



Facial expression recognition on the wild

野生での表情認識

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QR codes for download the slides
スライドをダウンロードするためのQRコード

2023/11/27

自己紹介

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- 電子工学の学位 (2006年-2011年)



- マイクロエレクトロニクスの修士号(2011年-2013年)



- 電子通信の博士号(2014年-2018年)(学業優秀との評価をいただき)

- 非常勤講師(2017年-2019年)



- 人工知能シニアコンサルタント(2019年)



- ポストドクター(2019年-2020年)



- ポストドクター(2020年-2022年)



- ポストドクター(2022年-)

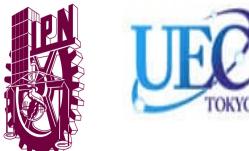


これまで研究状況

Pattern recognition
パターン認識



Facial expression recognition
野生での表情認識



ML/DL applied in healthcare
機械学習/深層学習のヘルスケアへの応用



DL in Anomaly detection
異常検知における深層学習



Privacy
プライバシー



Agenda

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- ▶ Objective・目標
- ▶ Introduction・イントロダクション
- ▶ Module for Recognizing the Profile・プロファイル認識
- ▶ Automatic Segmentation module of Regions of Interest・興味領域の自動認識モデル
- ▶ Classifier Based on Clustering Techniques and Fuzzy Logic・クラスタリングとファジ論理技術に基づく分類器
- ▶ Databases・データベース
- ▶ FER Images-Experimental Results・FERイメージの実験結果
- ▶ FER Video-Experimental Results・FERビデオの実験結果
- ▶ Conclusions・まとめ
- ▶ Future Work・これからの課題

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Objectives 目標

Develop a facial expression recognition system capable of identifying a person's profile, automatically segmenting regions of interest, and ultimately providing the percentage of resemblance to each facial expression.

表情認識システムを開発し、個人のプロファイルを識別し、自動的に興味のある領域をセグメンテーションし、最終的に各表情に対する類似度の割合を提供できるものとすること。

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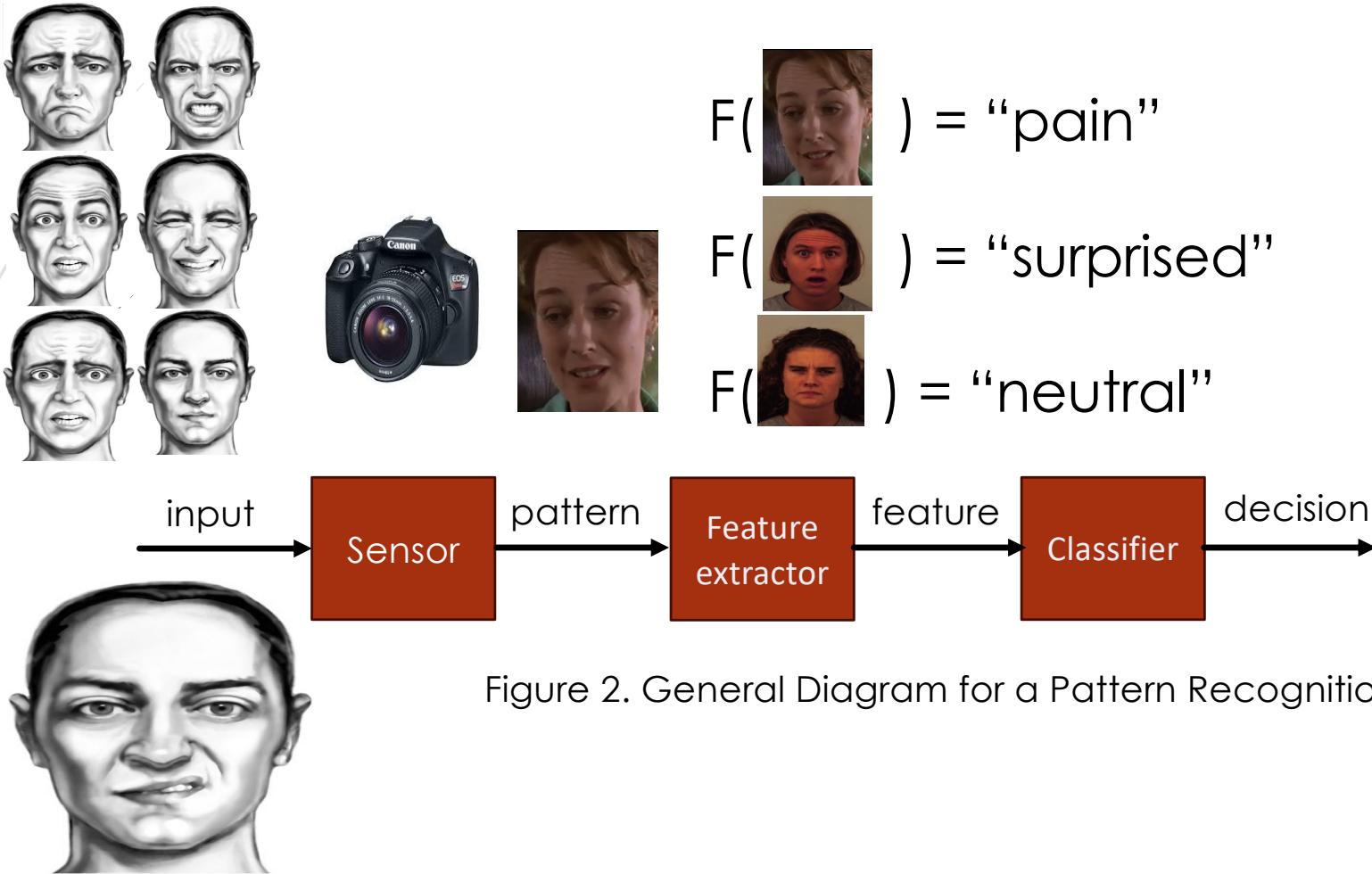
- Develop a system capable of recognizing the profile of a face in an image, determining whether the person is facing the camera or turned in a particular direction.
顔のプロフィールを認識し、その人物がカメラに向いているか、特定の方向に向いているかを判断する能力を持つシステムを開発すること。
- Create a system that automatically performs segmentation of the regions of interest on the face, specifically focusing on the mouth and forehead/eyes.
顔の興味深い領域を自動的にセグメンテーションするシステムを作成し、具体的には口と額/目に焦点を当てること。
- Build a classifier based on clustering techniques and fuzzy logic to reduce the training times of the system.
クラスタリング技術とファジー論理を基にした分類器を構築し、システムのトレーニング時間を短縮すること。
- Apply the developed system to a database of videos in an uncontrolled environment.
開発されたシステムを無制御環境の動画データベースに適用すること。

Introduction イントロダクション



Figure 1. Possible Applications.

Machine Learning model マッキン ラーニング モデル



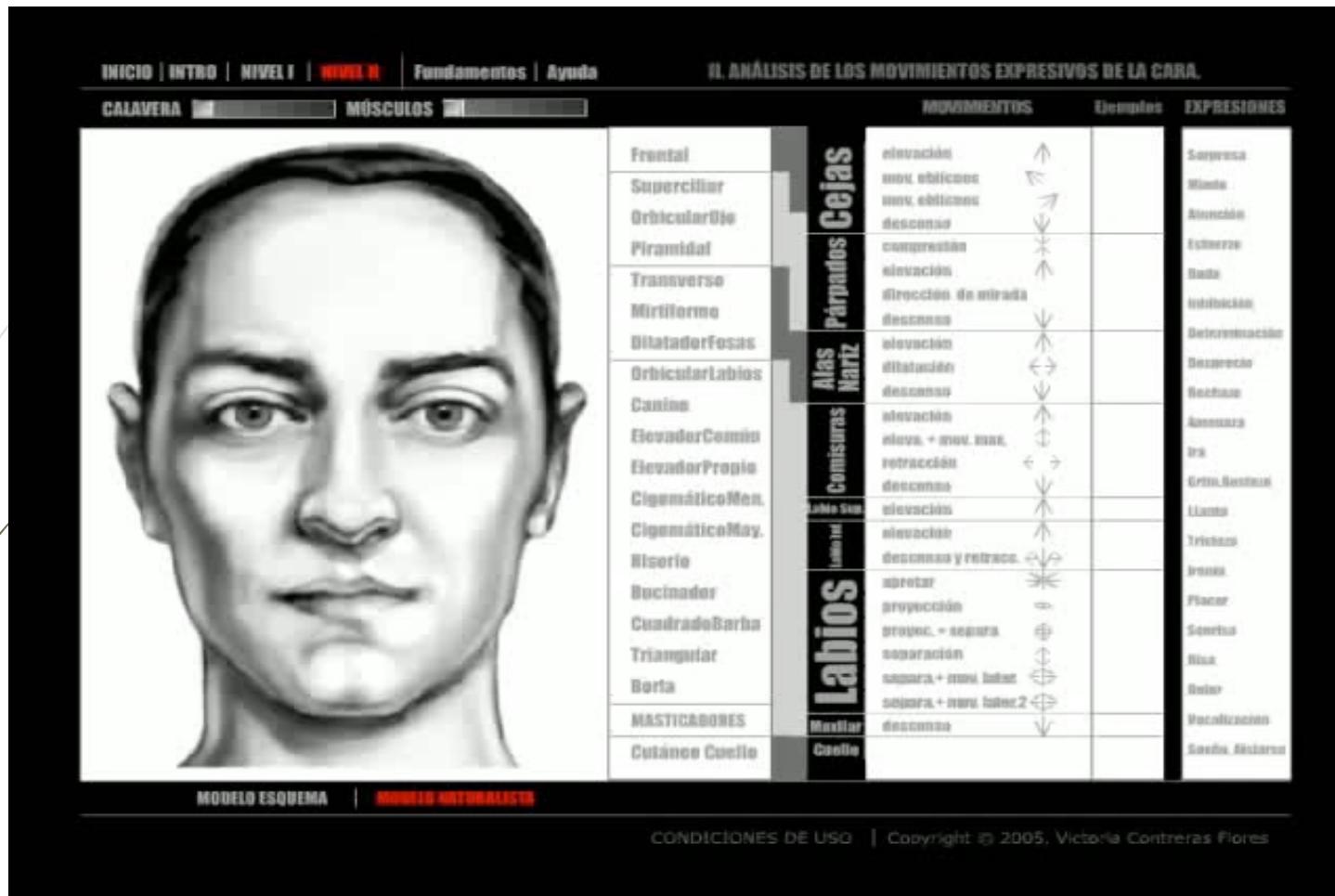


Figure 3. ARTNATOMY/ARTNATOMIA, www.artnatomia.net.

