User-Independent Gaze Estimation by Exploiting Similarity Measures in the Eye Pair Appearance Eigenspace

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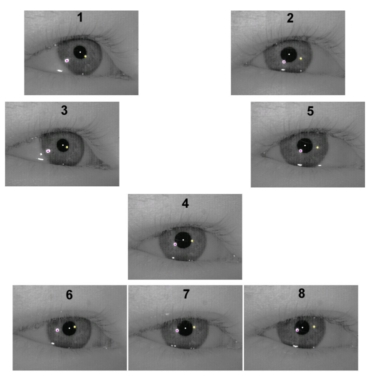
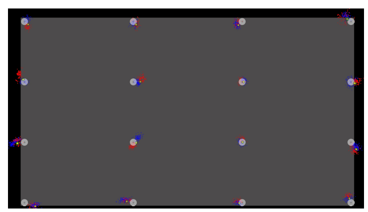
Motivation

- Gaze indicates visual awareness
  - Human-computer interaction (HCI)
  - Market analysis
  - Social behavior
  - Driver distraction

Common Approach

- User and setting specific parameters are acquired by calibration
  - Repetitive and tedious calibration process
  - Constraints imposed on the user





Field of Interest

IR light

Our Vision

- User-independent gaze estimation that do not require calibration, or put any constraints on the users
  - Appearance-based approach (simple system setting)
  - Focus on eye pair image (implied head pose)
  - Large database (capture variance among the users)

MSP-GAZE Database

It considers:

- Individual differences
  - 46 subjects
  - Gender balanced
  - Diverse ethnic groups (Caucasian - 16, Asian - 10, Indian - 10, and Hispanic - 10)
- Head movement
  - Balanced between with and without head movement
- Inter-session variability
  - Two sessions for each subject on two different days
- Distance between user and screen
  - User defined
  - Near - 0.4m
  - Medium - 0.5m
  - Far - 0.6m

MSP-GAZE Database

System setup

MSP-GAZE Database

Recording	Head Movement	Distance	Pattern
1	Yes	User-defined	Testing
2	Yes	User-defined	Training
3	Yes	Near	Training
4,5	Yes	Medium	Training
6,7	Yes	Far	Training
8	No	User-defined	Testing
9	No	User-defined	Training
10	No	Near	Training
11,12	No	Medium	Training
13,14	No	Far	Training

Highlights of the Study

- **Appearance based model**
  - Eigenspace representation (PCA)
- **Reduce the gap between user-dependent (UD) and user-independent (UI) gaze estimation**
  - Similar frame
  - Similar subject

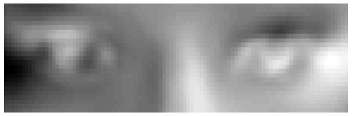
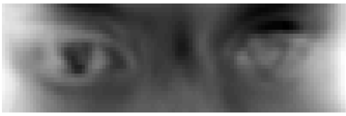
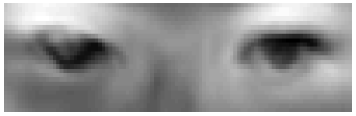
Appearance Based Model

- Eigenspace representation (PCA)
  - PCA construct the orthogonal basis - eigenvectors to the larger eigenvalues of the covariance matrix Σ.

