# Modelling Human Perception of Facial Expressions by Discrete Choice Models

Javier Cruz, Thomas Robin, Matteo Sorci,
Michel Bierlaire and Jean-Philippe Thiran

30th of August, 2007
Workshop on DCM

TRANSP-OR

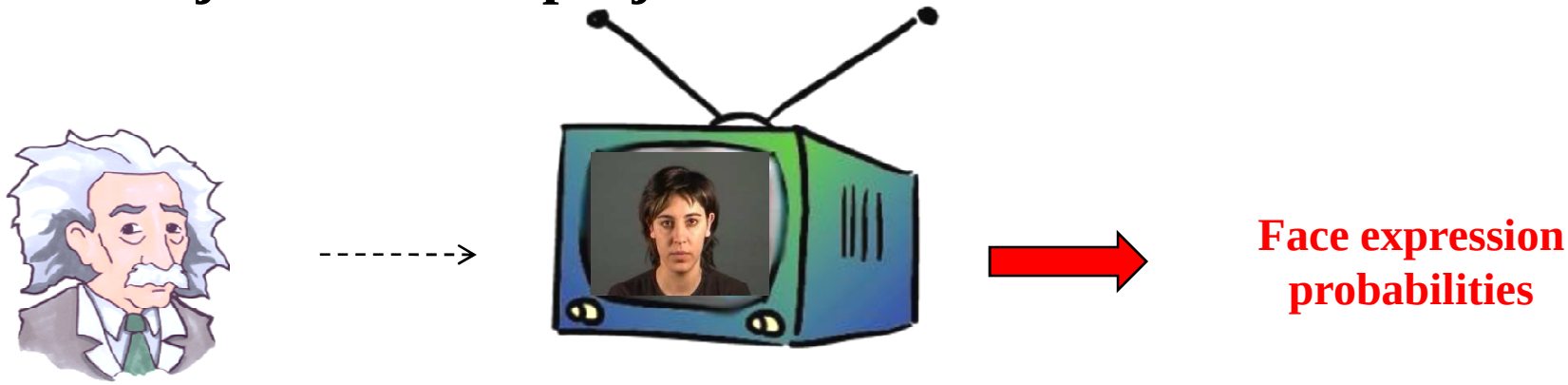
EPFL
ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

# Outline

- Introduction
- Classical Approach vs DCM Approach
- Framework
- Data description
- Model description
- Model Validation and problems
- Simulation results
- Conclusions and Future Work