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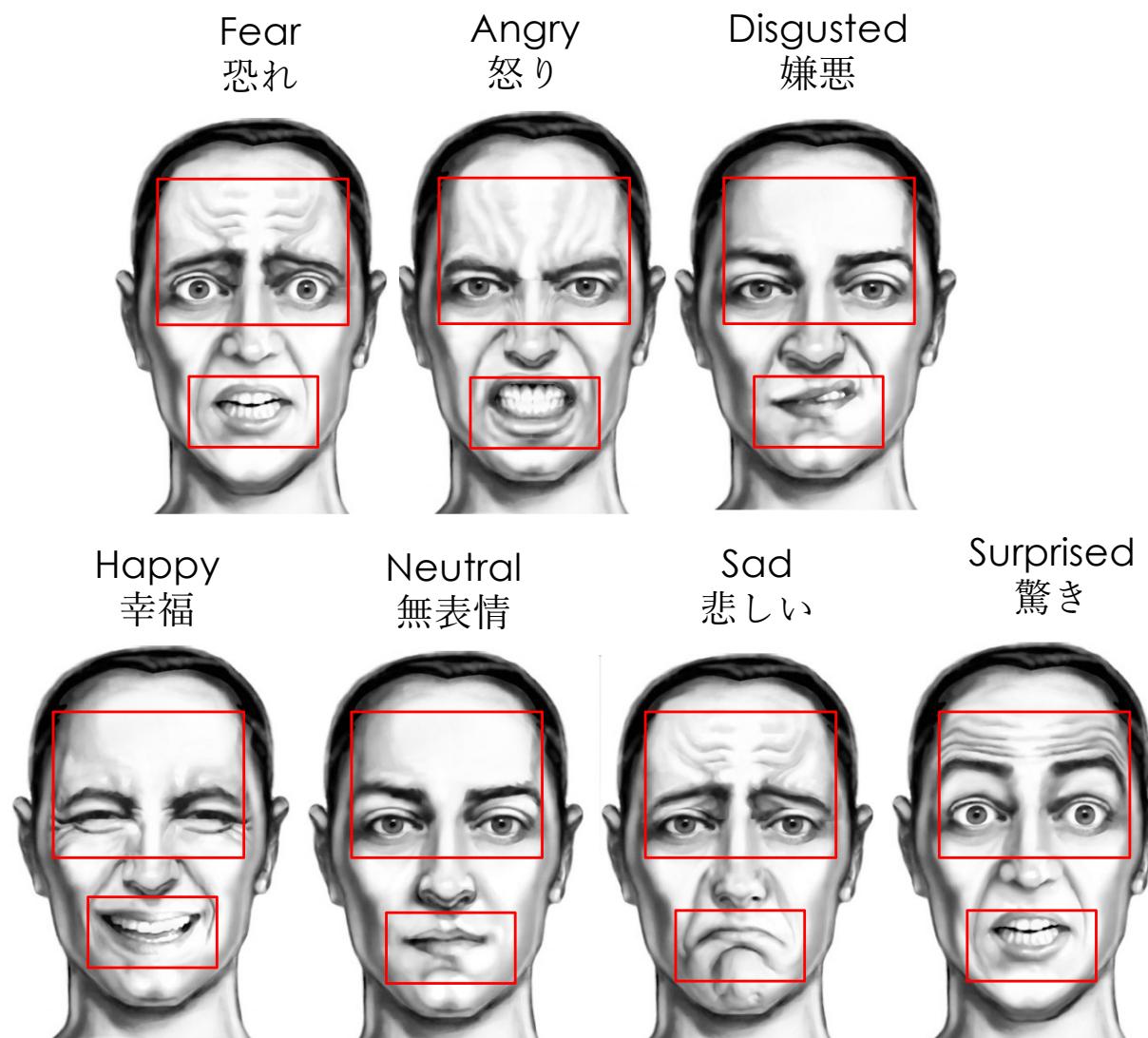
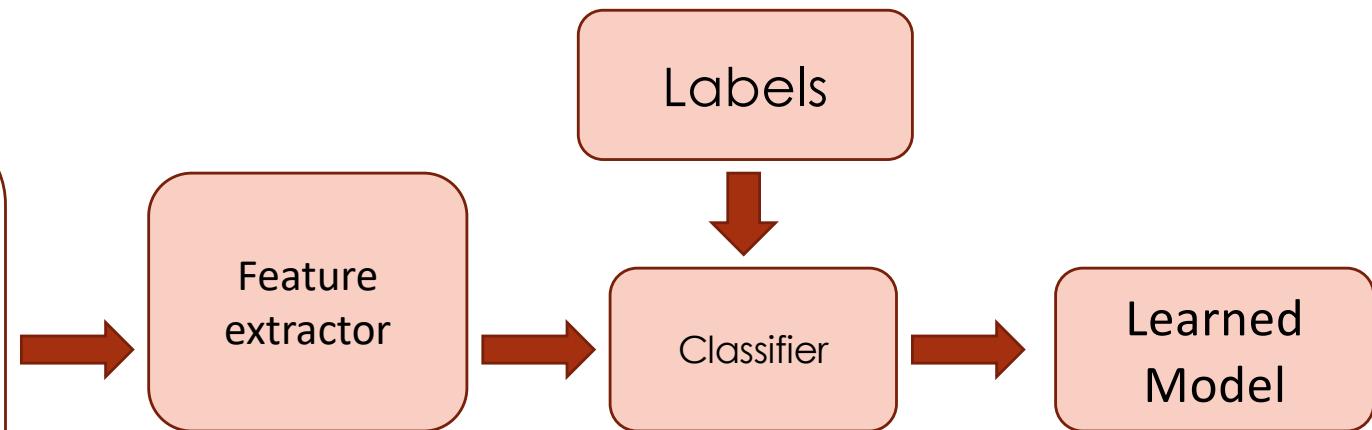
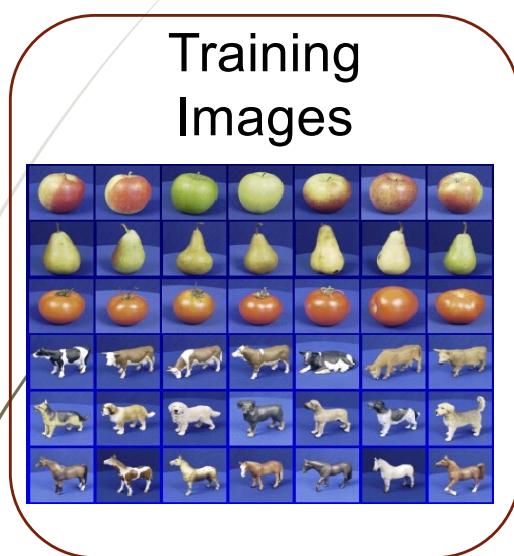


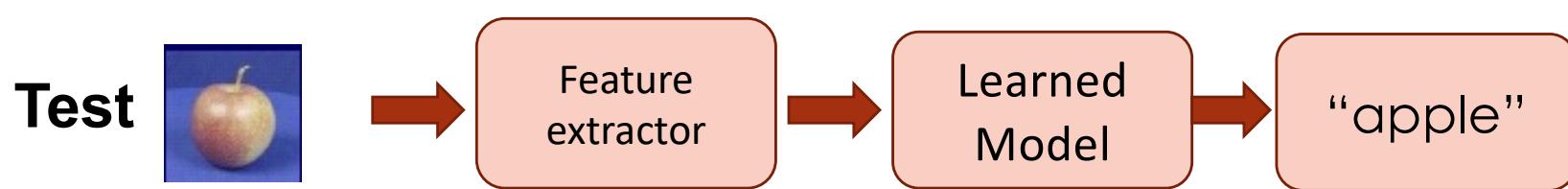
Figure 4. ROI (Regions of Interest) in Faces.

Machine Learning Training/set マシン ラーニング" トレーニング"・セット

Training



$$f(\text{apple}) = \text{"apple"} \\ f(\text{tomato}) = \text{"tomato"}$$



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Learning model
ラーニング モデル

Label
ラベル

Artificial Neural Networks
Support Vector Machine
Proposal

No label
ラベル なし

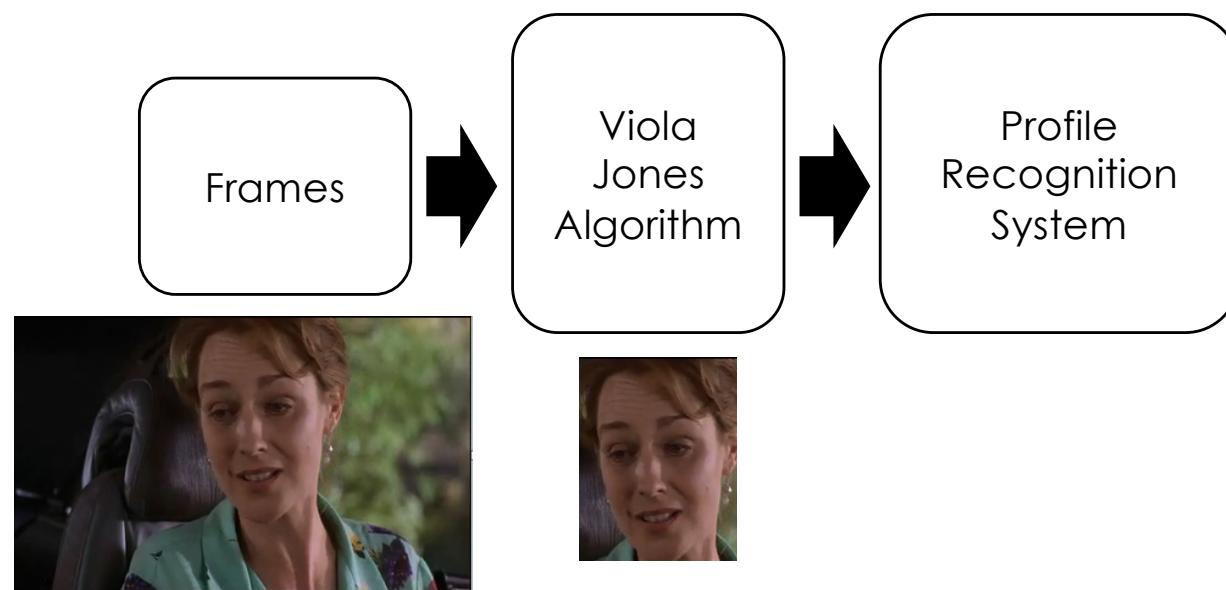
Associative memories
Kohonen networks
Adaptive method
Batchelor and Wilkins
algorithm



Module for Recognizing the Profile

プロファイル認識

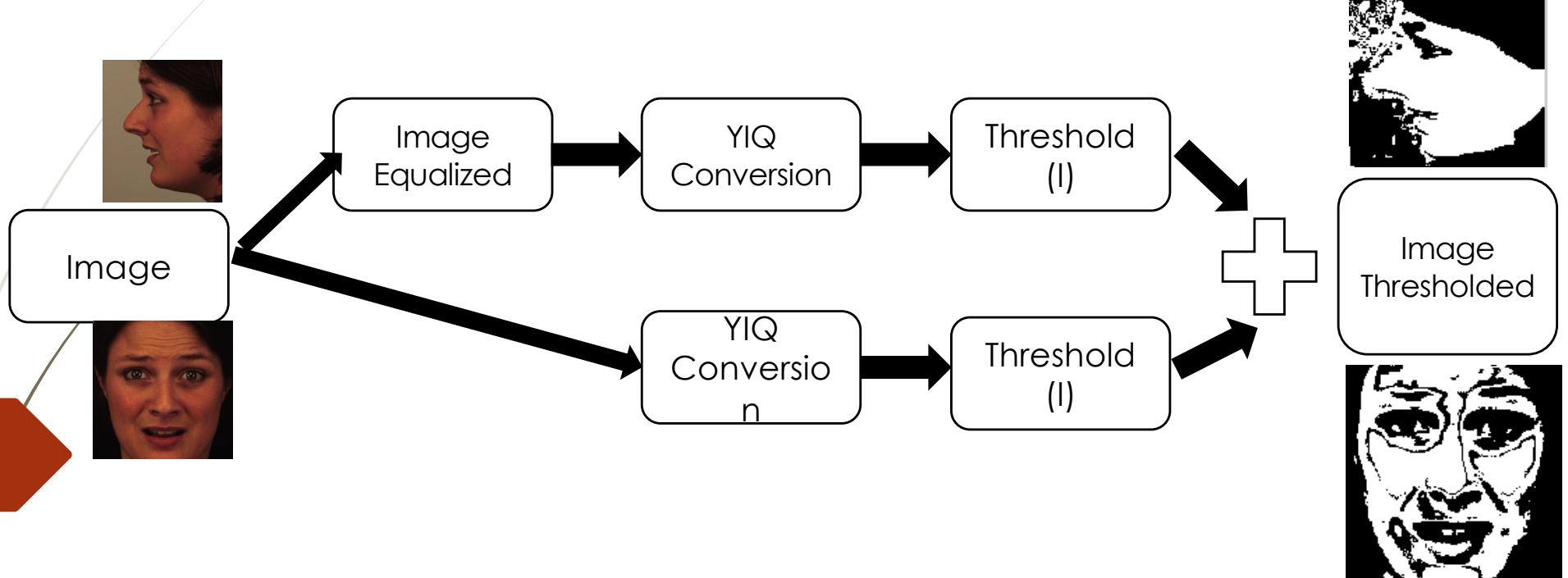
Module for Recognizing the Profile プロファイル認識



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Figure 5. Module diagram.

Module for Recognizing the Profile • プロファイル認識



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Figure 6. Profile Recognition System.