$$\Sigma=\sum_{i=1}^{N}\Phi_i^T\Phi_i$$

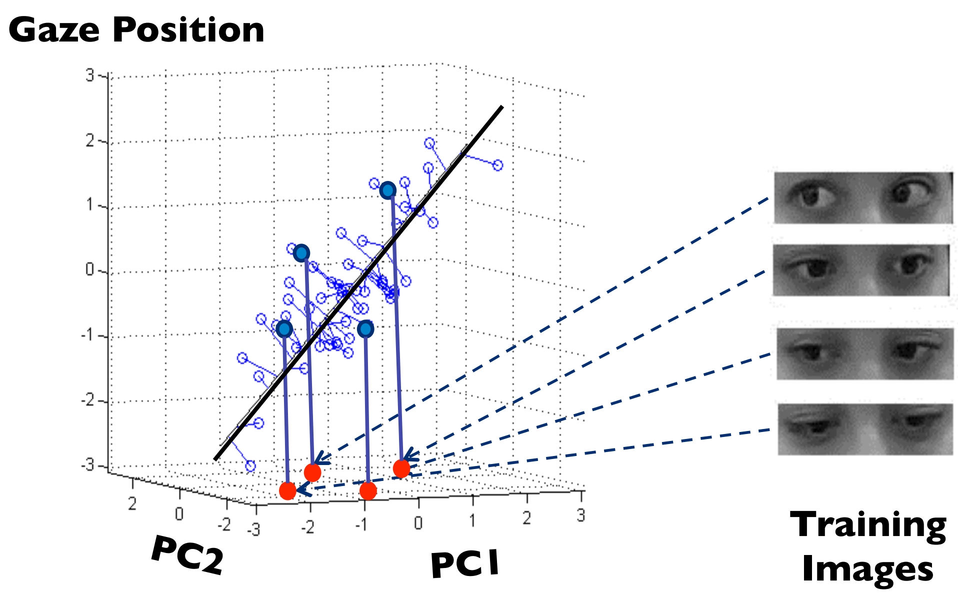
Φ_i - mean removed vectorized eye pair images

  - These bases capture the main variance among the eye appearance
  - We use the projections to these bases as independent variables to build regression model for gaze estimation

Appearance Based Model

- PCA and Regression model for gaze estimation



y = β{ β p2 + β + β p 30 + β p2 @ 1280, ..., β > 1080 @ 10

Difference between UD and UI

- User Dependent Results

	Without head motion			With head motion		
Distance	ρ_x	ρ_y	Θ_{error}	ρ_x	ρ_y	Θ_{error}
Near	0.90	0.85	4.7	0.91	0.84	4.5
Medium	0.89	0.84	3.8	0.91	0.83	3.9
Far	0.88	0.83	3.5	0.90	0.83	3.4
User-Defined	0.89	0.82	3.9	0.88	0.82	3.9

2.0

2.1

- User Independent Results

	Without head motion			With head motion		
Distance	ρ_x	ρ_y	Θ_{error}	ρ_x	ρ_y	Θ_{error}
Near	0.85	0.76	7.0	0.87	0.75	6.8
Medium	0.86	0.75	6.0	0.85	0.74	5.9
Far	0.85	0.68	5.3	0.85	0.73	5.2
User-Defined	0.85	0.78	5.9	0.86	0.70	6.0

