From Pixels to People: A Model of Familiar Face Recognition by *Burton, Bruce and Hancock*

Presented by
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Agenda

- Motivation
- IAC model
- Front-End to the IAC model
- Combination model
- Testing the model
- Frequently Asked Questions
- Discussion & Conclusion

Motivation

- Research in Face Recognition has been divided into perception-based and cognition-based projects
- This paper presents a model of human face recognition which combines perceptual and cognitive components

Combining Perception and Cognition

- Perception maps visual image onto a given representation or label
- Cognition is used for analysis of the individuated faces in perception
- Combination was attempted in Speech perception earlier (TRACE)
- Combination was done by attaching a front-end to an existing cognitive model of person recognition

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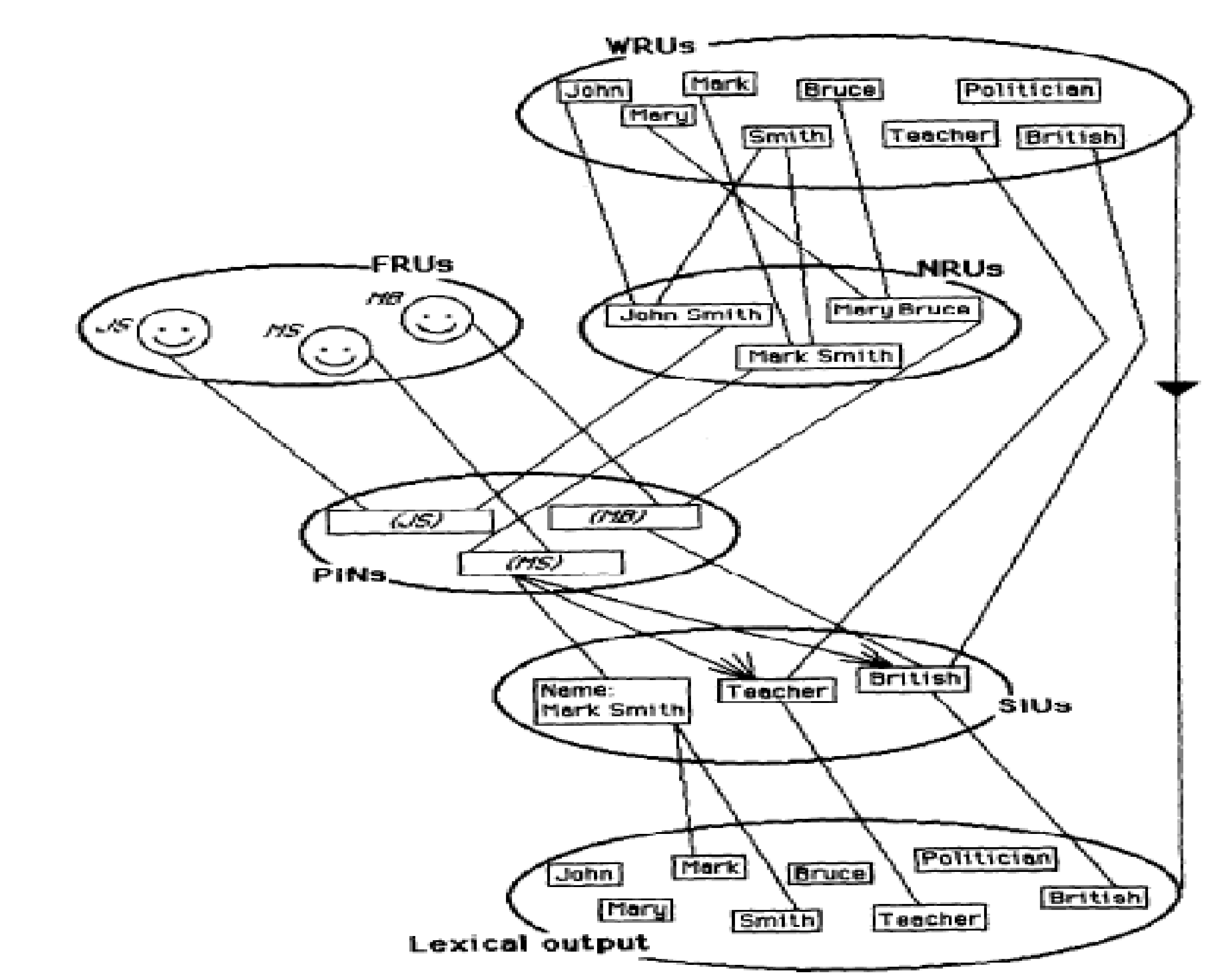
IAC (Interactive Activation & Competition) Model

