
[PIT2017] I. Pitas, “Digital video processing and analysis” , China Machine Press, 2017 (in Chinese).
[PIT2013] I. Pitas, “Digital Video and Television” , Createspace/Amazon, 2013.
[NIK2000] N. Nikolaidis and I. Pitas, “3D Image Processing Algorithms”, J. Wiley, 2000.
[PIT2000] I. Pitas, “Digital Image Processing Algorithms and Applications”, J. Wiley, 2000.

Q & A

Thank you very much for your attention!

More material in
http://icarus.csd.auth.gr/cvml-web-lecture-series/

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