ρ_x - x correlation; ρ_y - y correlation; Θ_{error} – angular error

Difference between UD and UI

Challenges in UI gaze estimation

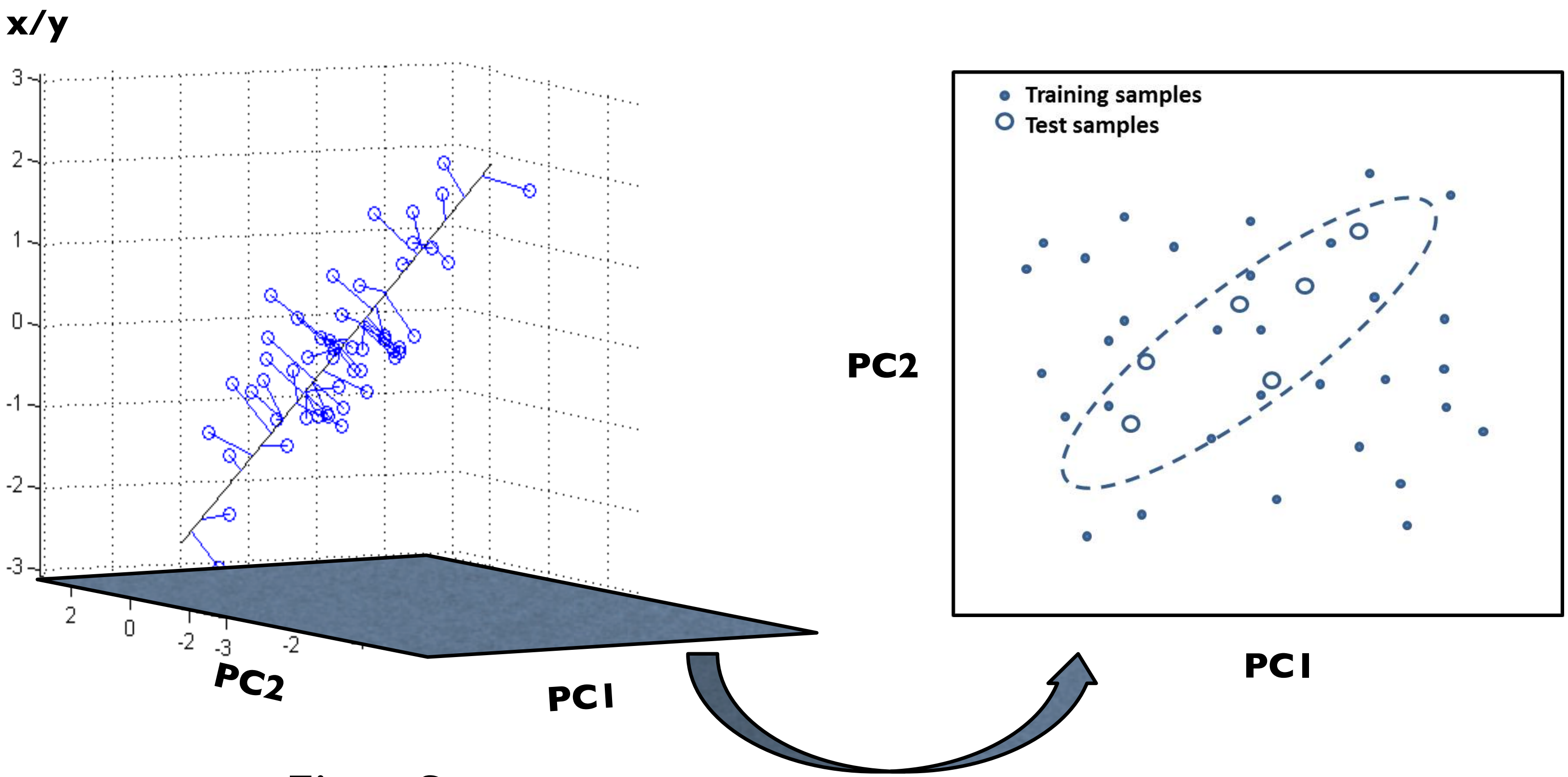
- Individual differences affect the orthogonal basis to represent the target subject

Based on the premise that "*not all data is good data*", we use similarity measures in the eigenspace to find "good data"

- Similar frames
- Similar subjects

$$\Sigma_{All} = \sum_{i=1}^{N} \Phi_i^T \Phi_i \rightarrow \Sigma_S = \sum_{i \in S} \Phi_i^T \Phi_i$$