# Introduction

**Final objective of the project:**



Expert

Video sequence

**Face expression probabilities**

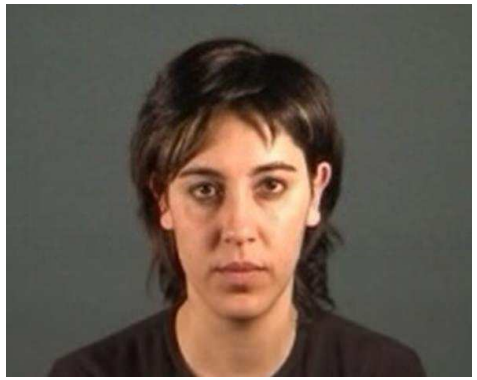
**Some applications:**

- Smart meeting rooms
- Driver's attention
- Human-Machine interfaces

# Introduction

**Current state:**

Expert



Single image

**Face expression probabilities**

# Handling the Problem: Classical Approach

Expert

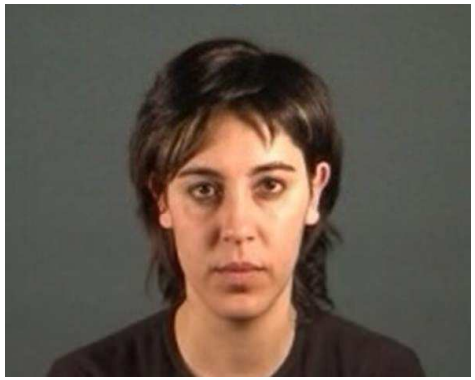


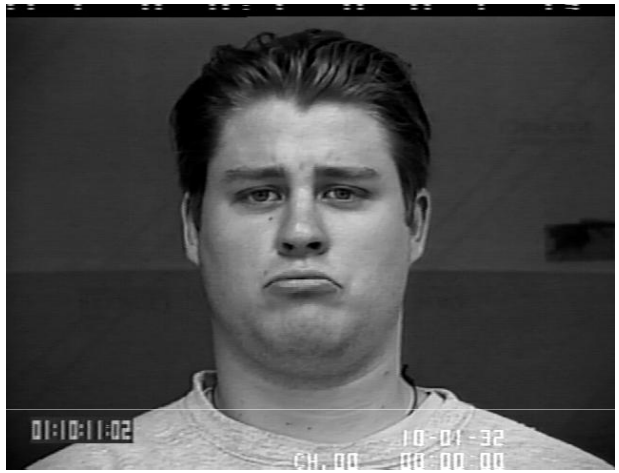
Image or Video

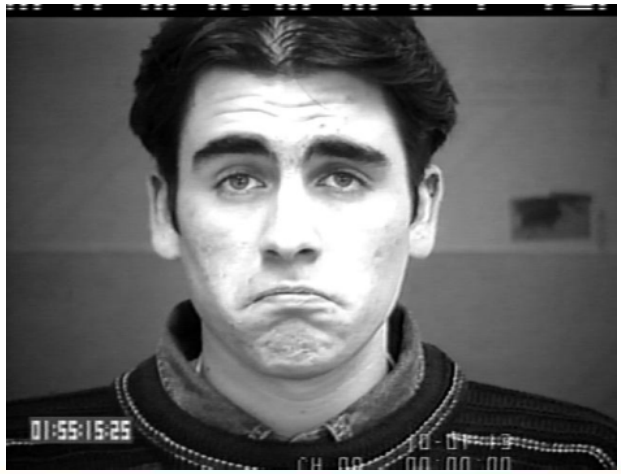
**1 Expression**

1 Label
(Ground Truth)

Number of Images or Videos = Number of Labels

# Handling the Problem: Classical Approach??



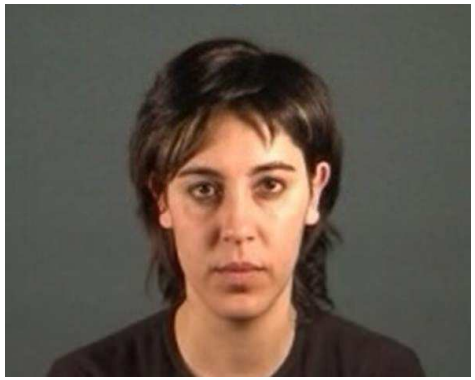


TRANSP-OR

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

# Handling the Problem: DCM Approach

Set of Experts



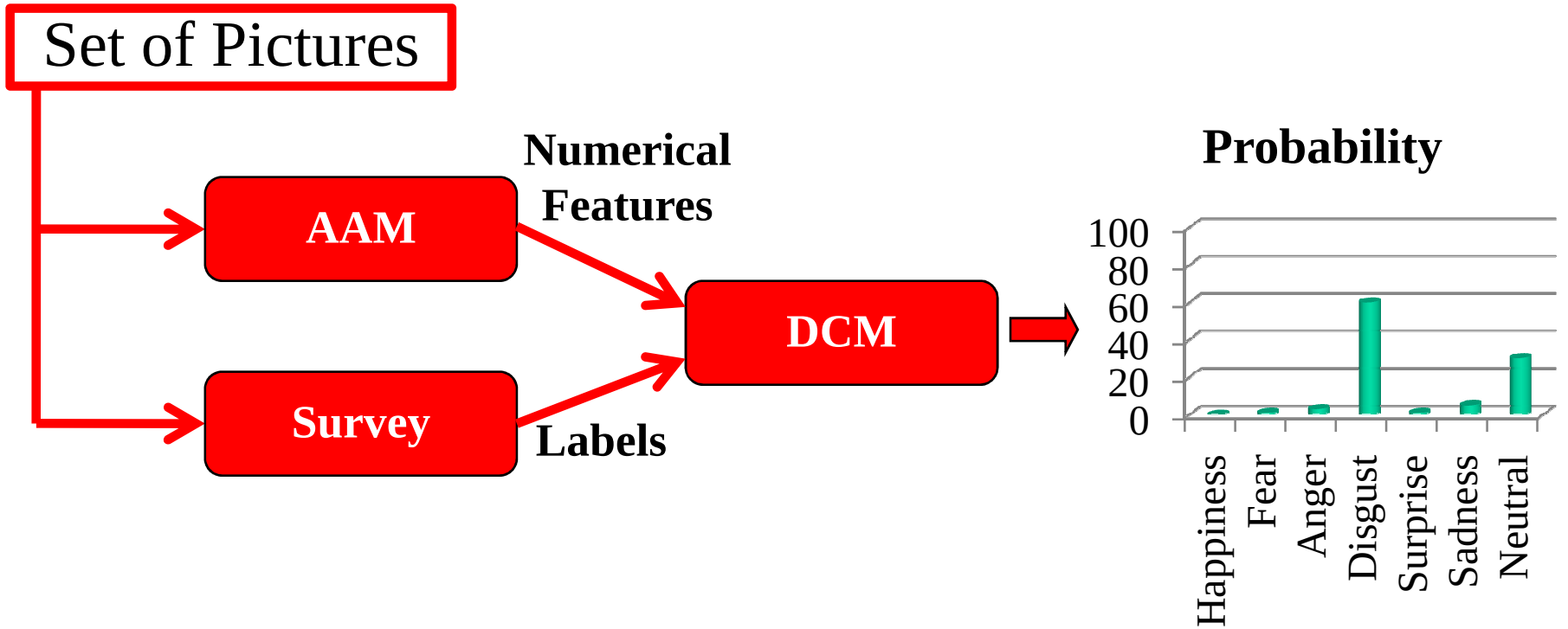
1 Image

**Probability distribution over emotions**

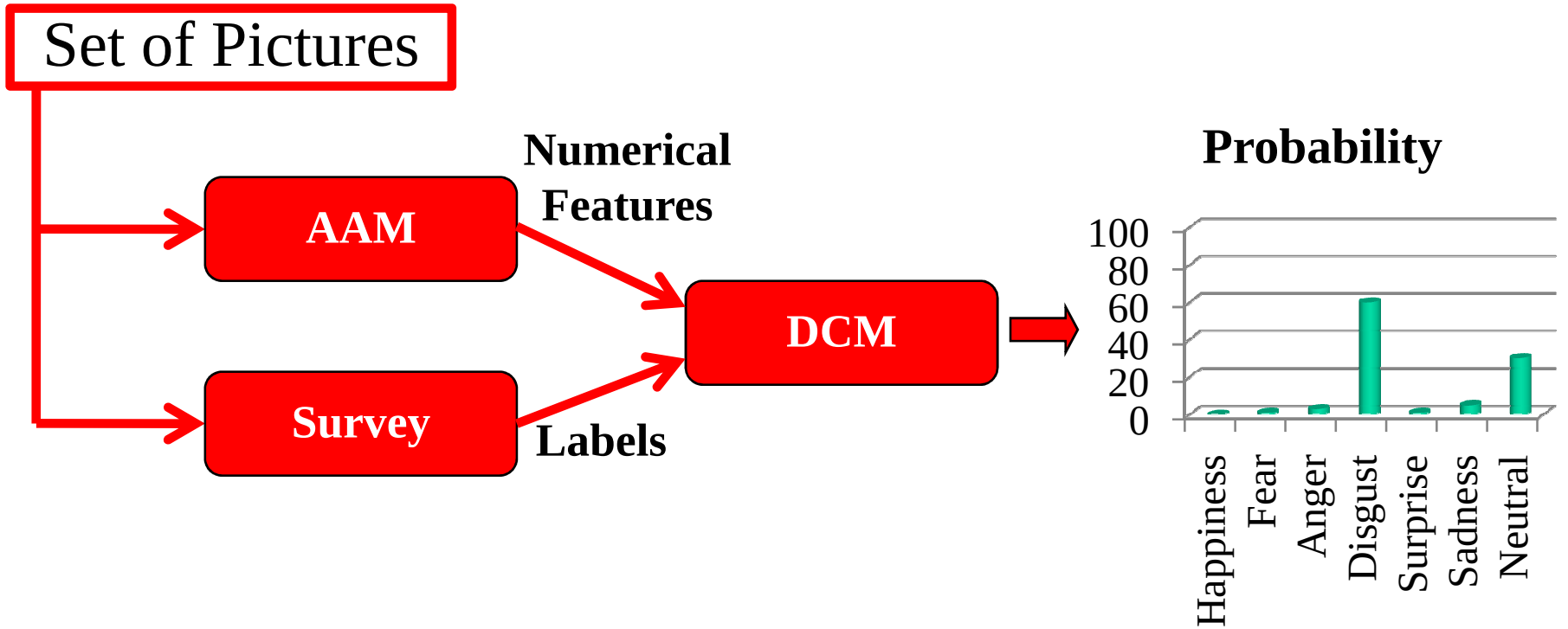
Set of Labels

Number of Images or Videos < Number of Labels

# Modelling Facial Expressions by DCM

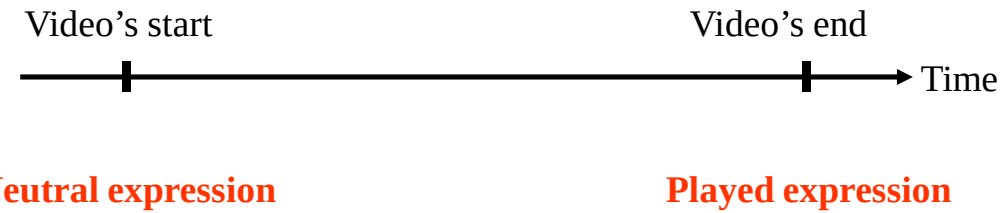


# Modelling Facial Expressions by DCM



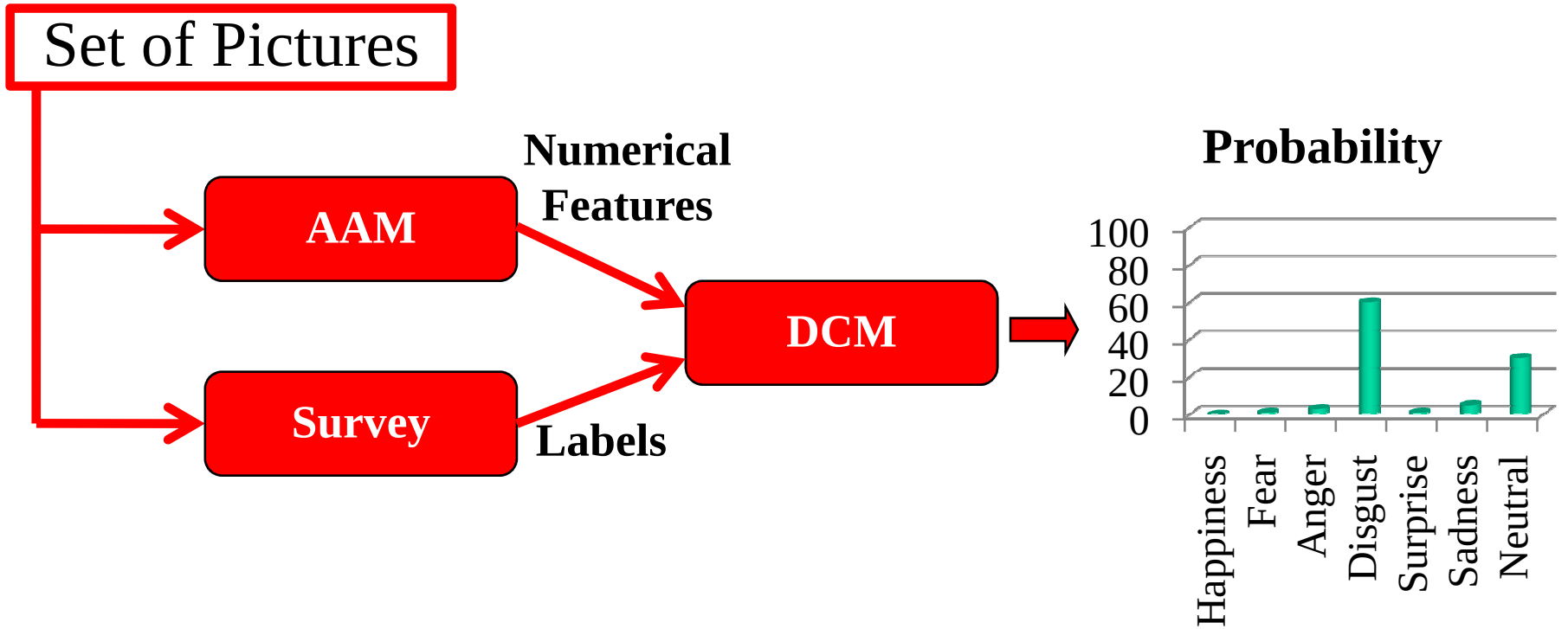
# Data: Images

- A portion of the Cohn – Kanade Database
  - 1272 images (frames) from 11 subjects
  - From neutral to expression