(1) Face Detection and Facial Feature Localization for Human-machine Interface. Md. Al-Amin BHUIYAN National Institute of Informatics . 2003

Module for Recognizing the Profile プロファイル認識

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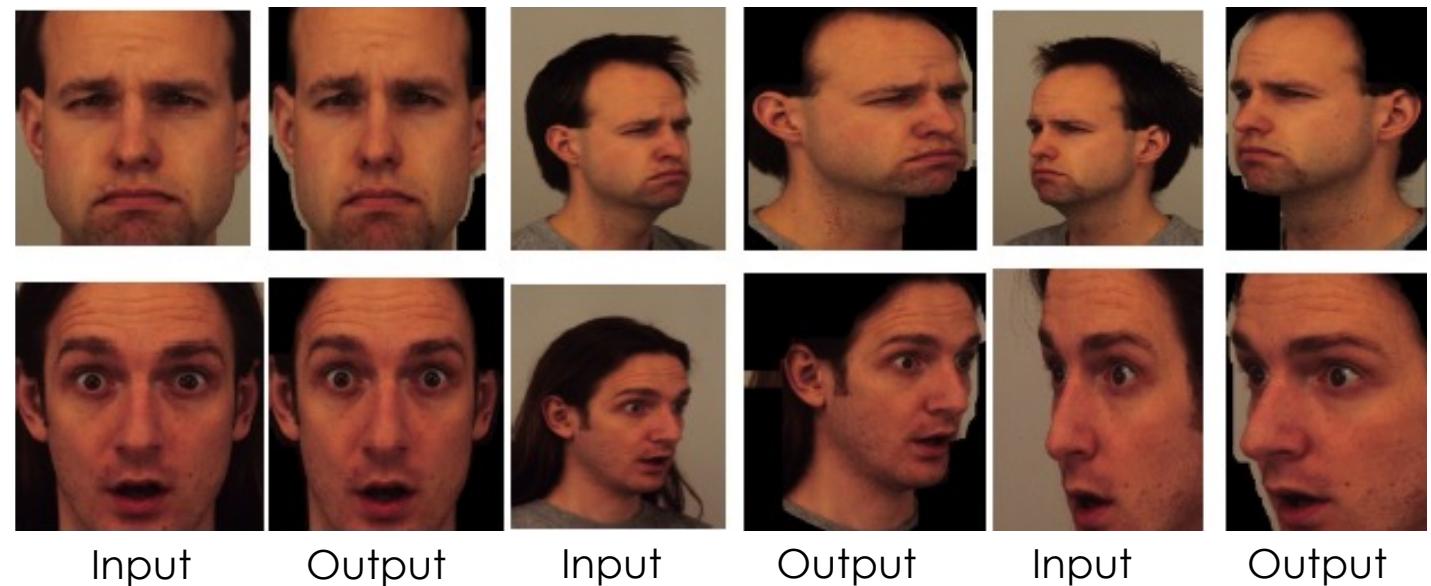


Figure 7. Profile detector results.

Module for Recognizing the Profile • フロファイル認識

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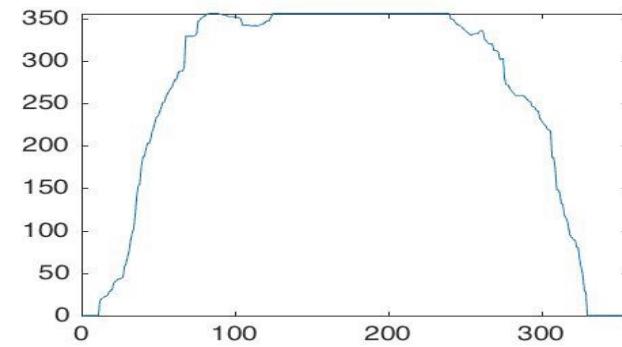
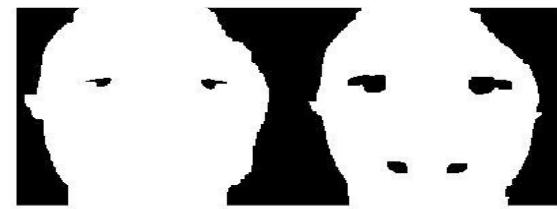


Figure 8. Results of the profile detector, person from the front.

Module for Recognizing the Profile プロファイル認識

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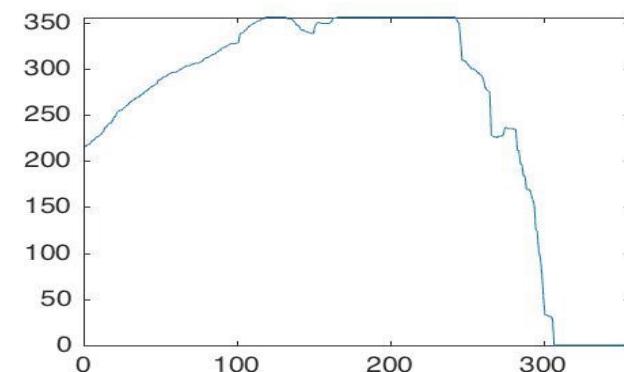
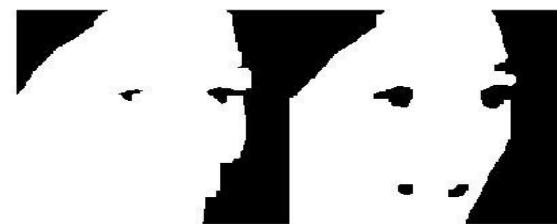
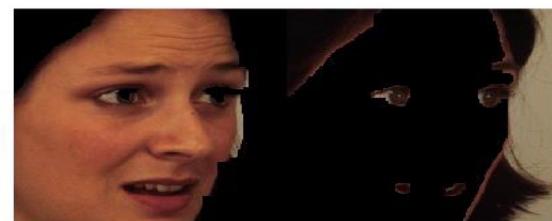


Figure 9. Results of the profile detector, person turning to the right.

Module for Recognizing the Profile プロファイル認識

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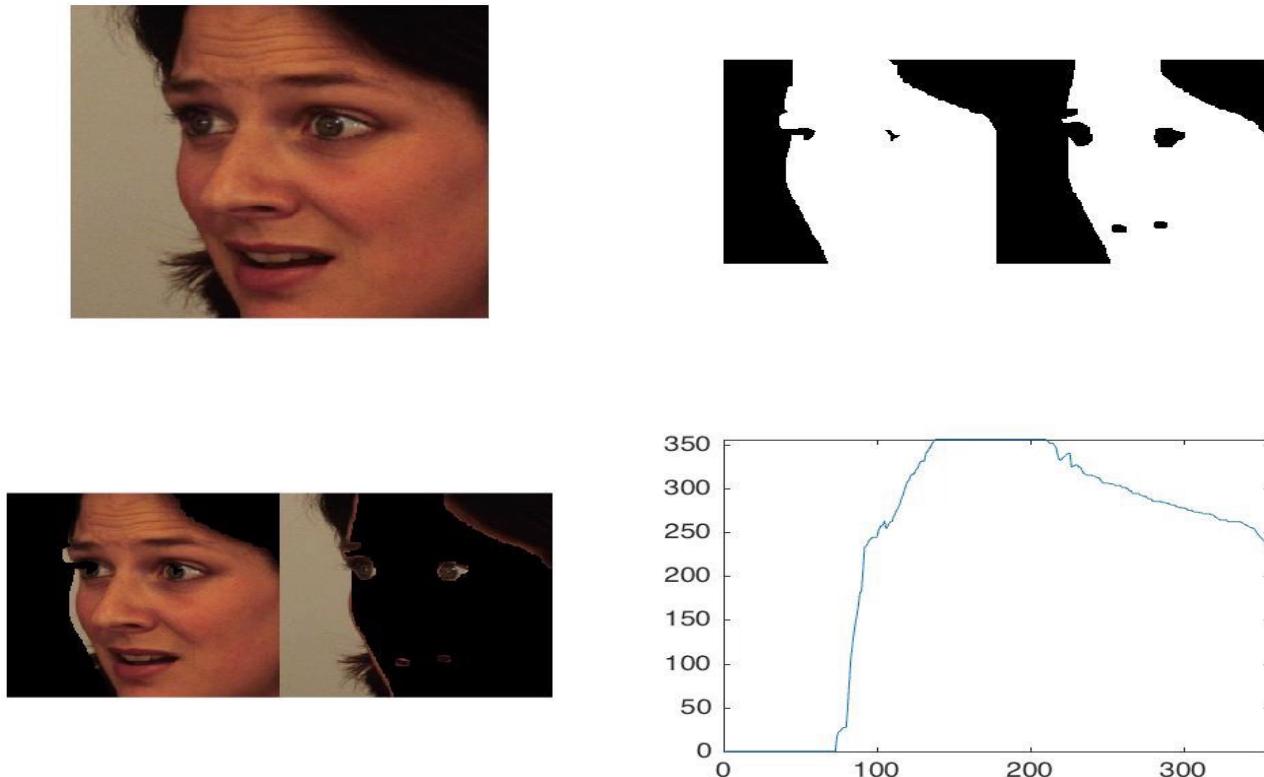


Figure 10. Results of the profile detector, person turning to the left.

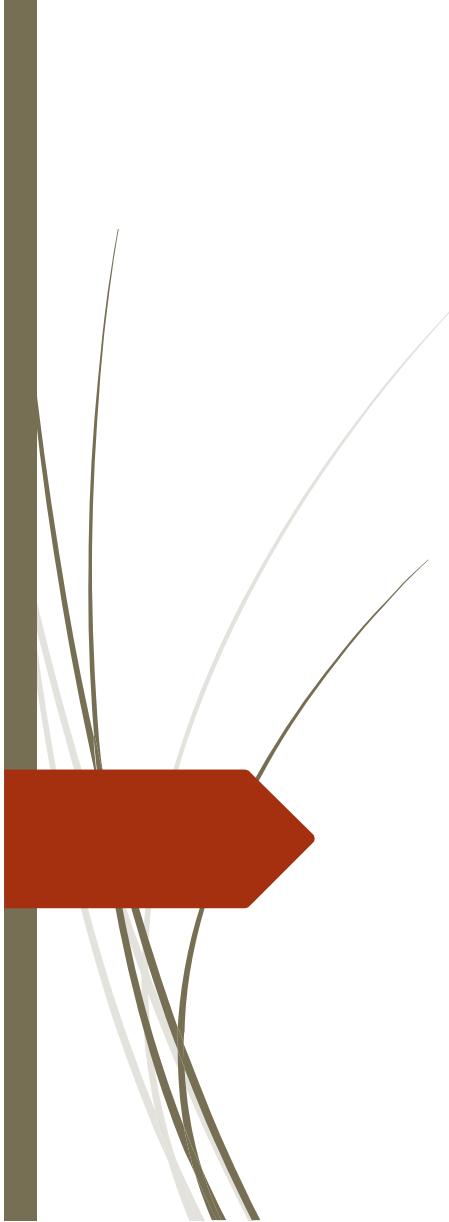
Module for Recognizing the Profile プロファイル認識

Using a Clustering-based Classifier
(260 training, 230 test)

99.13% Left
99.56% Center
97.36% Right

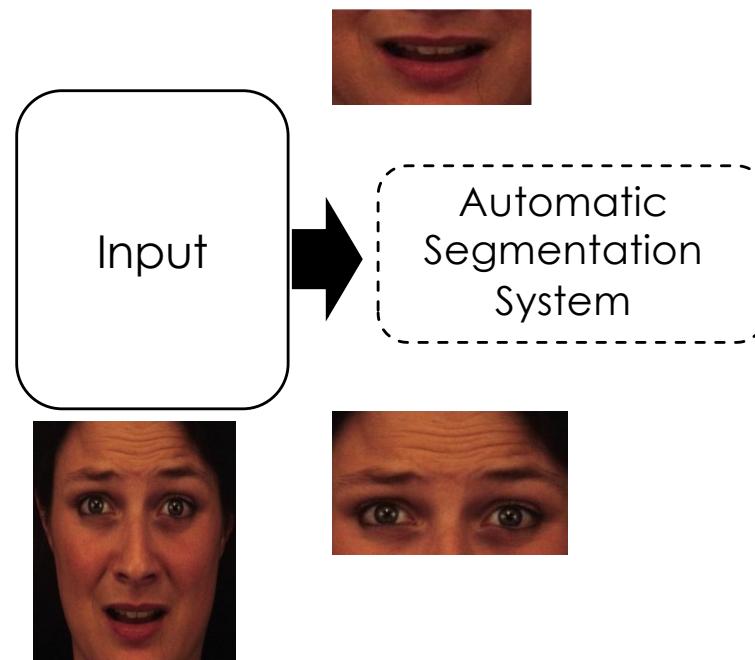
98.68% Average

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Automatic
segmentation module
of regions of interest
興味領域の自動認識モデル

Automatic segmentation module of regions of interest • 興味領域の自動認識モデル



Automatic segmentation module of regions of interest • 興味領域の自動認識モデル

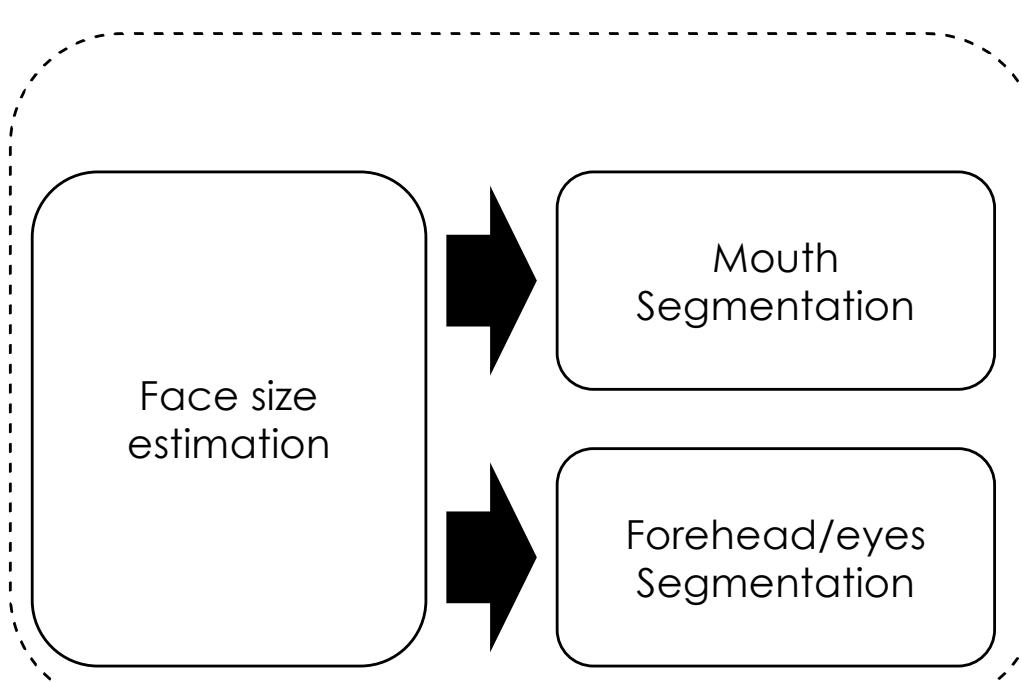


Figure 11. Diagram of automatic segmentation of ROIs.