- Model of cognitive aspects
- Simple form of connectionist architecture comprising pools of simple processing units
- Within pools all units inhibit each other
- Across pools, excitatory links will be there between individual units
- All links are initially of equal strength

IAC model diagram



FRUs and PINs

- For face classification, view independent Face Recognition Units (FRUs) were proposed
- Next level of classification is for persons rather than faces and Personal Identity Nodes (PINs) were proposed
- Locus for familiarity decisions is the PINs

SIUs and Lexical Outputs

- Information about a person is coded in the form of a link between the person's PIN and relevant SIU (Semantic Information Unit)
- *Lexical Outputs* are the pool of units intended to capture the first stage of processes involved in speech and other output modalities

WRUs and NRUs

- WRUs (Word Recognition Units) are the input lexicon which code the names.
- WRUs are linked to NRUs (Name Recognition Units)
- NRUs are linked to PINs
- WRUs which are not names are connected to SIUs and all WRUs are connected to lexical output

Semantic (Association) Priming

- Semantic priming is most often demonstrated with the face familiarity decision task
- Face is recognized faster if immediately preceded with the face of an associated person (Bruce & Valentine,1986).
- Example is Laurel & Hardy
- Semantic priming is crossing domains
- Effect of priming is expected to be short-lived

Repetition Priming

- Face can be recognized faster if it has been seen previously (Bruce, & Valentine, 1985; Ellis, Young, Flude, & Hay, 1987a).
- Comparatively long-lasting
- Effect is strong when prime and target are same and will still be there when different images of same person were used
- This phenomenon was captured by global hebbian strengthening in the model
- No prediction of cross-domain priming

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Front-End to the IAC model

- How do FRUs become active?
- How might we implement as system in which FRUs act as localized units for individualized faces?
- What are the primitives of face recognition?
- Research suggests that face descriptions are based upon *image features* rather than *edge features*
- *Principal Component Analysis* (PCA) is a description scheme based on image features

Principal Component Analysis

- Radical data compression
- Aim is to deliver a new basis to a set of multi-dimensional data
- Analogous to Factor Analysis Technique used in Psychology
- PCA delivers a new set of axes, each of which can be displayed in an image of the same size as the originals. These new axes are called “eigenfaces” (Kirby & Sirovich, 1990)

PCA Contd..

- The reason for selecting PCA as image processing technique is
  - PCA encodes the whole face image rather than a symbolic description such as edge-based distances
  - PCA delivers the information about the ways in which faces vary
- PCA approach to face recognition might have some correspondence with human face perception
- O’Toole, Deffenbather,Valentin, and Abdi (1994) have demonstrated that PCA provides a natural account of the other race effect.

Problems Faced

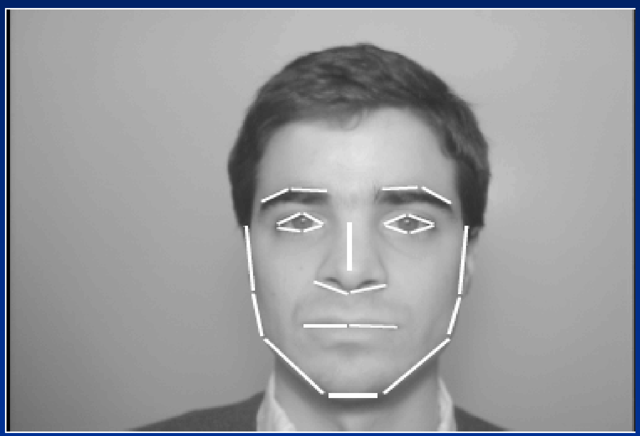
- Size and position of face in the image
- Standardization, typically of eye positions, of faces before applying PCA
- More efficient technique is to standardize the shape of the face, by Craw (1995; Craw & Cameron, 1991)

Craw's technique (Shape-free faces)

- Overlaying each face with a standard grid, with key points at the eyes, nose mouth and round the shape of the face.
- Faces are then morphed to a standard shape, typically average of all the images used resulting in shape-free faces
- The eigen faces are independent of the background
- Gross features (mouth and nose) are in the same position for each face
- The eigen faces can be combined in linear form to give rise to face-like objects