# Data: Images

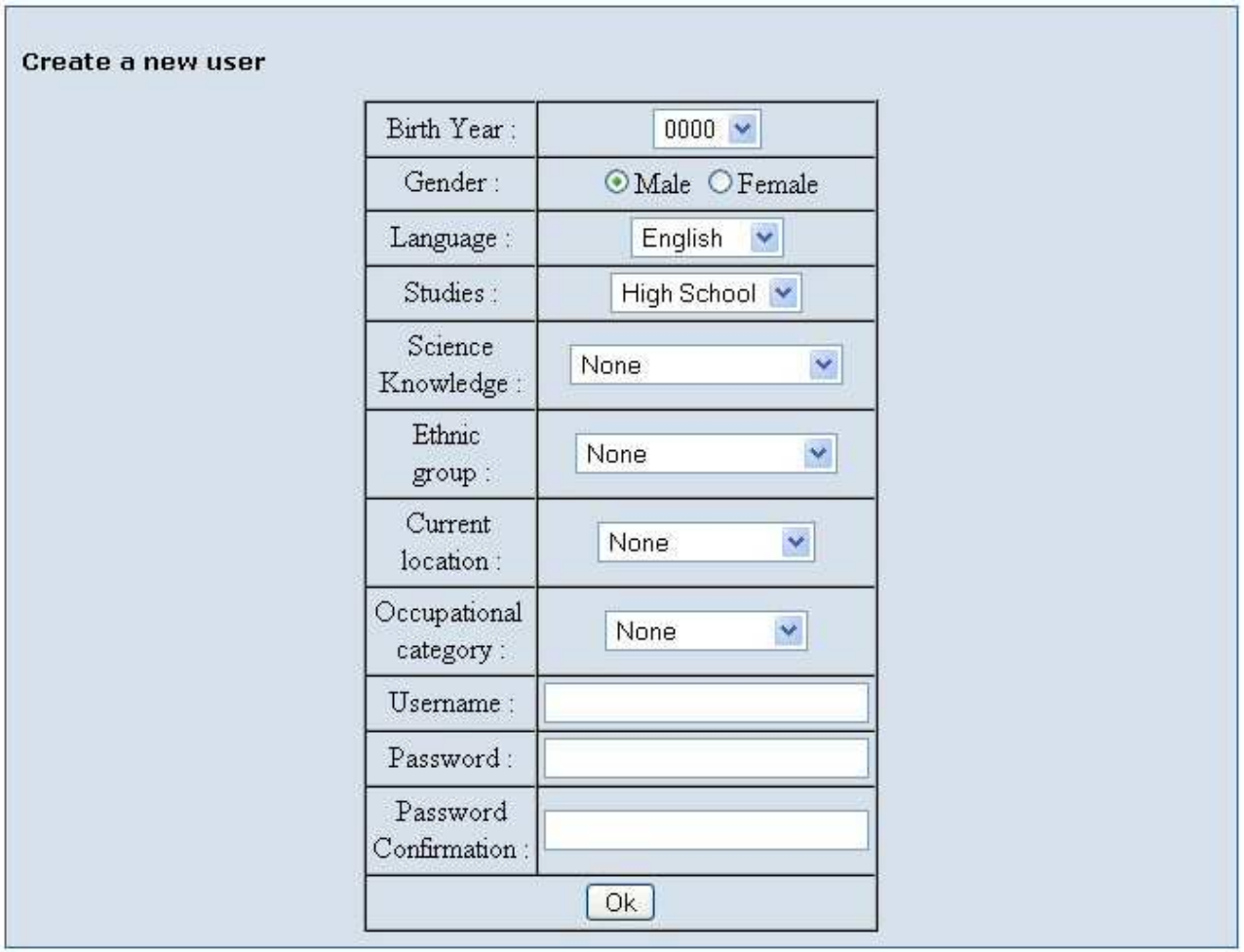
# Modelling Facial Expressions by DCM



# Data: Labels
# (Facial Expressions Evaluation Survey)


- Developed by Matteo Sorci at LTS
- Expression labelling is a subjective task
- We are collecting data on-line in order to include socioeconomic information in the labelling procedure
- Up to now we have around 1720 participants and >39000 labelled images