Automatic segmentation module of regions of interest • 興味領域の自動認識モデル

Face size estimation • 顔のサイズの推定

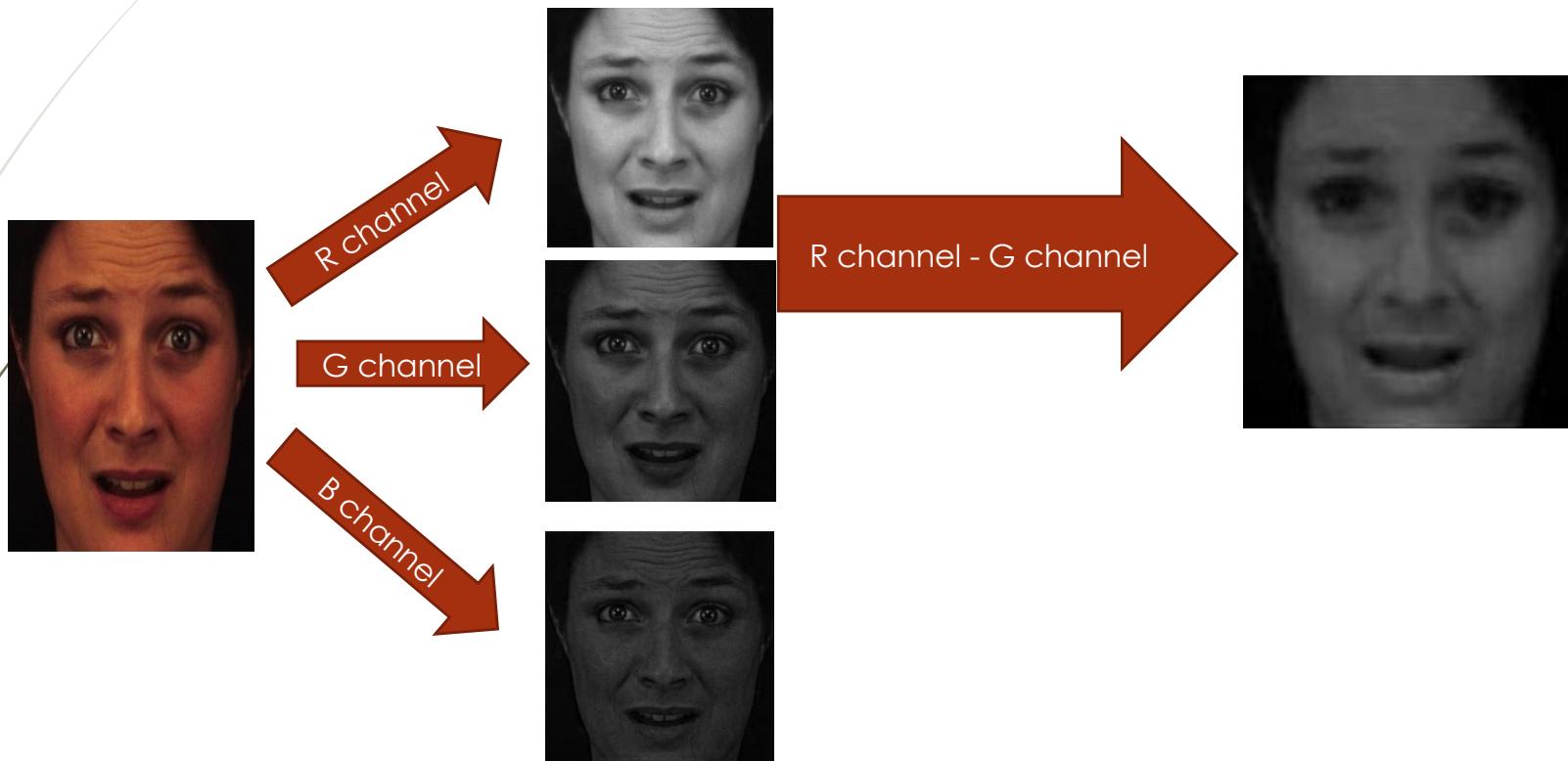


Figure 12. RGB image, R and G channel subtraction.

Automatic segmentation module of regions of interest • 興味領域の自動認識モデル

Face size estimation • 顔のサイズの推定

$$I(x,y) = \begin{cases} 0, & I(x,y) < 1 \\ 255, & I(x,y) \geq 1 \end{cases}$$



Figure 13. Image before and after thresholding.

Automatic segmentation module of regions of interest • 興味領域の自動認識モデル

Face size estimation • 顔のサイズの推定

$$M_{p,q} = \sum_{x=1}^N \sum_{y=1}^M x^p y^q I(x, y) \text{ Equation (1)}$$

Moment of an image

$I(x, y)$ is the intensity of the image at position (x, y) .

N is the number of columns.

M is the number of rows.

P & q define the momentum of the image.

Automatic segmentation module of regions of interest • 興味領域の自動認識モデル

Face size estimation • 顔のサイズの推定

Center of gravity[1]

$$X_c = \frac{M_{1,0}}{M_{0,0}} \text{ Equation (2)} \quad Y_c = \frac{M_{0,1}}{M_{0,0}} \text{ Equation (3)}$$

We define 3 intermediate variables

$$a = \frac{M_{2,0}}{M_{0,0}} - X_c^2 \text{ Equation (4)}$$

$$c = \frac{M_{0,2}}{M_{0,0}} - Y_c^2 \text{ Equation (5)}$$

$$b = 2\left(\frac{M_{1,1}}{M_{0,0}} - X_c Y_c\right) \text{ Equation (6)}$$

[1] M.Pizer, Adaptive Histogram Equalization and its Variations, Computer Vision, Graphics and Image Processing, 39(1987)355-368

Automatic segmentation module of regions of interest • 興味領域の自動認識モデル

Face size estimation • 顔のサイズの推定

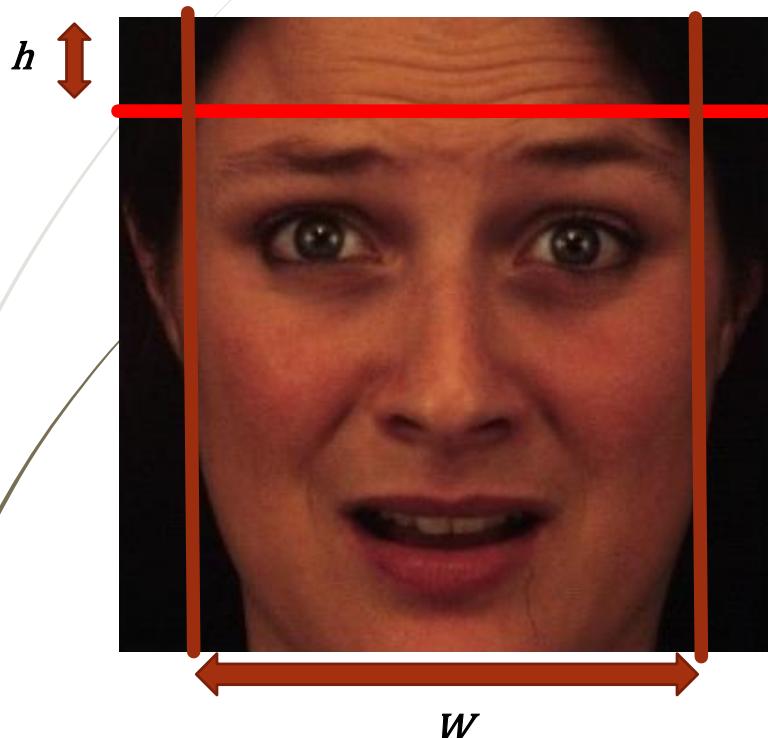


Figure 14. Face segmentation.

$$W = 2 \sqrt{\frac{(a+c) - \sqrt{b^2 + (a-c)^2}}{2}} \quad \text{Equation (7)}$$

$$h = Y_C - 0.84 \frac{W}{2} \quad \text{Equation (8)}$$

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Automatic segmentation module of regions of interest • 興味領域の自動認識モデル

Mouth segmentation • 口セグメンテーション

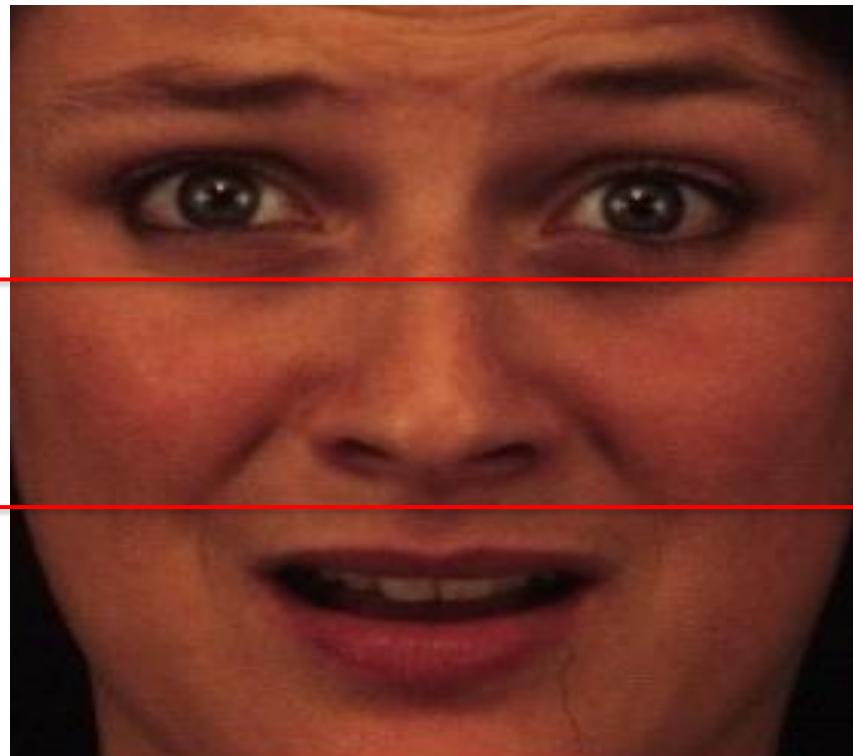


Figure 15. Facial symmetry.

Automatic segmentation module of regions of interest • 興味領域の自動認識モデル

Mouth segmentation • 口セグメンテーション

Where "D" is
the
maximum
value of
the
projective
integral.

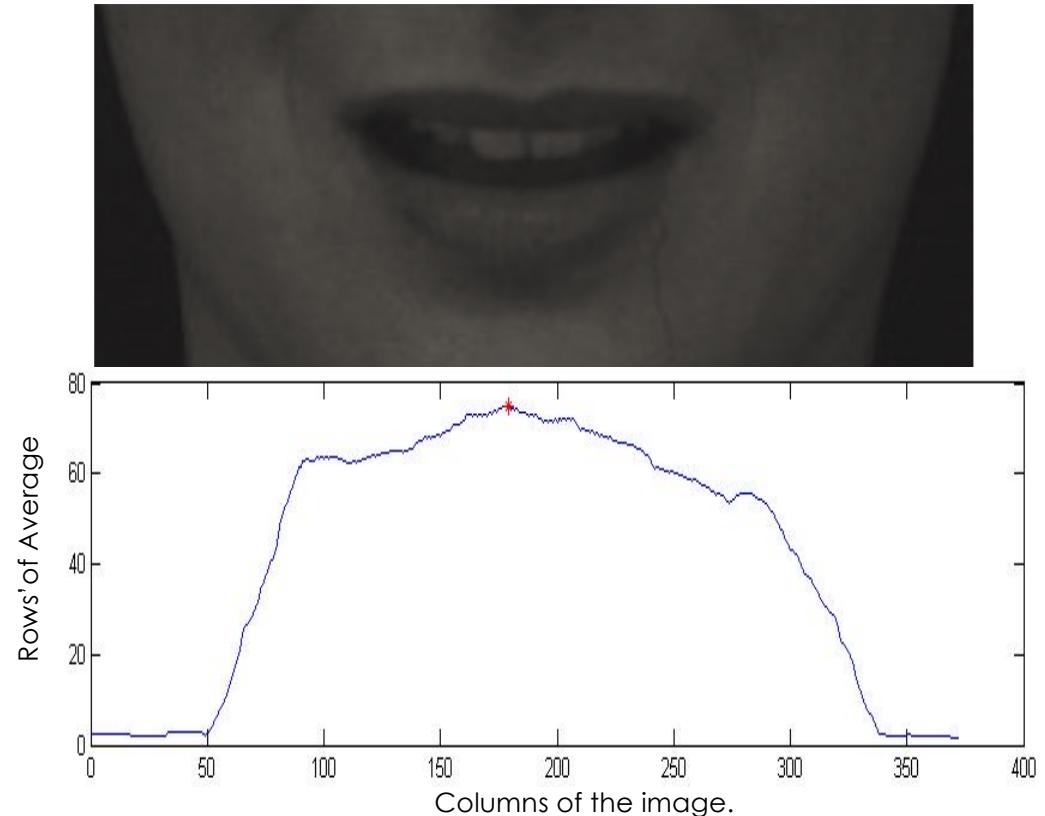


Figure 16. Projective integral of the mouth.