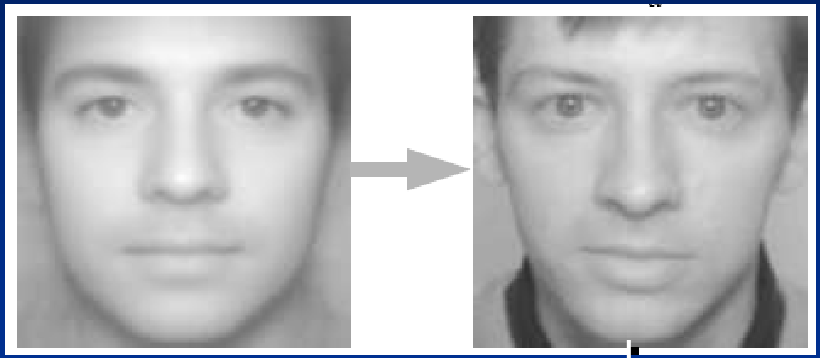
Craw's Technique

grids



Average face

Given face



Face obtained

1995, Beymer

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Combination Model

- The model is combination of IAC component, representing cognitive aspects of face recognition, and the PCA front-end, representing perceptual aspects of face recognition

PCA front-end

- The model was constructed to know 50 people
- 50 young men were photographed to get 50 neutral and 136 expression faces
- All photographs were captured onto grey-level (8 bit) computer images at resolution 280x240 pixels.
- Shape-free versions of all the images were generated by specifying the coordinates of 31 points on each face by hand.

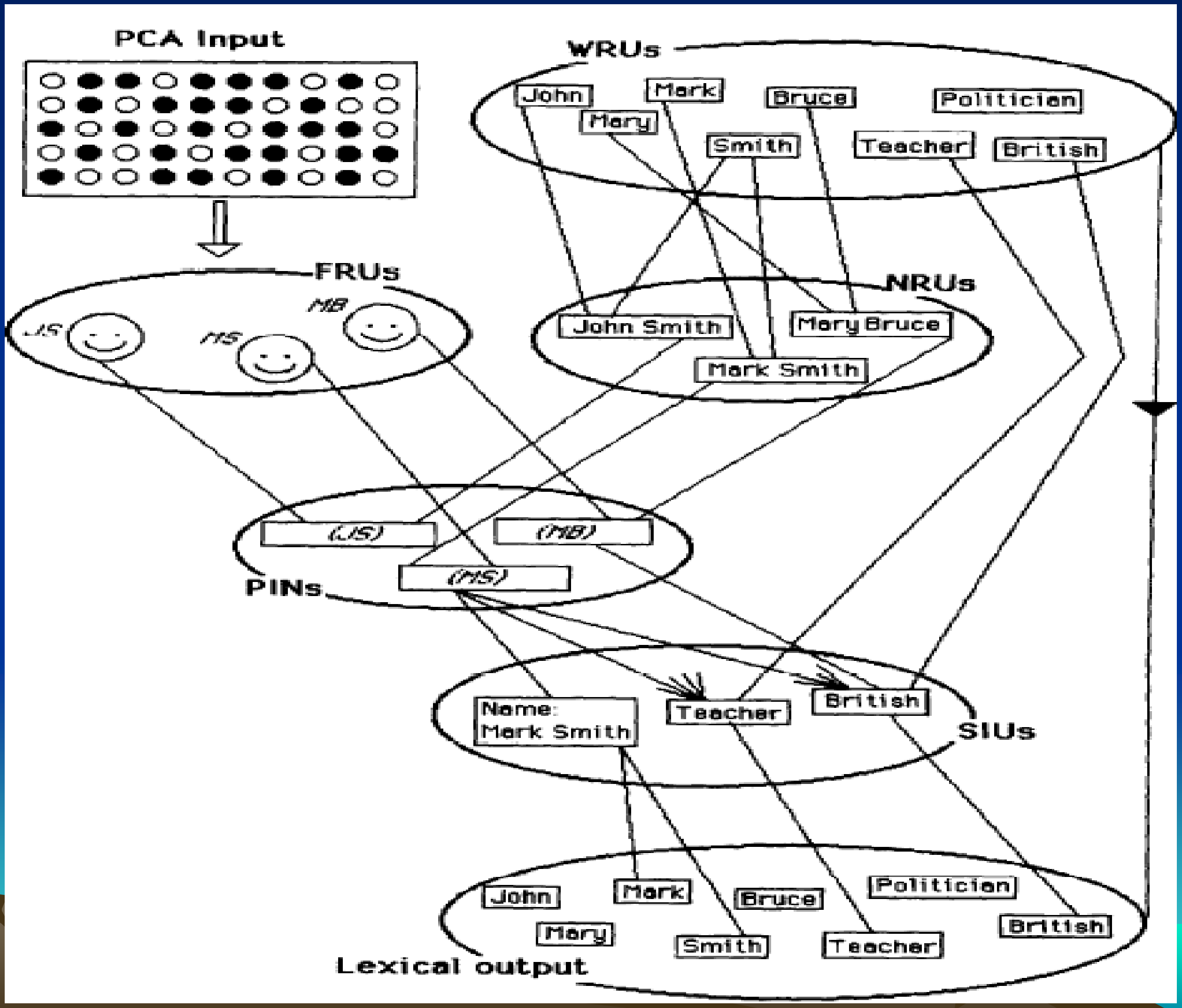
PCA front-end

- Three models were constructed each one with different PCA input from neutral expression faces only
- First model takes raw images and standardize them by eye positions. Images were reduced to 50X66 pixels and the 1st 50 components were extracted by applying PCA
- Second model was similar, but using shape-free faces
- Third model included the shape along with the information from second model