# Data: Labels
# (Facial Expressions Evaluation Survey)



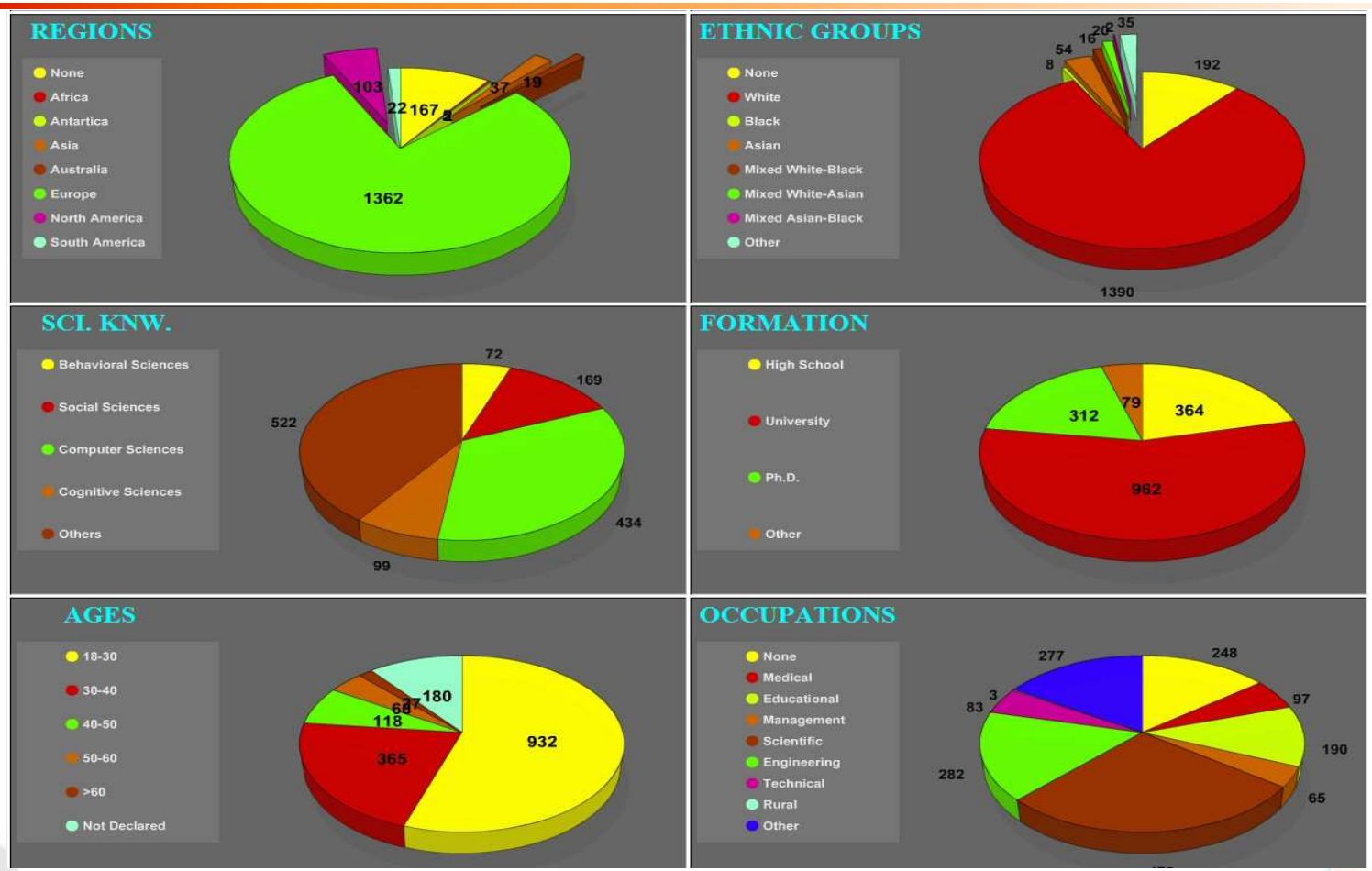

TRANSP-OR

EPFL ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

# Data: Labels
# (Facial Expressions Evaluation Survey)

**http://lts5www.epfl.ch/face**

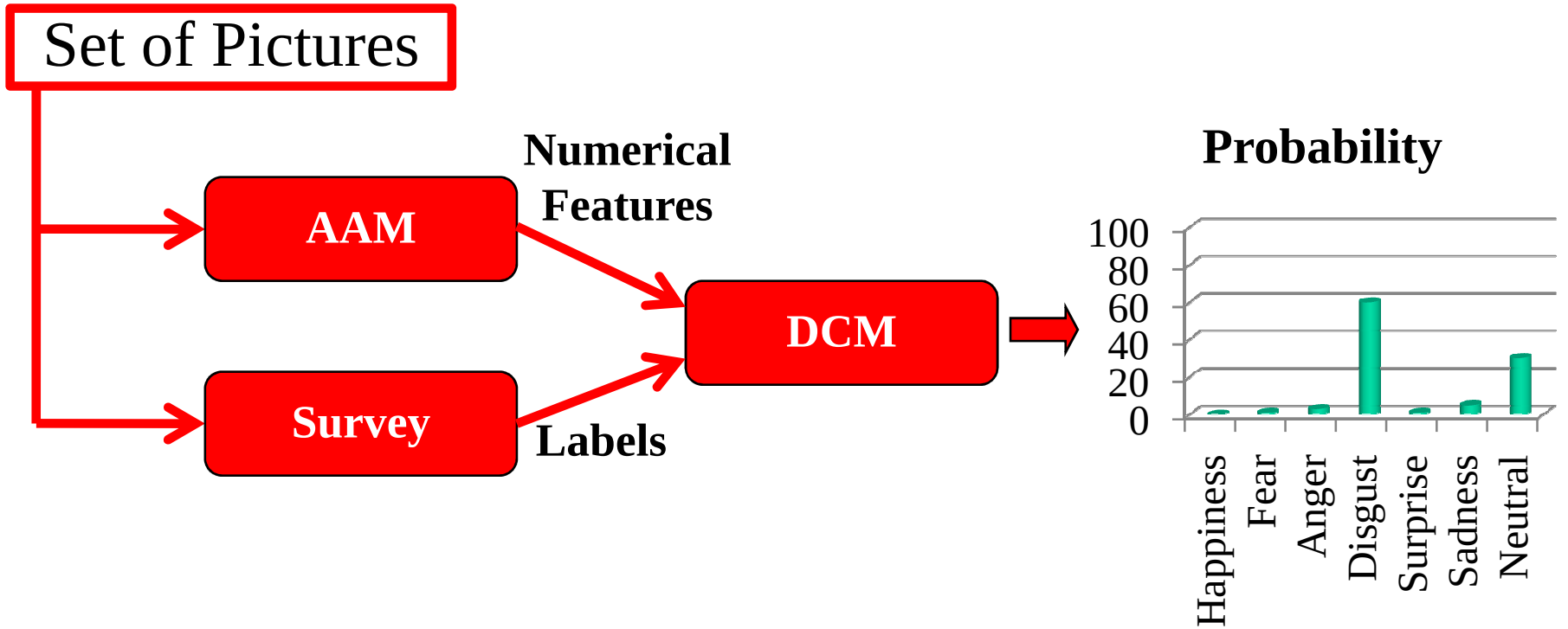
# Data: Labels
# (Facial Expressions Evaluation Survey)



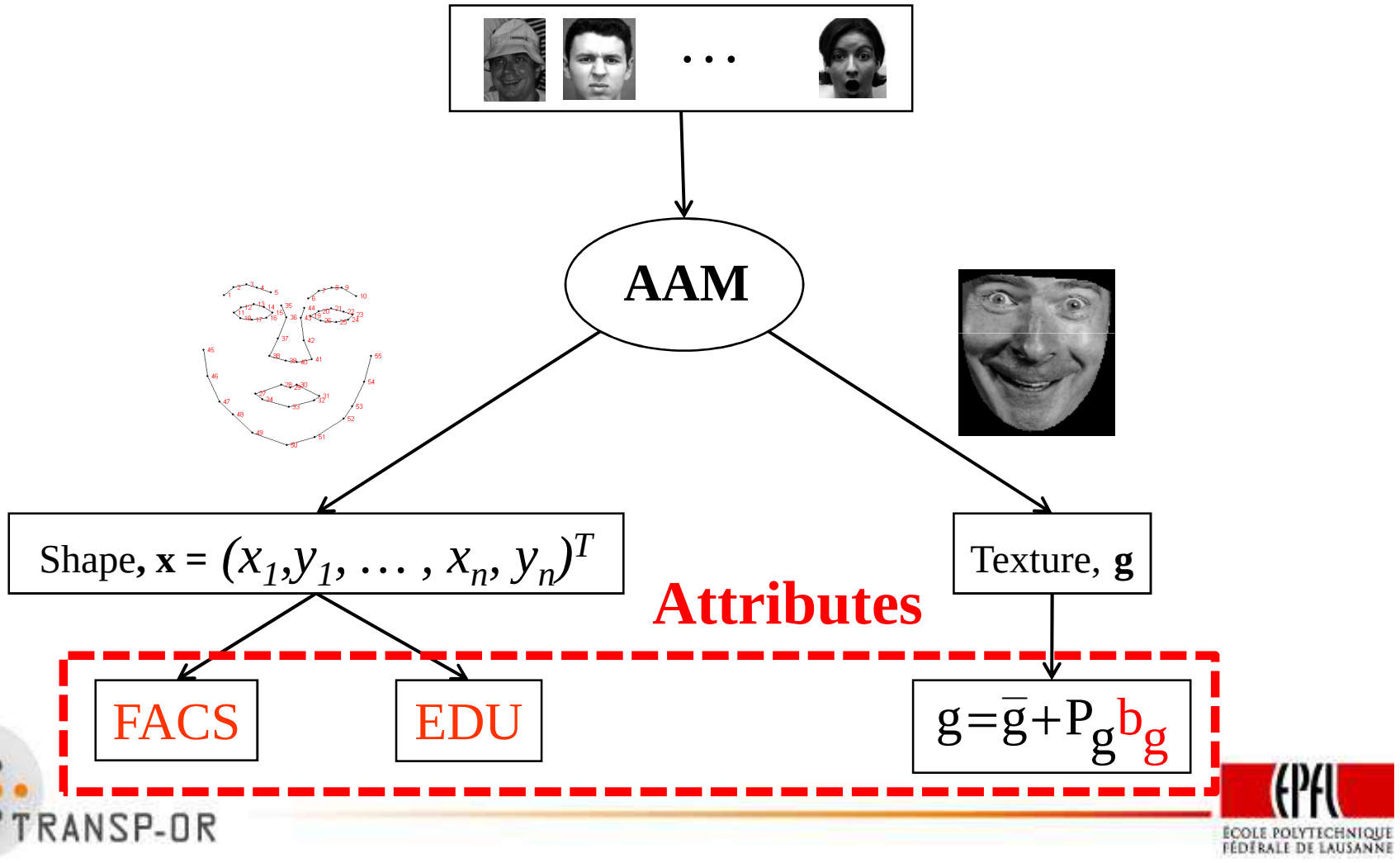

TRANSP-OR

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

# Modelling Facial Expressions by DCM



# Data: Active Appearance Model



# Data: Active Appearance Model

Shape, $\mathbf{x} = (x_1, y_1, \ldots, x_n, y_n)^T$ $\xrightarrow{\text{PCA}}$ $x = \bar{x} + P_s b_s$

Texture, $\mathbf{g}$ $\xrightarrow{\text{PCA}}$ $g = \bar{g} + P_g b_g$

$$\mathbf{b}_c = \begin{pmatrix} \mathbf{W}_s \mathbf{b}_s \\ \mathbf{b}_g \end{pmatrix} \xrightarrow{\text{PCA}} b_c = P_c c \Rightarrow \begin{cases} \mathbf{x} = \bar{\mathbf{x}} + \mathbf{Q}_s \mathbf{c} \\ \mathbf{g} = \bar{\mathbf{g}} + \mathbf{Q}_g \mathbf{c} \end{cases}$$