Automatic segmentation module of regions of interest • 興味領域の自動認識モデル

Mouth segmentation • 口セグメンテーション

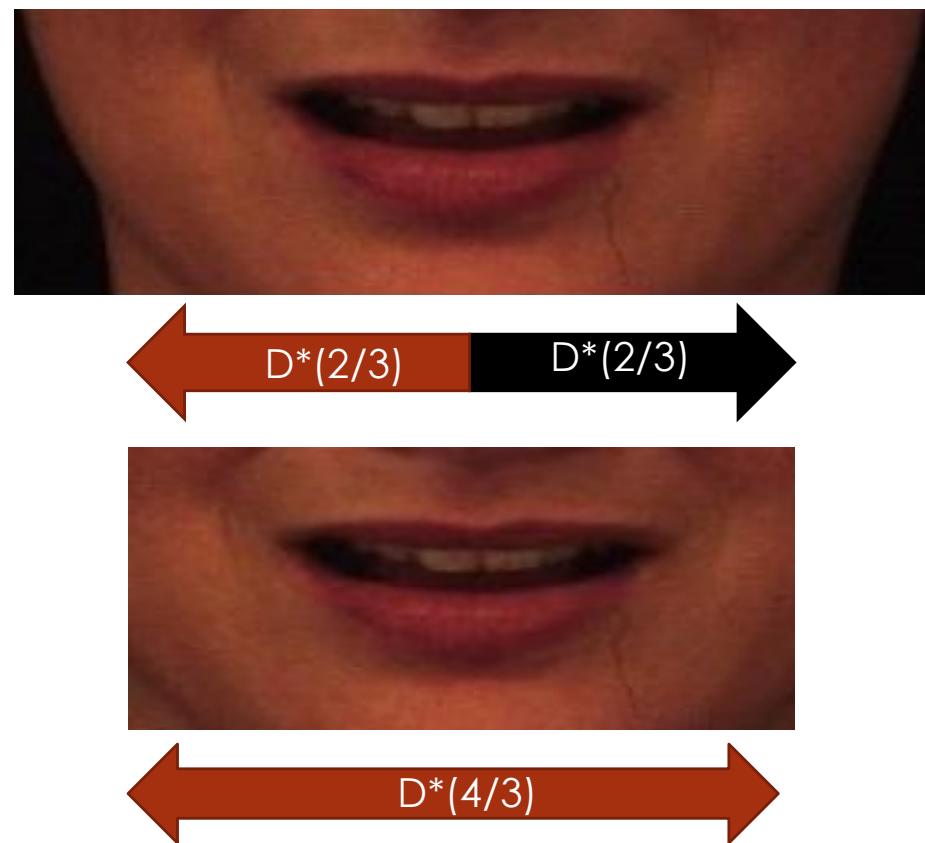


Figure 17. Segmentation of the mouth.

Automatic segmentation module of regions of interest • 興味領域の自動認識モデル

Mouth segmentation • 口セグメンテーション

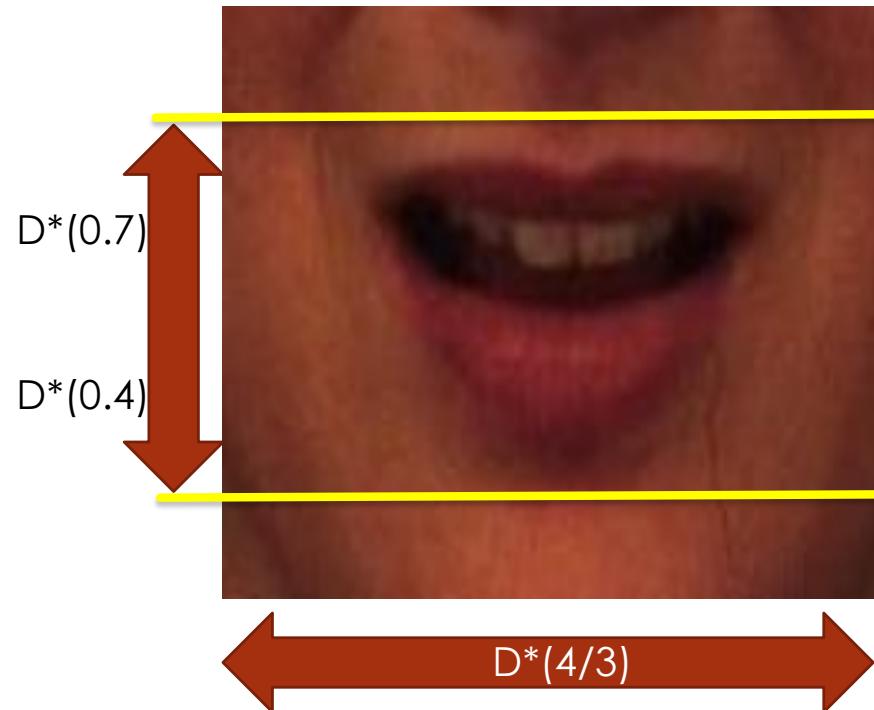


Figure 18. Mouth segmentation.

Automatic segmentation module of regions of interest • 興味領域の自動認識モデル

Forehead/eyes segmentation • 額/め セグメンテーション



Figure 19. Facial symmetry.



Figure 20. Forehead/eyes segmentation

Automatic segmentation module of regions of interest • 興味領域の自動認識モデル

Forehead/eyes segmentation • 額/め セグメンテーション



Figure 21. Forehead/eyes segmentation.



Table 1. Comparison of ROI.

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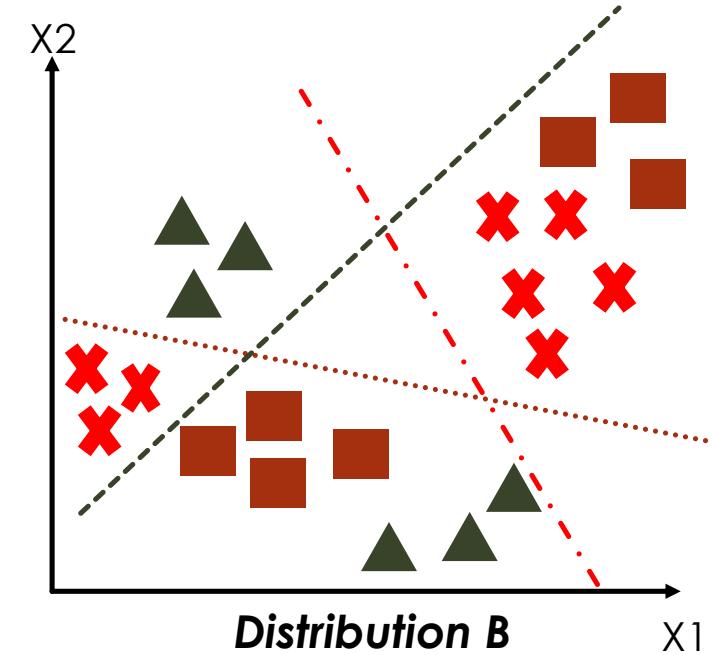
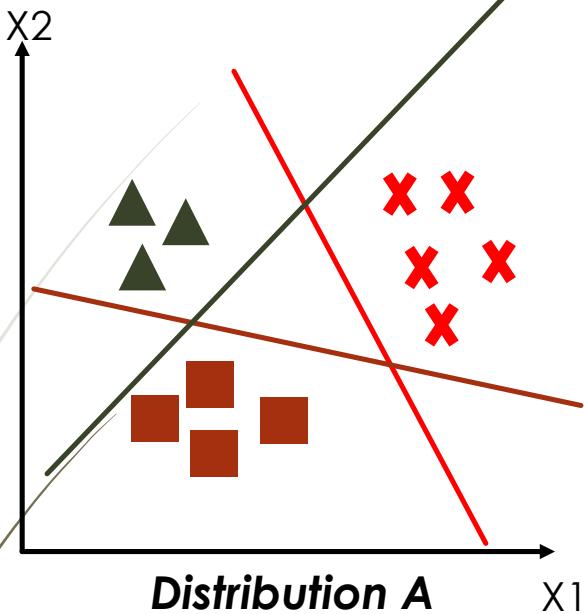
Video 1. Automatic ROI segmentation results.



Classifier Based on Clustering Techniques and Fuzzy Logic

クラスタリングとファジ論理 技術に基づく分類器

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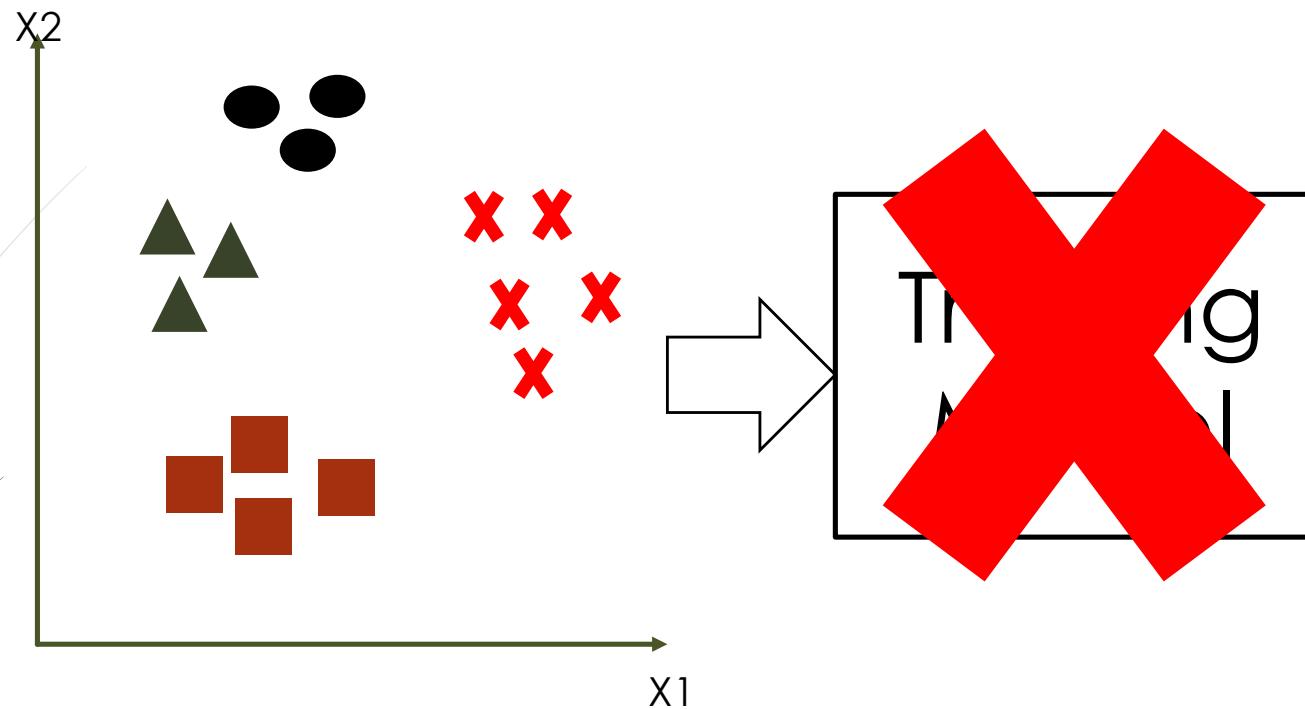
Clustering Distribution A is easy for classic approaches.

Clustering Distribution B is difficult for classic approaches.