IAC component

- 50 FRUs, 50 NRUs and 50 PINs for the 50 people
- 120 SIUs with 50 coding the names and 70 coding personal information
- Each person is connected to 6 SIUs with one for name coding and other 5 chosen at random
- 110 WRUs and 110 Lexical Outputs (10 coding forenames, 30 coding surnames and 70 coding general information)

IAC model with PCA units



Connection

- Front-end system is connected to the IAC model through FRUs
- Three models were tested
- PCA inputs-50 each for raw images model and shape-free faces model and 70 for shape-free plus shape model (20 for shape signature)

Artificial Aspects of the Model

- The model "knows" everybody equally well
- All excitatory and inhibitory links in the model have equal weights
- Bi-directional links have same weight in all directions

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Testing the Model - Face Recognition

- PIN level is the locus of familiarity decision. So a hit is considered as a situation in which correct PIN becomes most active
- Results suggest that shape-free representation is the most efficient from the tests on expression faces

Correct Hits (correct maximally active PINs) for Neutral and Expressing Faces in the Three Different Versions of the Model

	Neutral faces (/50)	Expressing faces (/136)
Raw Image (50 bit)	50	113 (83%)
Shape-Free (50 bit)	50	129 (95%)
Shape-Free plus Shape (70 bit)	50	131 (96%)

Multimodal input and Cueing

- It is possible to cue recognition of faces in this model through simultaneous presentation of a face and another piece of information
- The 7 errors made in shape free version of first test were considered
- Single extra piece of information was sufficient in the 7 cases
- possibility that WRUs might be having an overpowering effect on recognition was checked
- a small amount of information appears to be sufficient to resolve a difficult recognition problem, whereas a correspondingly small amount of information is not sufficient to destroy intact recognition.

Distinctiveness

- 50 neutral faces were rated with hair and without hair to test the model for typicality
- The number of processing cycles required for the appropriate PIN to reach the recognition threshold level were noted
- Latency values were correlated with the distinctiveness ratings allocated to these faces by human raters.
- Product-moment correlation is -0.31 (significantly –ve) for “without hair” and -0.22(not significant) for “with-hair” case

Semantic Priming

- 10 neutral faces were chosen as target faces
- Faces were presented to the model in 2 ways
  - Following face of a unrelated person (no SIU sharing)
  - Following face of a related person (sharing 2 SIUs)
- Prime face was presented to the model & was allowed to cycle (100 cycles)
- Inter-stimulus interval of 20 cycles
- Target face was presented and the results were

Mean Cycles for PINs to Reach Threshold for Faces Primed by Related and Unrelated Faces and Names

	Unrelated prime	Related prime
Face prime	65	38
Name prime	63	41

Related-means t-test
$t(9) = 6.2, p < 0.01$
$t(9) = 4.0, p < 0.01$

Repetition Priming

- The model was presented with a set of expressing faces in 3 conditions
  - Unprimed
  - Primed by the same image
  - Primed by a different image of same face
- Filler faces were used to show that there is no transitory unit activations, but only link-strengthenings

Repetition Priming contd..

- In unprimed case, Filler face was presented and the simulation was done for 100 cycles. Then an ISI of 20 cycles followed by the target face presentation
- For the primed responses, prime face was presented after ISI and the system was allowed to settle. Hebb-like operation was applied to all FRU-PIN links
- The target face was presented in the same way as unprimed and the results were

Mean Cycles for PINs to Reach Threshold for Faces Primed by the Same Different Pictures

Unprimed	Primed with same image	Primed with different image
78.6	60.1	64.8

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Frequently Asked Questions

- Surely semantic units should not inhibit one another: Does this not lead to absurdities such as "British" inhibiting "actor"?
- Is the model not inefficient? It seems that there is some duplication of structure between the FRUs, NRUs and PINS.
- Is number of cycles to threshold a good analogue of RT data?
- The model is static, is this type of architecture suitable for learning?
- Surely humans do not do PCA on pixel-like properties of images

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Discussion & Conclusions

- The combination model extends the range of findings the model can simulate
- Allows us to examine the interaction between perceptual and cognitive processes (cueing, distinctiveness, semantic and repetition priming)
- Range of simulation is in the context of face recognition only (not for expression etc)
- Far from complete