Varying **c** changes both, shape and texture

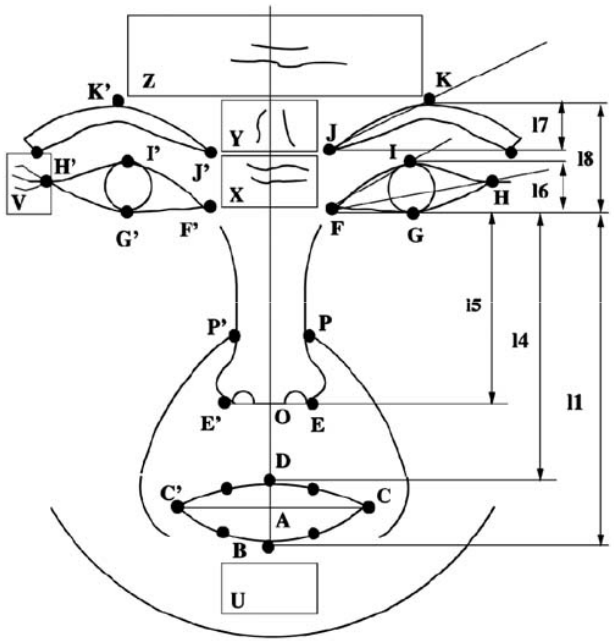
TRANSP-OR

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

# AAM Example


# AAM Output: FACS

- In 1978 Ekman and Friesen developed the Facial Action Coding System
- Mesurement units: “Action Units” (AUs)
  - AUs are contractions or relaxations of one or more muscles
    - 46 AUs account for changes in facial expression
    - 12 AUs describe changes in gaze direction and head orientation




**The FACS has become the leading standard for measuring facial expressions**

TRANSP-OR

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

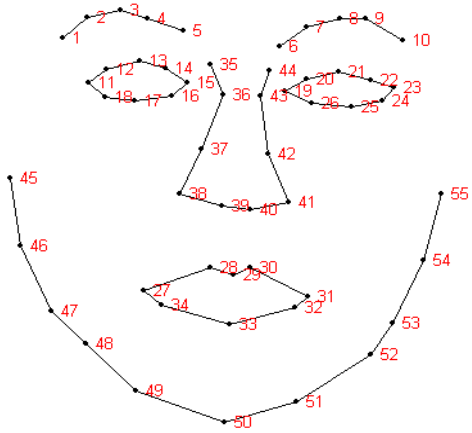
# AAM Output: FACS

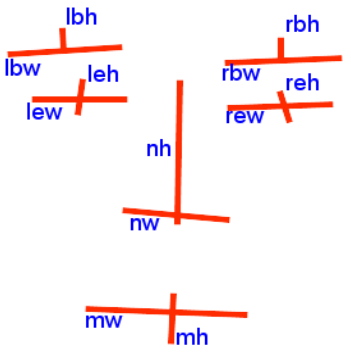
| Emotional | Primary Visual Cues | | | | | Auxiliary Visual Cues | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Category | AU | AU | AU | AU | AU | AU | AU | AU | AU | AU | Transient Feature(s) |
| Happiness | 6 | 12 | | | | 25 | 26 | 16 | | | wrinkles on outer eye canthi<br>presence of nasolabial furrow |
| Sadness | 1 | 15 | 17 | | | 4 | 7 | 25 | 26 | | |
| Disgust | 9 | 10 | | | | 17 | 25 | 26 | | | presence of nasolabial furrow |
| Surprise | 5 | 26 | 27 | 1+2 | | | | | | | furrows on the forehead |
| Anger | 2 | 4 | 7 | 23 | 24 | 17 | 25 | 26 | 16 | | vertical furrows between brows |
| Fear | 20 | 1+5 | 5+7 | | | 4 | 5 | 7 | 25 | 26 | |

# AAM Output: EDU

- Introduced by Antonini, Sorci, Bierlaire and Thiran in « Discrete Choice Models for Static Facial Expression Recognition »

| | | | |
|---|---|---|---|
| **EDU1** | $\frac{lew+rew}{leh+reh}$ | **EDU8** | $\frac{leh+reh}{lbh+rbh}$ |
| **EDU2** | $\frac{lbw}{lbh}$ | **EDU9** | $\frac{lew}{nw}$ |
| **EDU3** | $\frac{rbw}{rbh}$ | **EDU10** | $\frac{nw}{mw}$ |
| **EDU4** | $\frac{mw}{mh}$ | **EDU11** | EDU2 / EDU4 |
| **EDU5** | $\frac{nh}{nw}$ | **EDU12** | EDU3 / EDU4 |
| **EDU6** | $\frac{lew}{mw}$ | **EDU13** | EDU2 / EDU10 |
| **EDU7** | $\frac{leh}{mh}$ | **EDU14** | EDU3 / EDU10 |





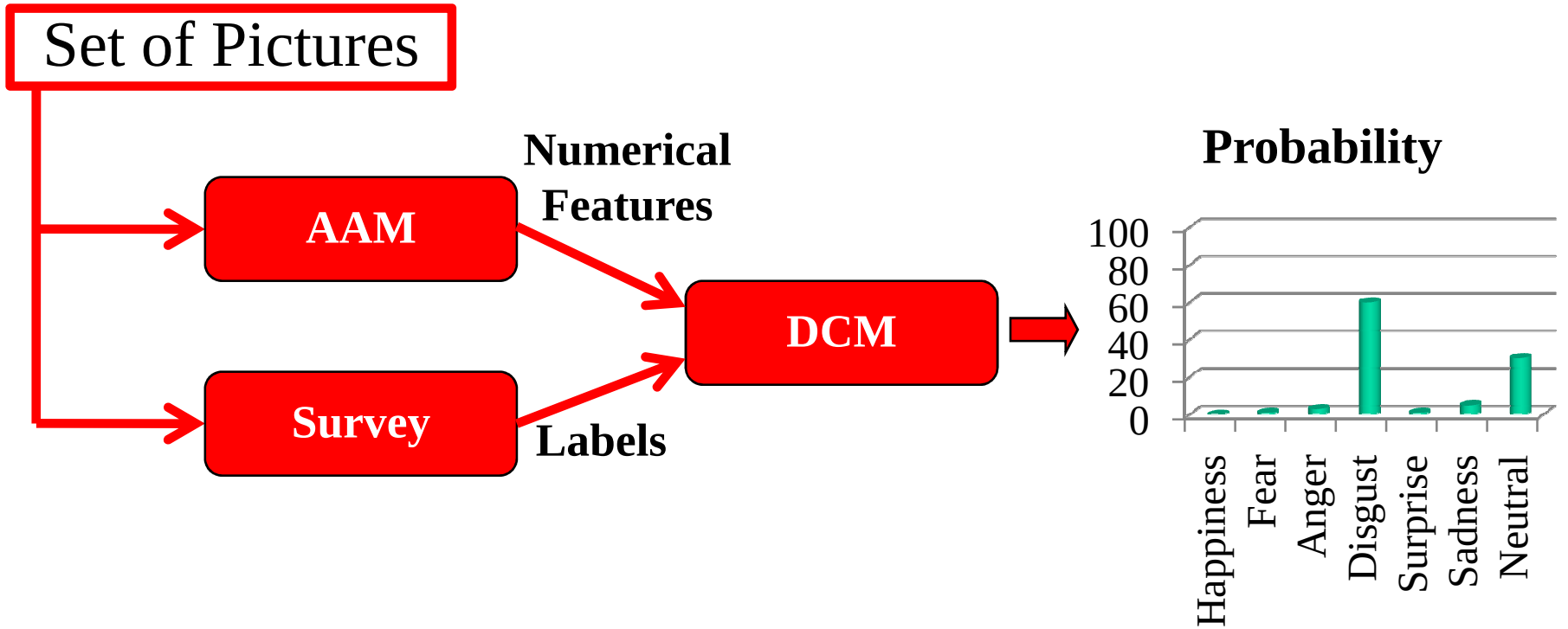

TRANSP-OR

EPFL ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

# AAM Output: Texture Parameters

**AAM** $\longrightarrow g = \bar{g} + P_g b_g$

# Modelling Facial Expressions by DCM



# DCM: Estimation

- Multinomial Logit
- 9 Alternatives:

1. Happiness
2. Surprise
3. Fear
4. Disgust
5. Sadness
6. Anger
7. Neutral
8. Other
9. I don’t know

- Estimation by likelihood maximization

**http://biogeme.epfl.ch/**

# DCM: Estimation

$$V_j = \underbrace{ASC_j + \sum_{k=1}^{K_1} I_{kj}\beta_{kj}^{FACS} AU_k}_{\text{Model 1}} + \underbrace{\sum_{h=1}^{K_2} I_{hj}\beta_{hj}^{EDU} EDU_h}_{\text{Model 2}} + \underbrace{\sum_{l=1}^{K_3} I_{lj}\beta_{lj}^{b_g} b_{g\,lj}}_{\text{Model 3}}$$

- Model 1: “FACS” (Primary AU + Secondary AU + Transient Features)
  - 93 parameters , **LL = - 57121**
- Model 2: “FACS + EDU”
  - 120 parameters , **LL = - 55027**
- Model 3: “FACS + EDU + TEXTURE COEFFICIENTS”
  - 145 parameters , **LL = - 54657**

# DCM: Model Parameters

ASC

Texture

EDU

FACS

| Name | Value |
|---|---|
| ASC_A | -2.81 |
| ASC_D | 0.307 |
| ASC_DK | -2.29 |
| ASC_F | -1.91 |
| ASC_H | 23.5 |
| ASC_N | 0 |
| ASC_O | -4.94 |
| ASC_SA | -15.7 |
| ASC_SU | 1.13 |
| BETA_T1_O | -10.4 |
| BETA_T1_SA | 5.63 |
| BETA_T2_A | 14.3 |
| BETA_T2_D | 9.34 |
| BETA_T2_F | 15.5 |
| BETA_T2_H | 22.8 |
| BETA_T2_O | -5.66 |
| BETA_T2_SA | 12.5 |
| BETA_T2_SU | 15.2 |
| BETA_T3_A | 42.2 |
| BETA_T3_H | 38.4 |
| BETA_T3_O | -8.5 |
| BETA_T3_SU | 7.77 |
| BETA_T4_A | -24.6 |
| BETA_T4_D | 32.3 |
| BETA_T4_F | 55.3 |
| BETA_T4_H | 32.6 |
| BETA_T4_O | 22.9 |
| BETA_T4_SA | 26.7 |
| BETA_T4_SU | 27 |
| BETA_T5_A | -13.3 |
| BETA_T5_D | -15.2 |
| BETA_T5_F | -29.6 |
| BETA_T5_H | -67.3 |
| b_EDU_10_O | 15.5 |
| b_EDU_10_SA | 15.5 |
| b_EDU_10_SU | -3.63 |
| b_EDU_5_D_F | -1.94 |
| b_EDU_5_H | 2.69 |
| b_EDU_5_SA | -1.3 |
| b_EDU_6_D | -20 |
| b_EDU_6_H | -16.3 |
| b_EDU_6_O | -25.9 |
| b_EDU_6_SA | -26.1 |
| b_EDU_7_A_F | 2.42 |
| b_EDU_7_D | 1.51 |
| b_EDU_7_H | 2.82 |
| b_EDU_7_O | 2.18 |
| b_EDU_7_SA | 2.23 |
| b_EDU_8_A_F | -1.95 |
| b_EDU_8_D | -4.02 |
| b_EDU_8_H | -6.72 |
| b_EDU_8_O | 0.76 |
| b_EDU_8_SA | 8.5 |
| b_EDU_8_SU | -5.76 |
| b_EDU_9_D | 12.5 |
| b_EDU_9_F | -2.46 |
| b_EDU_9_H | -5.22 |
| b_EDU_9_O | 11.8 |
| b_EDU_9_SA | 15.3 |
| b_RAP_brow_A_SU | -5.34 |
| b_RAP_brow_D | -9.29 |
| b_RAP_brow_F | -11.1 |
| b_RAP_brow_SA | 13 |
| b_RAP_eye_A | -3.84 |
| b_RAP_eye_F | 9.81 |
| b_RAP_eye_H | -18.6 |
| b_RAP_eye_O | -8.79 |
| b_RAP_eye_SA | -15 |
| b_RAP_eye_SU | 2.16 |
| b_RAP_mouth_A | -11.2 |
| b_RAP_mouth_F | 9.16 |
| b_RAP_mouth_H | 7.4 |
| b_RAP_mouth_O | 4.23 |
| b_RAP_mouth_SA | -5.16 |
| b_RAP_mouth_SU | 8.19 |
| b_brow_dist_A | -19.9 |
| b_brow_dist_F | -15.7 |
| b_brow_dist_SA | -50.7 |
| b_broweye_l2_A | -16.9 |
| b_broweye_l2_O | 36.6 |
| b_broweye_l2_SA | -16.1 |
| b_broweye_l2_SU | 35.1 |
| b_broweye_l3_A | -21.5 |
| b_broweye_r2_A | -90.9 |
| b_broweye_r2_D | -52.6 |
| b_broweye_r2_SA | -98.7 |
| b_browwr_D | 11.6 |
| b_browwr_O | 4.38 |
| b_eye_angle_below_r_F | 2.3 |
| b_eye_angle_l_A | 1.32 |
| b_eye_angle_l_F | 4.85 |
| b_eye_angle_l_SA | 2.09 |
| b_eye_angle_r_A | 1.74 |
| b_eye_angle_r_F | -3.25 |
| b_eye_angle_r_SA | -1.46 |
| b_eye_brow_angle_l_F | 3.77 |
| b_eye_brow_angle_l_O | -4.18 |
| b_eye_brow_angle_r_F | -2.02 |
| b_eye_brow_angle_r_O | -0.728 |
| b_eye_brow_angle_r_SA | 8.65 |
| b_eye_brow_angle_r_SU | -2.92 |
| b_eye_mouth_dist_l2_D | -16.3 |
| b_eye_mouth_dist_l_F | 55.9 |
| b_eye_mouth_dist_l_H | -57.7 |
| b_eye_mouth_dist_l_SA | 24.5 |
| b_eye_mouth_dist_r2_D | 34.8 |
| b_eye_mouth_dist_r2_O | -4.88 |
| b_eye_mouth_dist_r_F | -38.8 |
| b_eye_mouth_dist_r_H | -66.7 |
| b_eye_mouth_dist_r_SA | 27.5 |
| b_eye_nose_dist_l_A | 83.1 |
| b_eye_nose_dist_l_D | 89.2 |
| b_eye_nose_dist_l_F | 39.2 |
| b_eye_nose_dist_l_O | 77.4 |
| b_eye_nose_dist_l_SA | 93.8 |
| b_eye_nose_dist_r_A | -44.5 |
| b_eye_nose_dist_r_D | -129 |
| b_eye_nose_dist_r_F | -63.7 |
| b_eye_nose_dist_r_O | -74.5 |
| b_eye_nose_dist_r_SA | -106 |
| b_fore_F | 0.683 |
| b_fore_O | 0.126 |
| b_fore_SU | 0.525 |
| b_leye_h_F | -123 |
| b_leye_h_H | 130 |
| b_leye_h_SU | -30.5 |
| b_mouth_h_A | 96.2 |
| b_mouth_h_D | 23.9 |
| b_mouth_h_SA | 59.3 |
| b_mouth_nose_dist2_A | 5.13 |
| b_mouth_nose_dist2_SA | -20.2 |
| b_mouth_nose_dist_D | -14 |
| b_mouth_nose_dist_H | 50.1 |
| b_mouth_w_F | 23.5 |
| b_mouth_w_H | 36.8 |
| b_mouth_w_SA | -40 |
| b_naslab_D | 0.565 |
| b_naswr_D | 16.6 |
| b_naswr_O | 5.62 |
| b_reye_h_H | 183 |
| b_reye_h_SU | 45 |

TRANSP-OR

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

# DCM: Model Parameters

- Parameters of the HAPPINESS's utility $\begin{cases} \beta_{EDU\,4} = +7.4 \\ \beta_{FACS(eye\_mouth\_dist)} \end{cases} = \begin{cases} -57.7 \\ -66.7 \end{cases}$