→ **Clustering intermixed data**

混合データのクラスタリング

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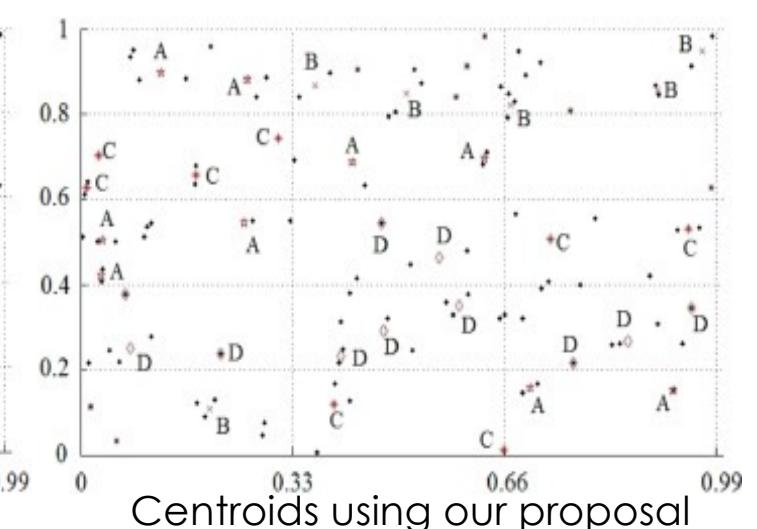
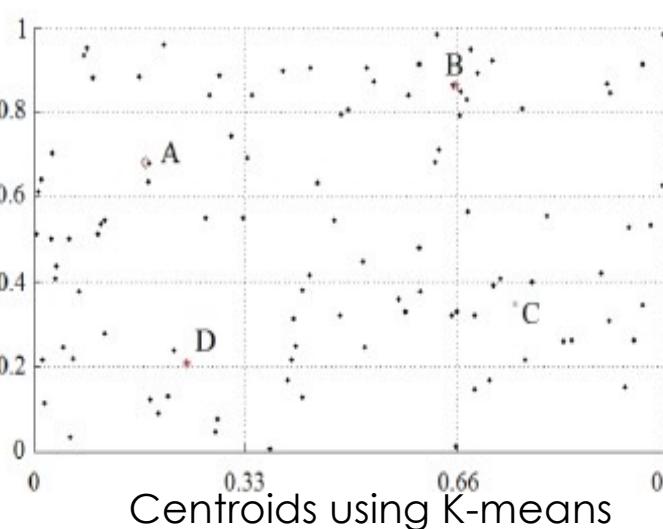
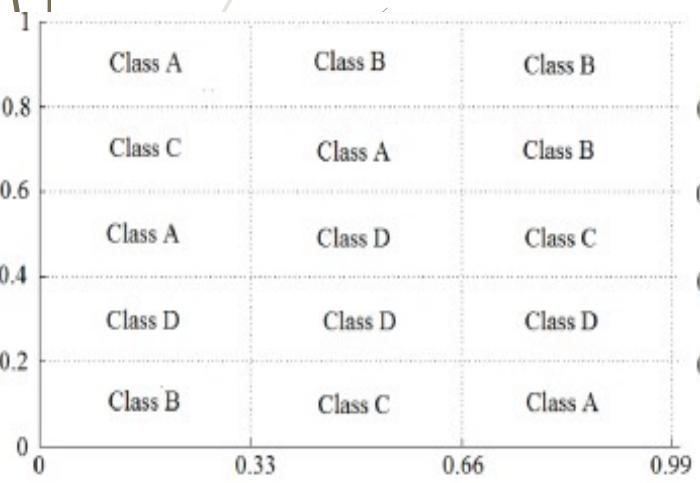


Learning methods require all classes in advance

→ Training a new class when the model is already trained
モデルがすでにトランニンゲされいる場合に新しいクラスをト
レーニングします

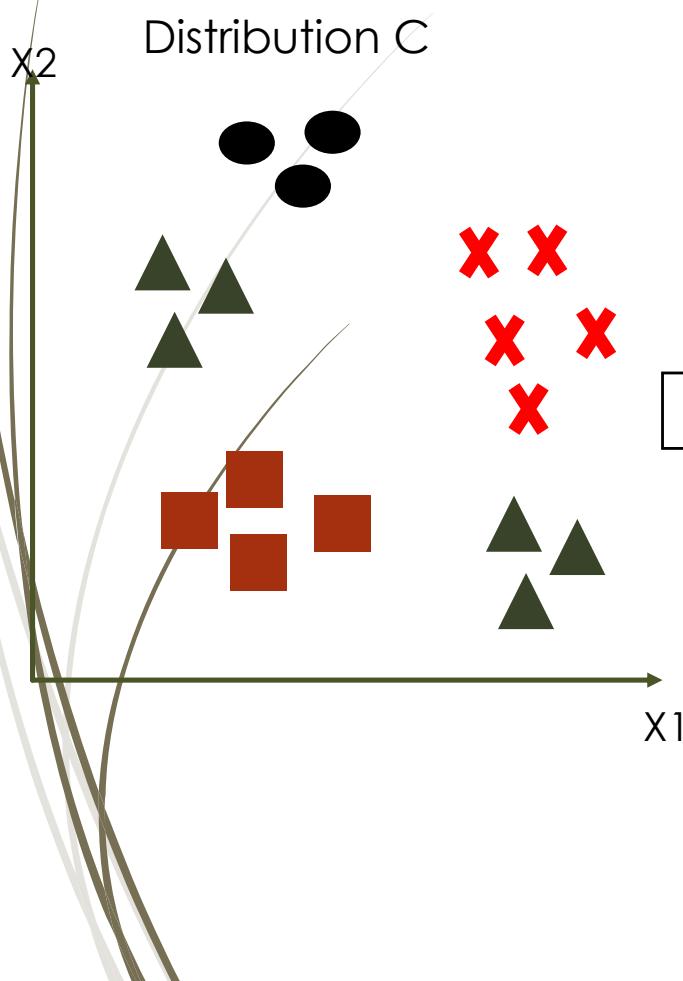
A classifier based on clustering algorithms and fuzzy logic.

Experimental results show that the classification rates are similar between our proposal and classic classification algorithms.



Images were taken from A. Hernandez-Matamoros, Et al., A supervised classifier scheme based on clustering algorithms, Central America and Panama Convention (CONCAPAN XXXIV), 2014 IEEE, Panama City, 2014, pp. 1-5.

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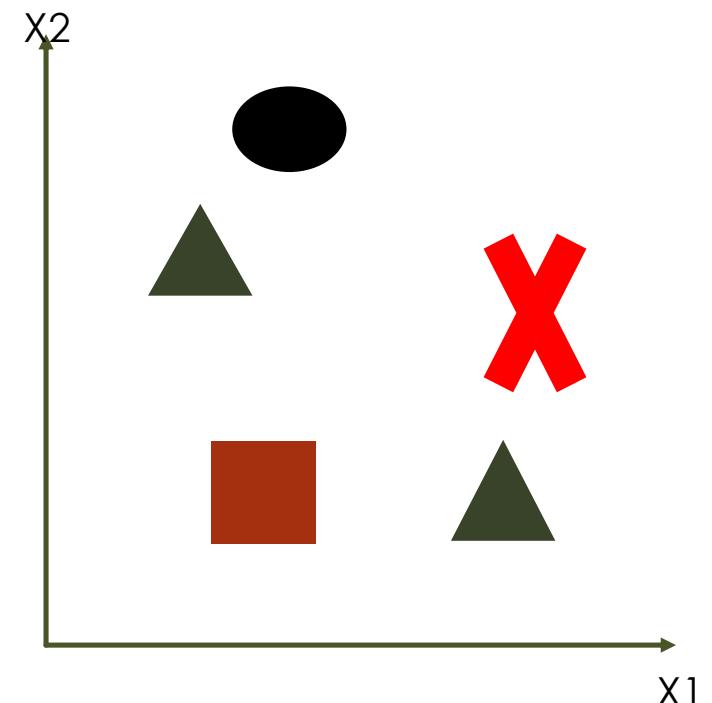
XX
X X
X X
X

x_1



How our model trains

Centroids of Distribution C



x_1

Databases • データベース KDEF (The Karolinska Directed Emotional Faces)

70 people, 7 facial expressions Miedo

- ▶ Angry
- ▶ Disgusted
- ▶ Fear
- ▶ Happy
- ▶ Sad
- ▶ Neutral
- ▶ Surprised



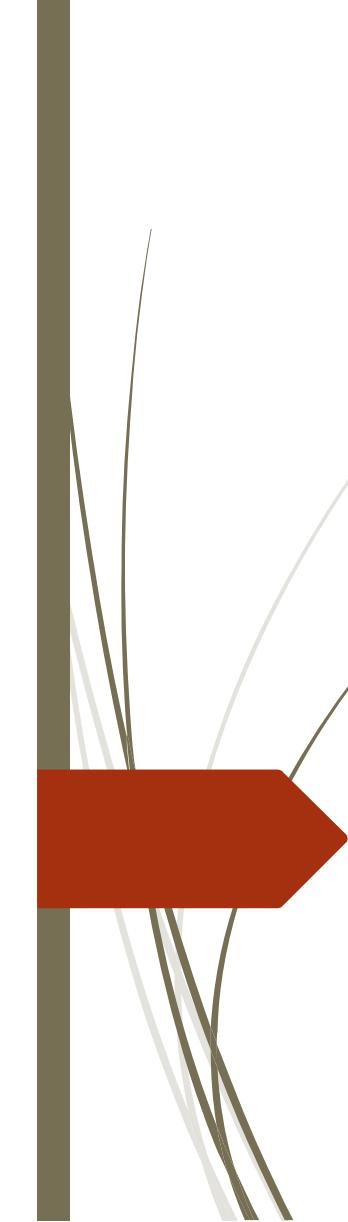
Figure 22. Examples of different profiles

HOHA (Hollywood Human Actions)

- 32 Movies
 - ▶ AnswerPhone
 - ▶ GetOutCar
 - ▶ HandShake
 - ▶ HugPerson
 - ▶ Kiss
 - ▶ SitDown
 - ▶ SitUp
 - ▶ StandUp



Figure 23. Example of frame.



FER Images- Experimental Results

FERイメージの実験結果

FER Images-Experimental Results ▪ FERイメージの実験結果

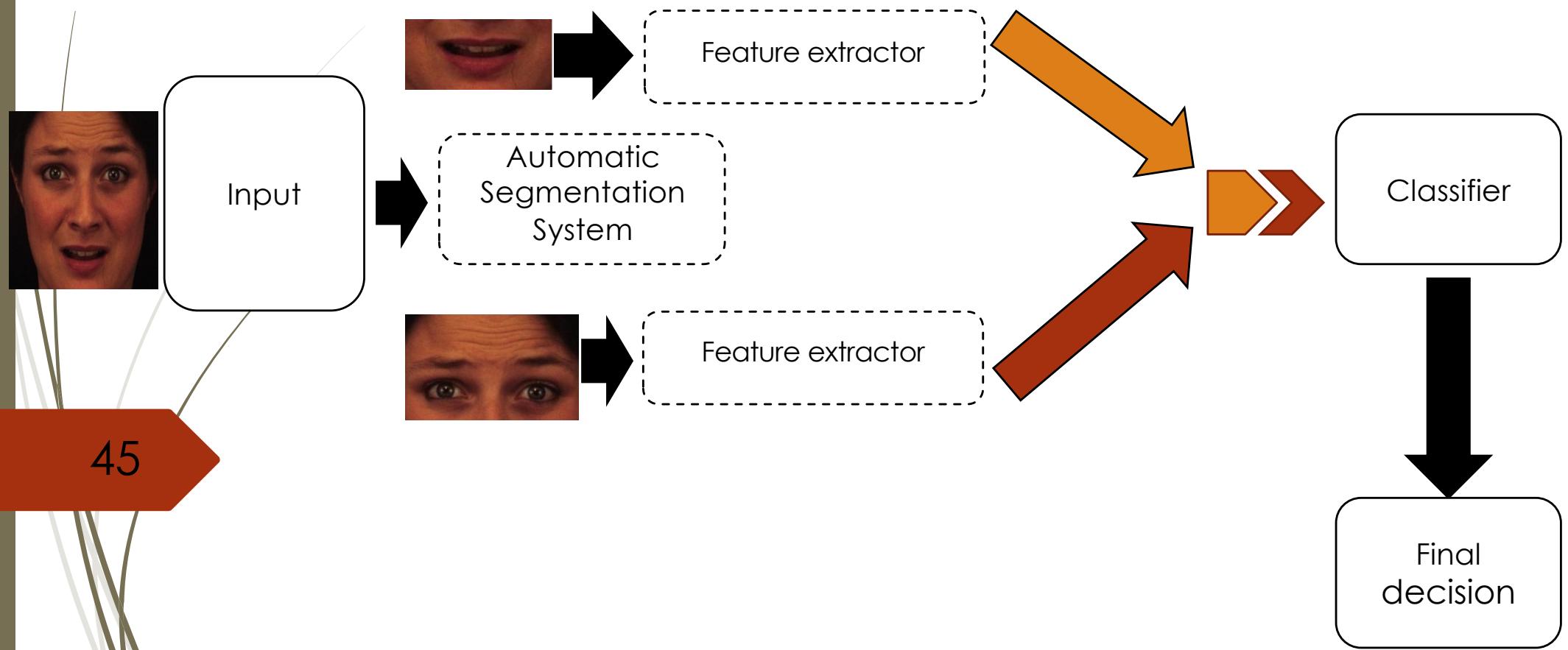


Figure 24. Recognition of facial expressions in images.