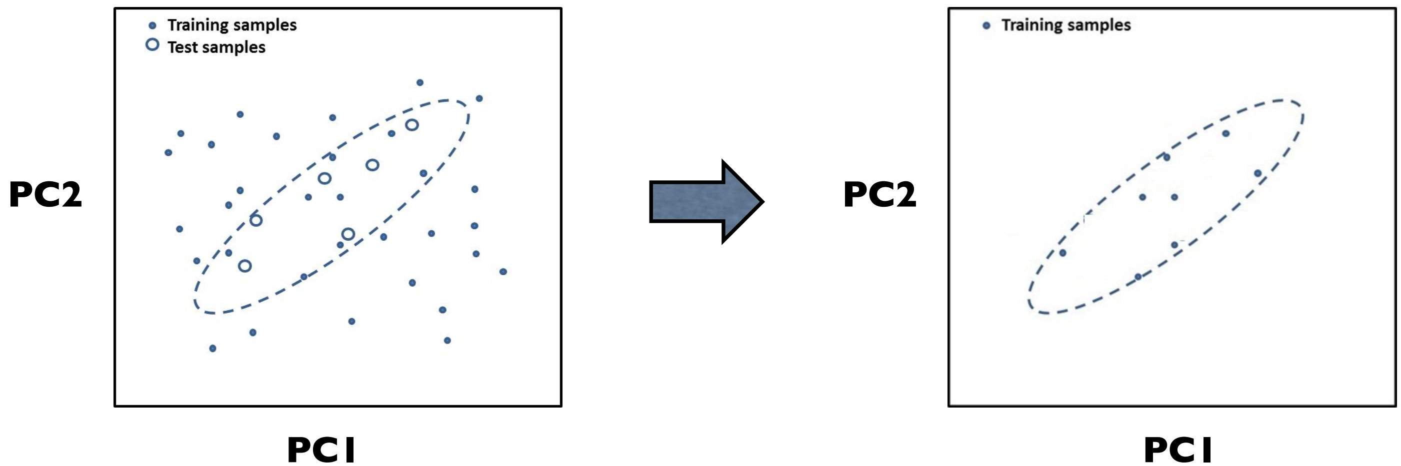
Finding Similar Data



Eigen Space

Finding Similar Data

- Similar frames



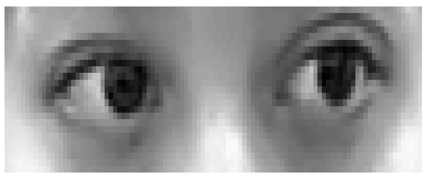
- Similar subjects
  - The most frequently appeared subject in the similar frames

Finding Similar Data

Test image

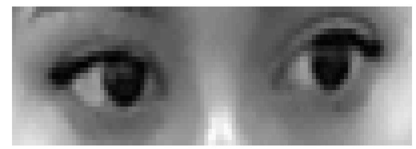
Identified Similar frames

Sub 36



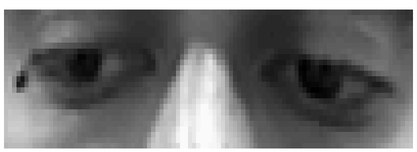
Gaze positions (68, 160)

Sub 44



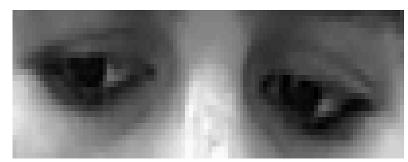
Gaze positions (75, 99)

Sub 1



Gaze positions (1600, 967)

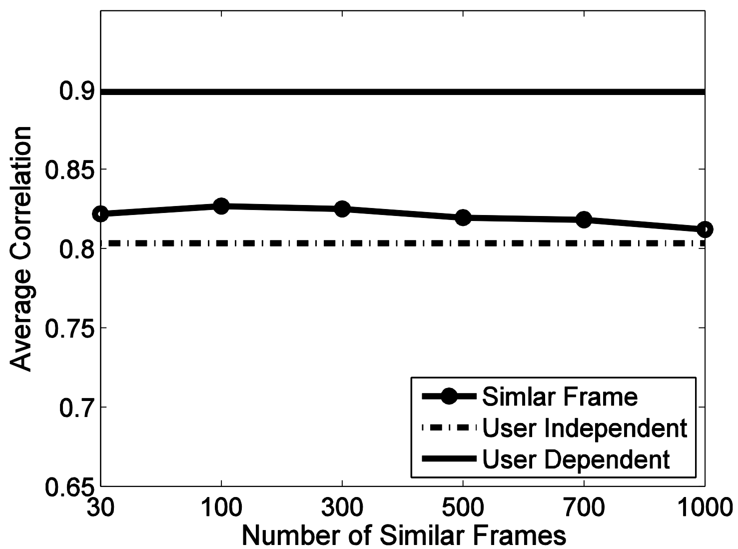
Sub 24



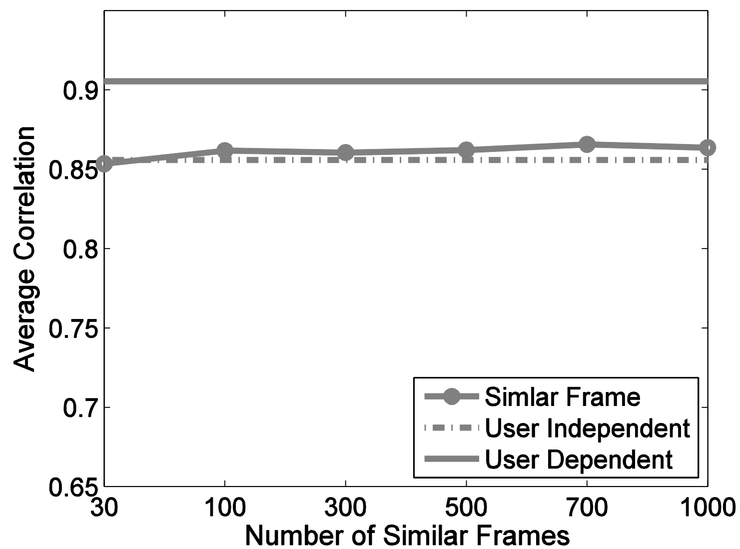
Gaze positions (1526, 931)