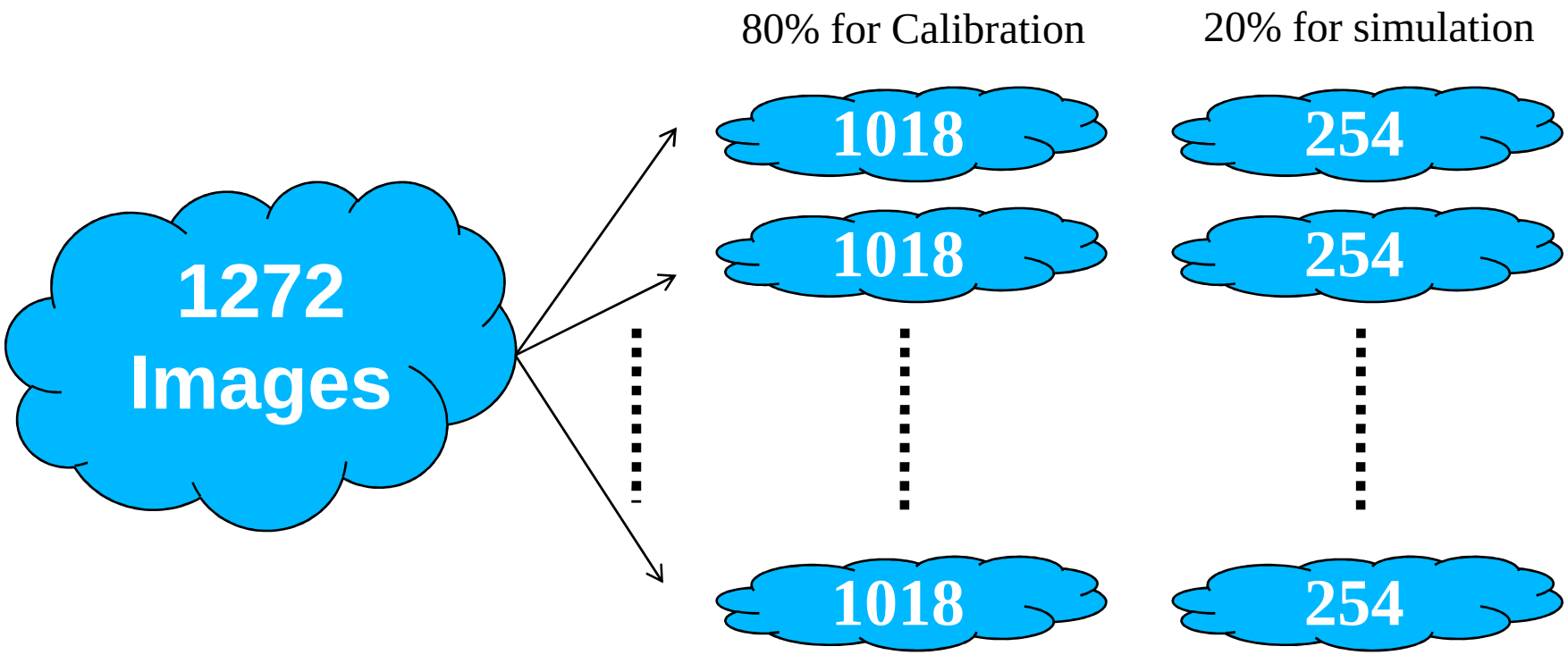
**EDU4** ↗
**eye_mouth_dist** ↘
} → $V_{Happiness}$ ↗ → $P_{Happiness}$ ↗



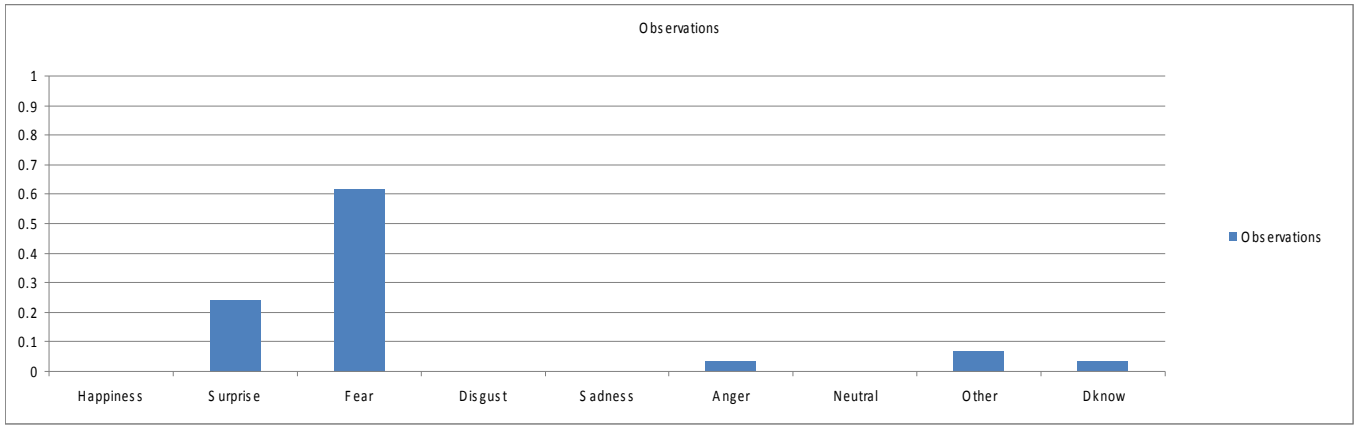
TRANSP-OR

EPFL ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

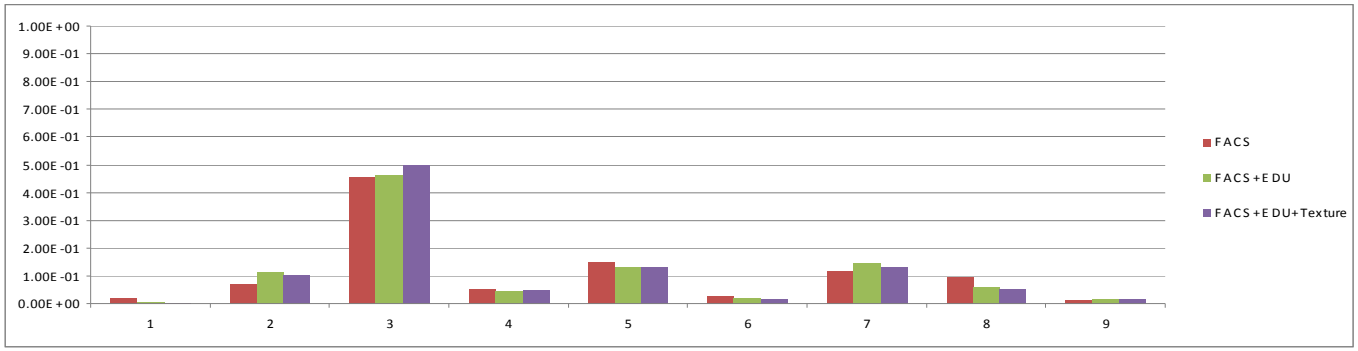
# DCM: Validation



# DCM: Validation


$\chi^2$ -Test




TRANSP-OR

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

# DCM: Validation

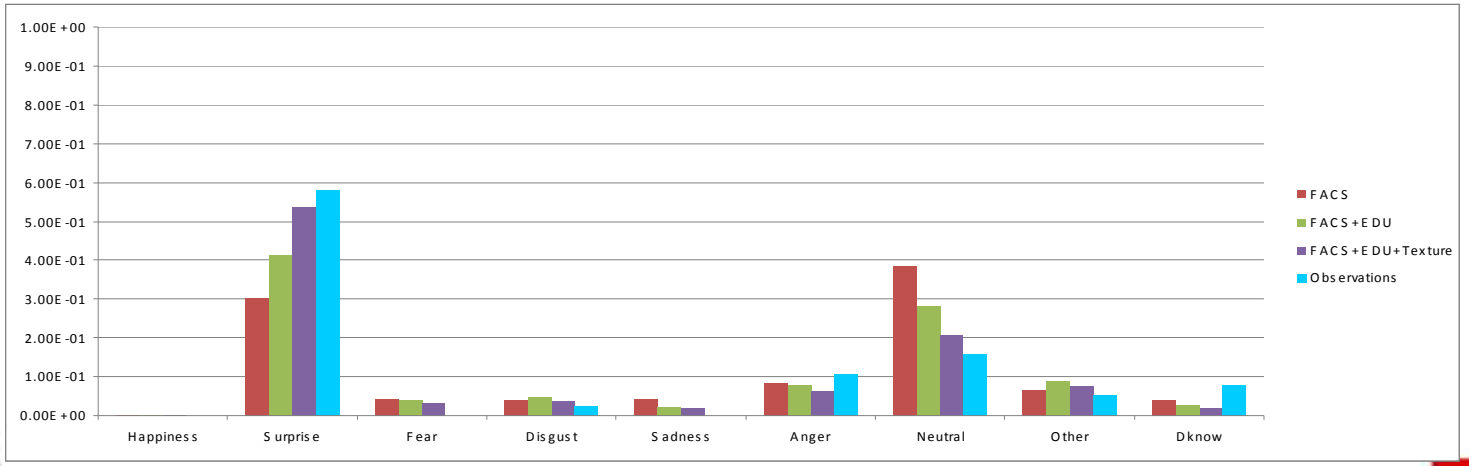
| Model \ Inst. | Inst 1 | Inst 2 | Inst 3 | Inst 4 | Inst 5 | | Average |
|---|---|---|---|---|---|---|---|
| **FACS** | 28.2% | 31.3% | 30.9% | 30.6% | 30.9% | | **30.38%** |
| **+ EDU** | 20.4% | 26.3% | 23.1% | 25.5% | 23.1% | | **23.68%** |
| **+ Texture** | 21.6% | 26.3% | 23.1% | 23.1% | 22% | | **23.22%** |