Feature extractor・特徴抽出器

- Gabor Filters
ガ"ボ"ールフィルター
- Principal Component Analysis
プリンシパル コンポーネント アナリシス

Table 2. Comparison with literature segmenting the face.

Reference	Feature extractor	Classifier	Forehead/eyes	Mouth	Forehead/eyes+Mouth	Database
<i>Proposal</i>	<i>Gabor Filter+PCA</i>	<i>Clustering</i>	<i>99.14</i>	<i>100</i>	<i>100</i>	<i>KDEF</i>
A(2014)(1)	MVA	SVM	60	79.3	82	CK
B(2014)	Gabor Template	SVM	95.1(2)	90.8	N/A	CK

(1) They only recognize 6 facial expressions (Afraid, Angry, Disgusted, Happy, Sad and Surprise).

(2) Only use eye regions for recognition.

[A] L. Zhang, D. Tjondronegoro, V. Chadran, Gabor based templates for facial expression recognition in images with facial occlusion, Neurocomputing, 145 (5) (2014) 451-464.

[B] G. Benitez-García, G. Sanchez-Perez, H. Perez-Meana, K. Takahashi and M. Kaneko, Facial expression recognition based on facial region segmentation and modal value approach, IEICE Transactions on information and systems, E97 (4) (2014) 928-935.

Comparison with full-face literature.

Reference	Feature extractor	Classifier	Classes	% Recognition	Database
<i>Proposal</i>	<i>Gabor Filter + PCA</i>	<i>Clustering</i>	<i>7</i>	<i>99.9</i>	<i>KDEF</i>
C (2015)	EMD + PCA + LDA, EMD + PCA + LFDA, EMD + KLFDA	KNN, SVM, ELM-RBF	7	99.9	JAFFE
C (2015)	EMD + PCA + LDA, EMD + PCA + LFDA, EMD + KLFDA	KNN, SVM, ELM-RBF	7	99.75	CK

[C] H. Ali, M. Hariharan, S. Yaacob, A. Hamid-Adom, Facial recognition using empirical mode decomposition, Expert Systems and Applications, 42 (3) (2015) 1261-1277.

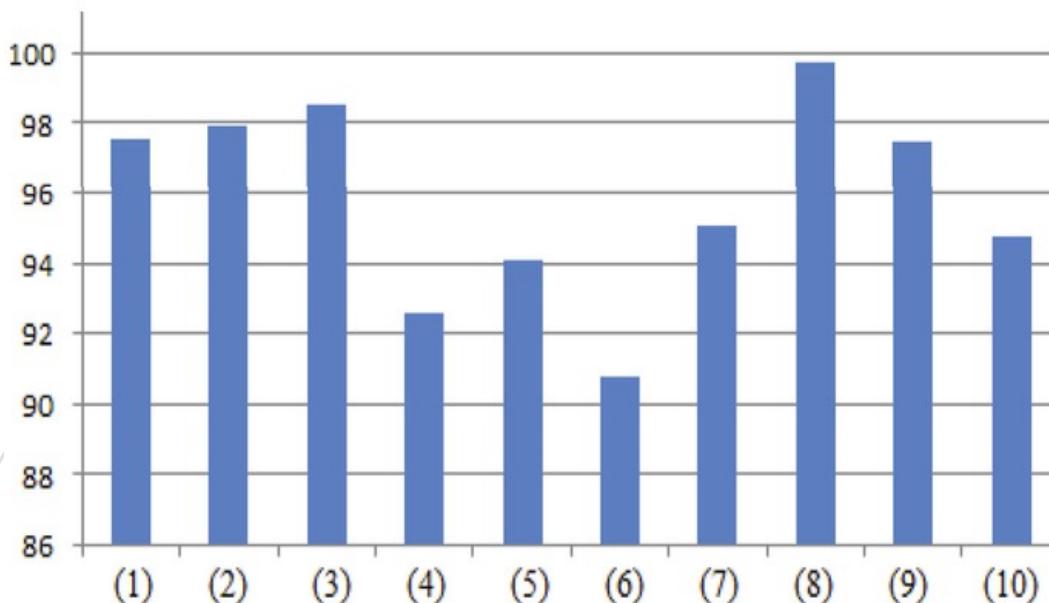


Figure 26. Recognition Percentages

- 1 Proposed Mouth
- 2 Proposed Forehead/Eyes
- 3 Proposed Both Regions
- 4 E. Benitez [B]
- 5 E. Zhang [A] Mouth
- 6 E. Zhang [A] Forehead/Eyes
- 7 E. Zhang [A] Both Regions
- 8 E. Ali [C]
- 9 E. Wang and Zhang [E]
- 10 E. Buciu and Pitas [D]

[A] L. Zhang, D. Tjondronegoro, V. Chadran, Gabor based templates for facial expression recognition in images with facial occlusion, *Neurocomputing*, 145 (5) (2014) 451-464.

[B] G. Benitez-García, G. Sanchez-Perez, H. Perez-Meana. K. Takahashi and M. Kaneko, Facial expression recognition based on facial region segmentation and modal value approach, *IEICE Transactions on information and systems*, E97 (4) (2014) 928-935.

[C] H. Ali, M. Hariharan, S. Yaacob, A. Hamid-Adom, Facial recognition using empirical mode decomposition, *Expert Systems and Applications*, 42 (3) (2015) 1261-1277.

[D] K. Buciu, and I. Pitas, An analysis of facial expression recognition under partial face image occlusion, *Image and Vision. Computing*, 26 (7) (2008) 1052-1067.

[E] Z. Wang and Q Rao, Facial expression based on orthogonal local Fisher discriminant analysis, *Proc. of International Conference on Signal Processing (ICSP) 2010*, pp. 1358-1361.

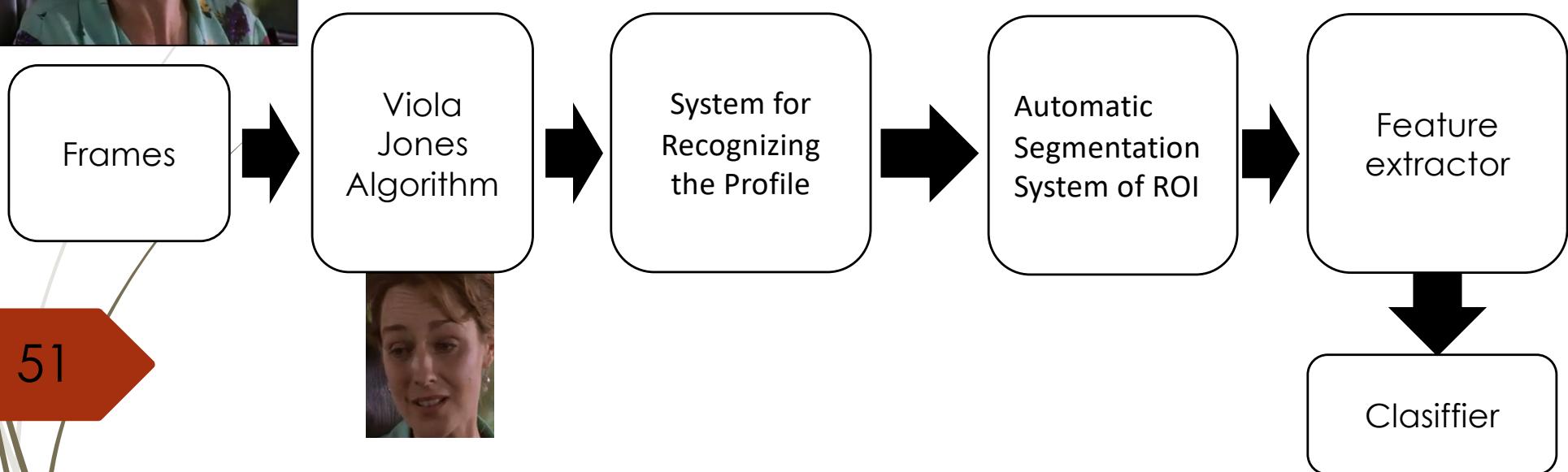


FER Video

Experimental Results

FERビデオの実験結果

FER-Video



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Figure 25. Diagram of the system.

Experimental results・実験結果

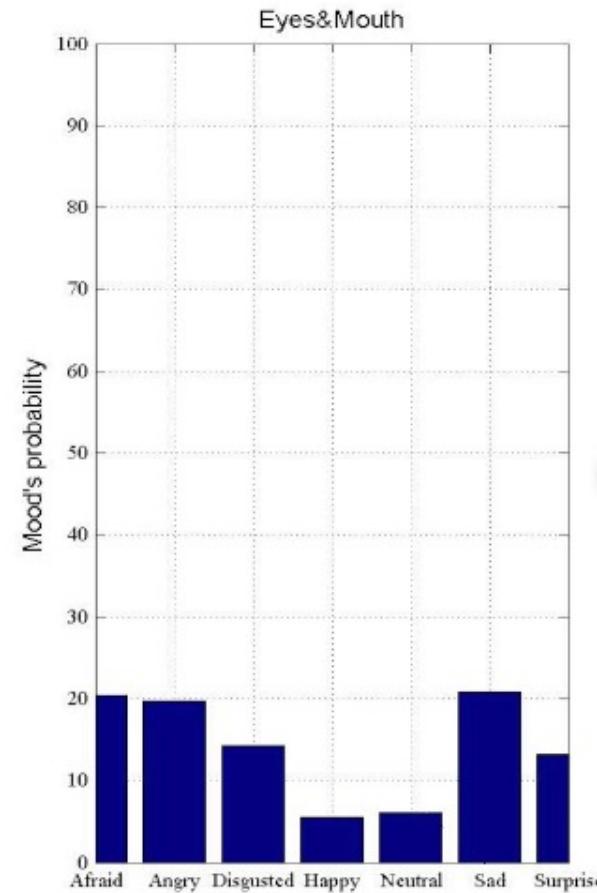


Figure 26.Example frontal FER.

Experimental results · 実験結果



Video: As Good As It Gets -
01766.avi
Action: Kiss

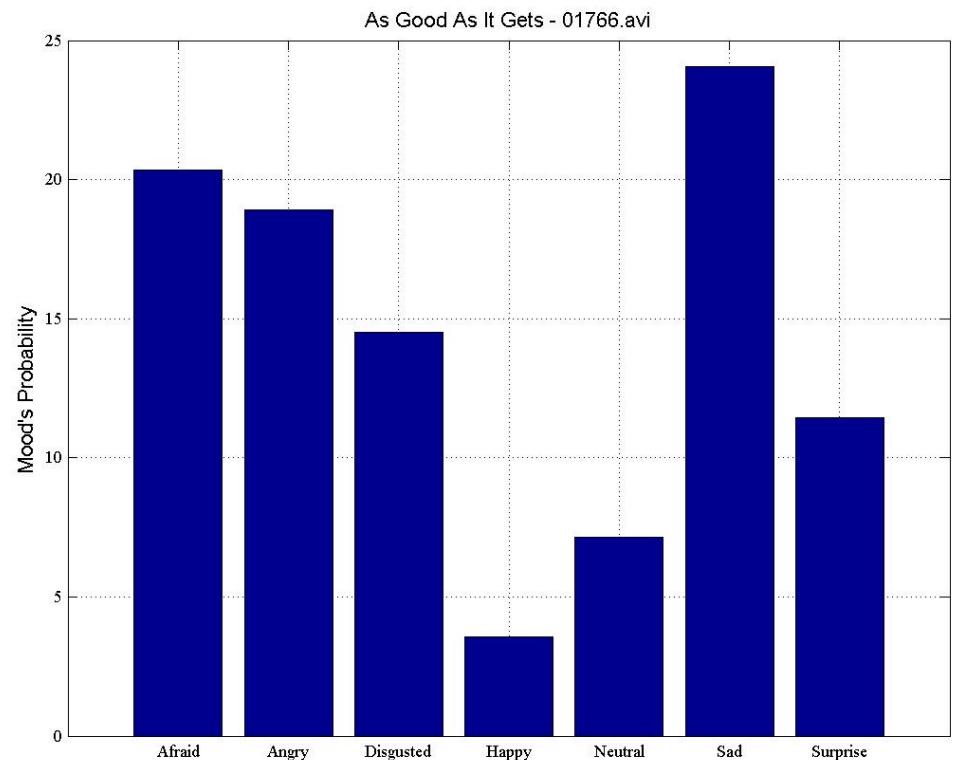


Figure 27. Probability of facial expressions for As Good As It Gets - 01766.avi.