Experiment results

- Similar frames



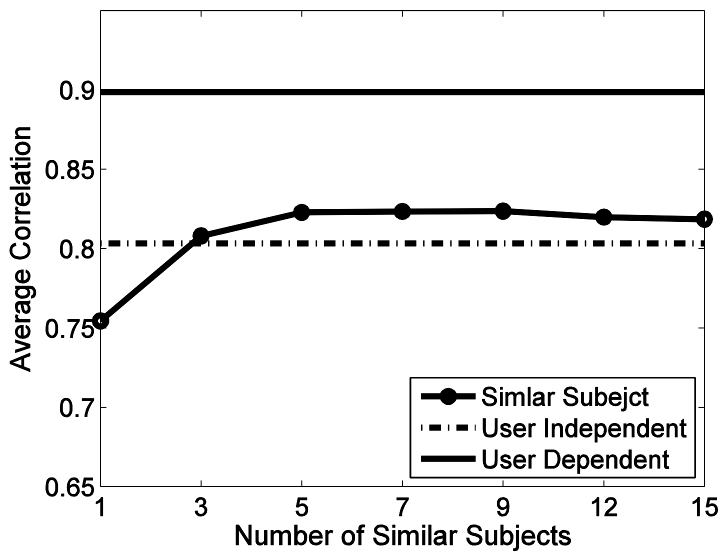
With Head Movement



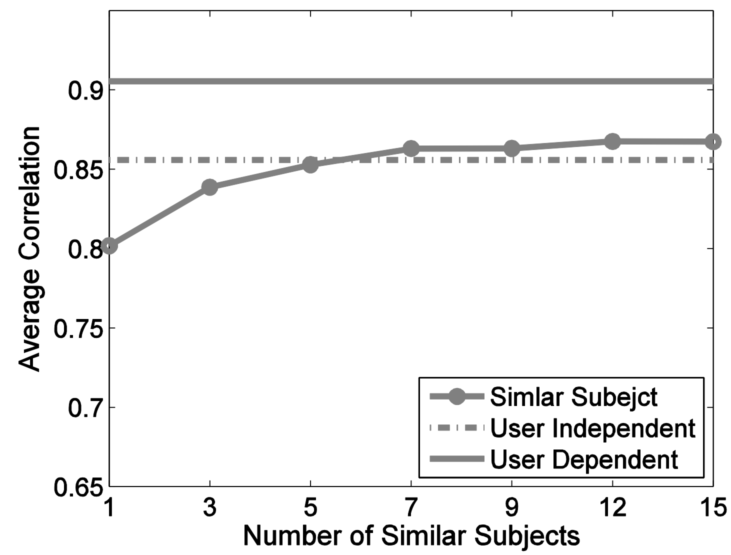
Without Head Movement

Experiment results

- Similar subjects



With Head Movement



Without Head Movement

Experiment results

		Without head movement		With head movement	
	Distance	ρ_x	ρ_y	ρ_x	ρ_y
7 Similar subjects	**Far**	0.90	0.79	0.88	0.72
	Medium	0.93	0.82	0.90	0.74
	Near	0.93	0.87	0.93	0.78
	User-Defined	0.91	0.78	0.88	0.74
100 Similar frames	**Far**	0.90	0.81	0.88	0.72
	Medium	0.92	0.80	0.90	0.74
	Near	0.93	0.82	0.93	0.77
	User-Defined	0.92	0.81	0.90	0.76

Conclusion

- We identified similar training data samples in the eigenspace for user-independent gaze estimation
- We used the reduced training set to build the eye appearance eigenspace
- By user-independent model, the proposed approach eliminates the requirement for calibration
- For real application, start with user-independent models, as more test samples become available, create and update the reduced set S

We would like to thank our sponsor SAMSUNG

Thank you!

Questions?