# DCM: Validation ...
# Houston, we have a problem!

- Cochran's Rule NOT satisfied
- Even worse with segmentation
- Other tests or measures must be studied
  - Kolmogorov-Smirnov Discrete Test
  - KL-Divergence
  - ...

# DCM: Simulation

**38 observations**

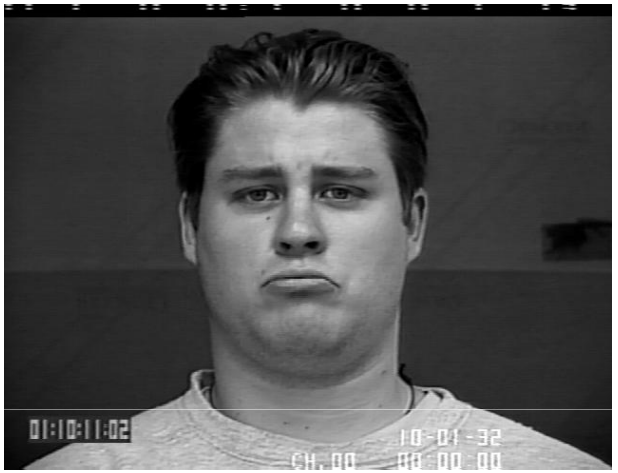



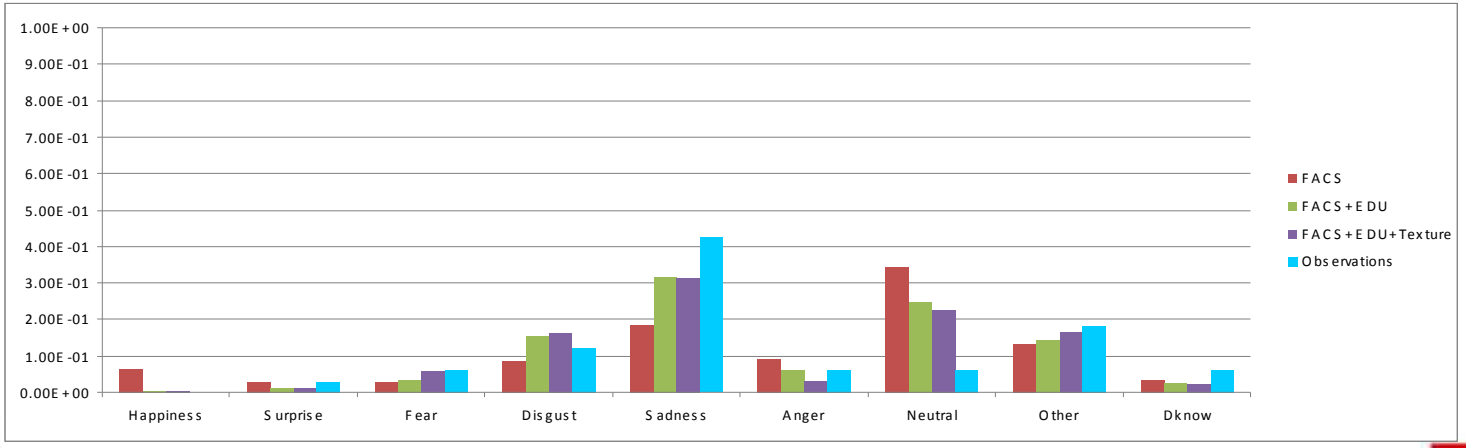

TRANSP-OR

EPFL ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

# DCM: Simulation

**33 observations**



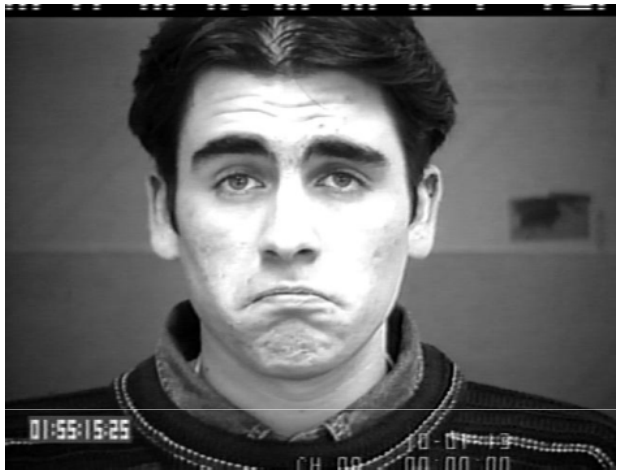


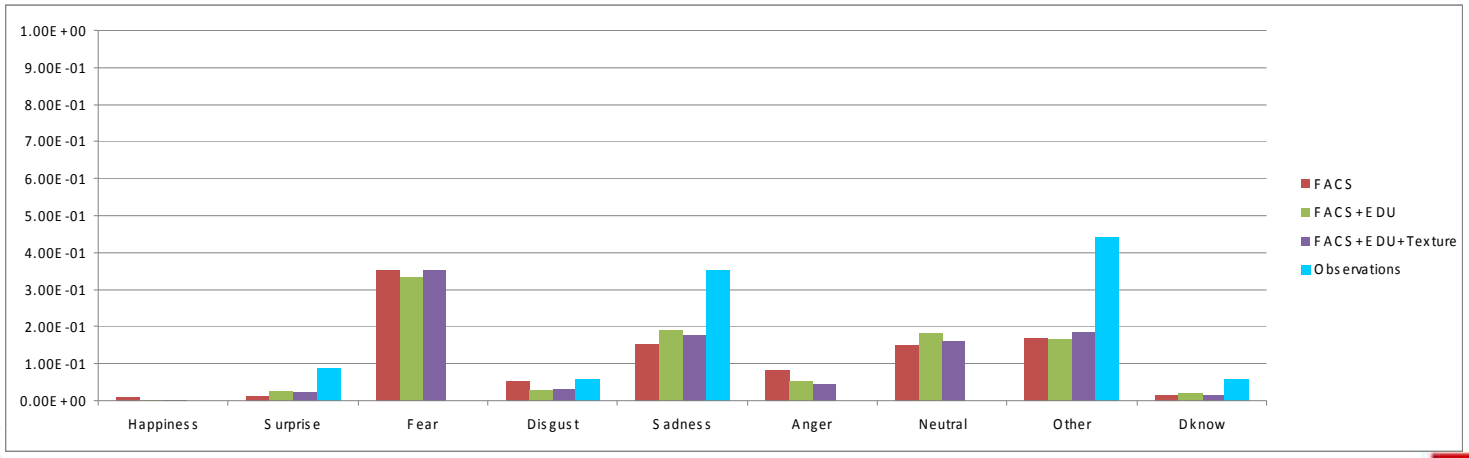

TRANSP-OR

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

# DCM: Simulation

**34 observations**




TRANSP-OR

EPFL ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

# Conclusions and Future Work

**Conclusions**

- New approach
- No ground truth hypothesis
- Promising preliminary results

**Future Work**

- Appropriate discrete test for prob. distributions
- Segmentation
- Other model structures
- Dynamic version