Experimental results · 実験結果



Video: Butterfly Effect, The -
02093.avi
Action: Stand Up

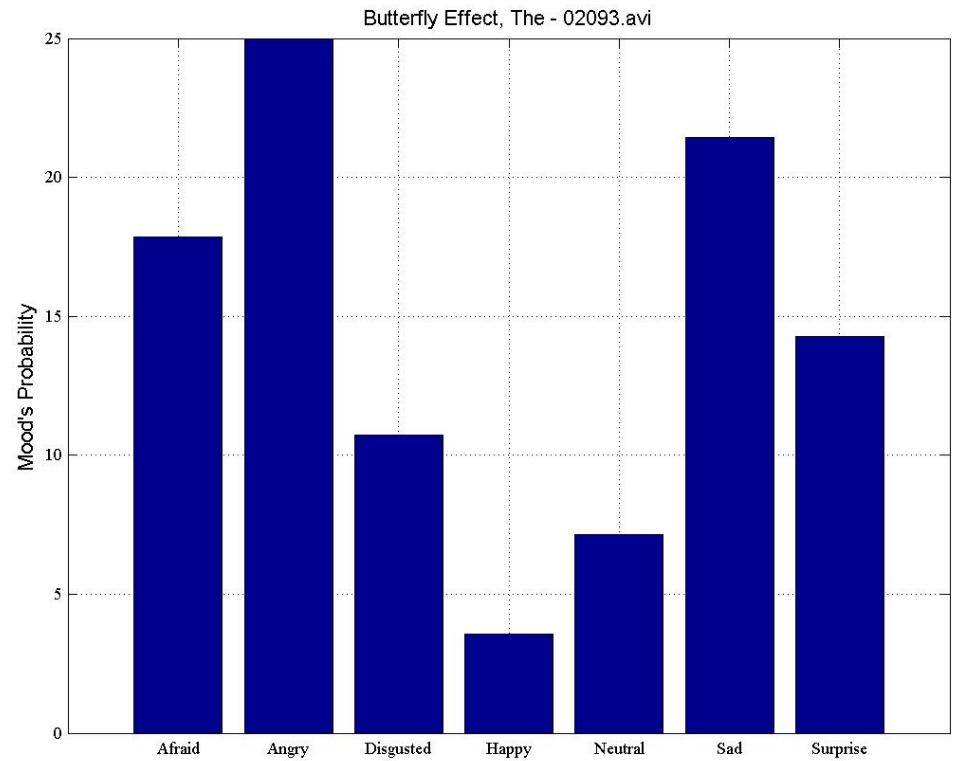


Figure 28. Probability of facial expressions
for Butterfly Effect, The - 02093.avi

Experimental results・実験結果

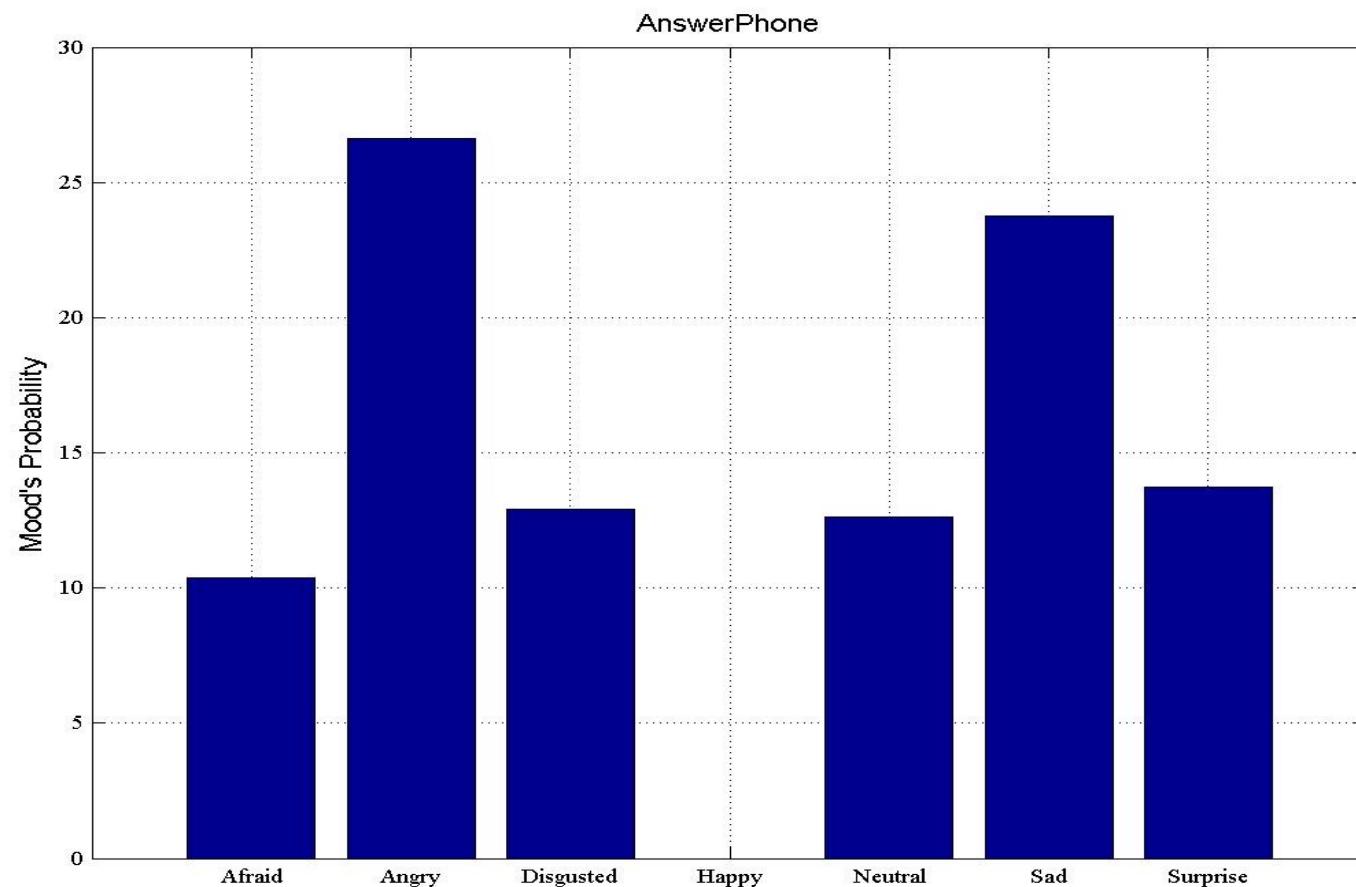


Figure 29. Probability of facial expressions for the Answer Phone action.

Experimental results・実験結果

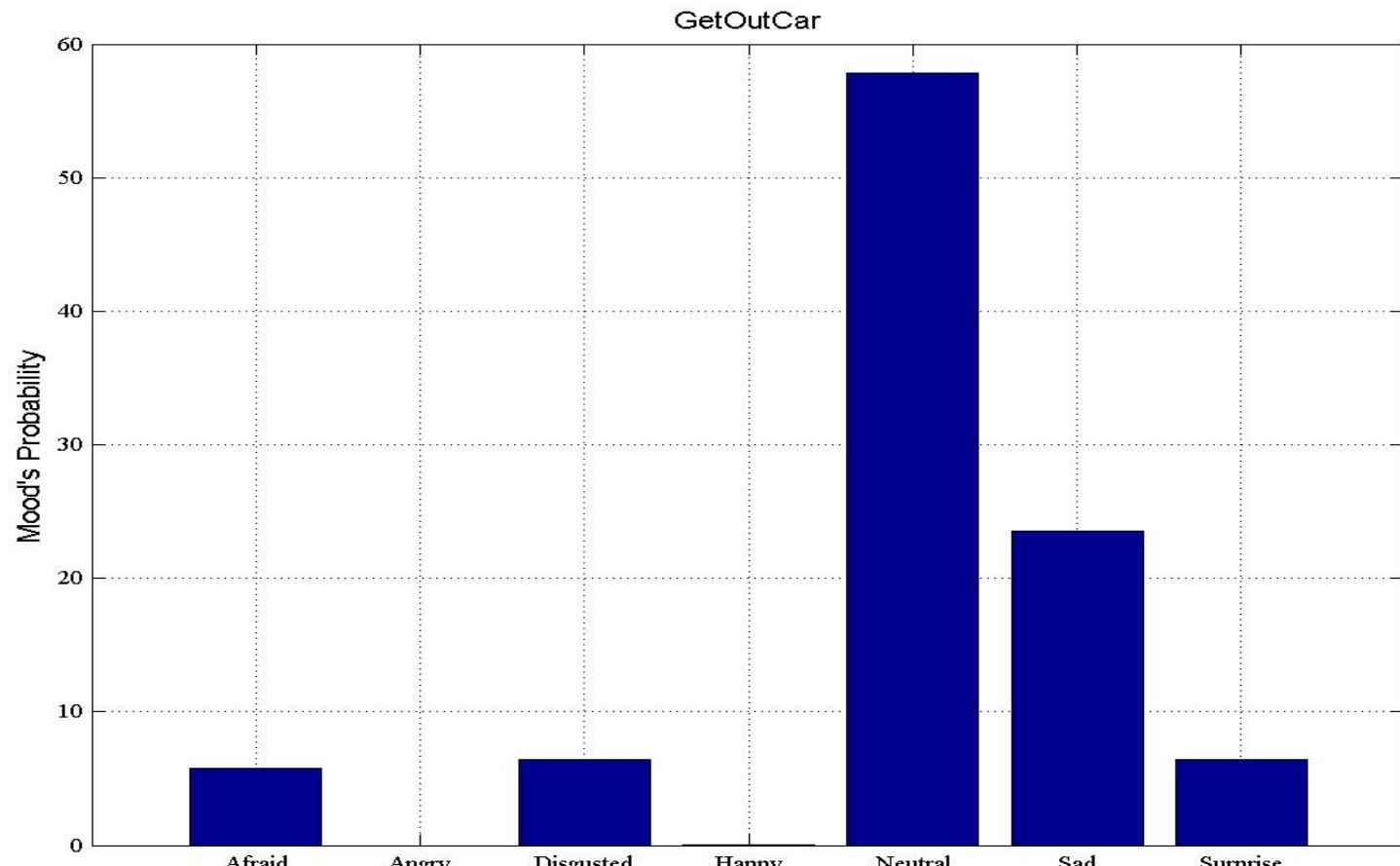


Figure 30. Probability of facial expressions for the Get out car action.

Conclusions・まとめ

- The first contribution is a system that detects the profile of the face, improving recognition rates when the face is facing forward.
成果は、顔のプロフィールを検出するシステムであり、顔が前を向いている場合の認識率を向上させます。
- This approach allows the creation of recognition systems for faces turned to one side.
このアプローチにより、片側を向いた顔のための認識システムの作成が可能になります。
- Another proposal automates the detection and extraction of regions of interest from the face, regardless of conditions such as brightness, gender or facial expression.
別の提案では、明るさ、性別、または表情などの条件に関係なく、顔から関心のある領域を自動的に検出および抽出します。

Conclusions・まとめ

- This system solves problems such as partial occlusion of the face.
このシステムは、顔の部分的な隠蔽などの問題を解決します。
- The last contribution presents a classifier based on clustering and fuzzy logic. Using clustering algorithms, the computational cost is low compared to classical classifiers.
成果は、クラスタリングとファジーロジックに基づく分類器が紹介されています。クラスタリングアルゴリズムを使用することで、計算コストは古典的な分類器と比較して低くなります。
- Fuzzy logic allows to provide class membership percentages, unlike classical neural networks.
ファジーロジックは、クラスの所属割合を提供することができ、これは古典的なニューラルネットワークとは異なります。

Future Work・これからの課題

- Address the problem of partial occlusion in the regions of interest.
部分的な遮蔽が発生している領域の問題に対処すること。
- An important aspect to consider in future research is to solve the problem of facial recognition when the person is not looking directly at the camera.
将来の研究で考慮すべき重要な側面は、被写体がカメラに直接向いていない場合の顔認識の問題を解決すること。
- In addition, it is suggested to work on the development of facial expression recognition systems when the face is horizontally rotated.
顔が水平に回転している場合の表情認識システムの開発に取り組むこと。
- The application of deep learning techniques could be explored to improve the robustness and generalization of the proposed models in these future research lines.
これらの将来の研究分野で提案されたモデルの頑健性と一般化を向上させるために、ディープラーニングの技術の開発。

ご清聴ありがとうございました。

Thank you so much for
your attention and
valuable time !

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