Infant Pain Assessment:

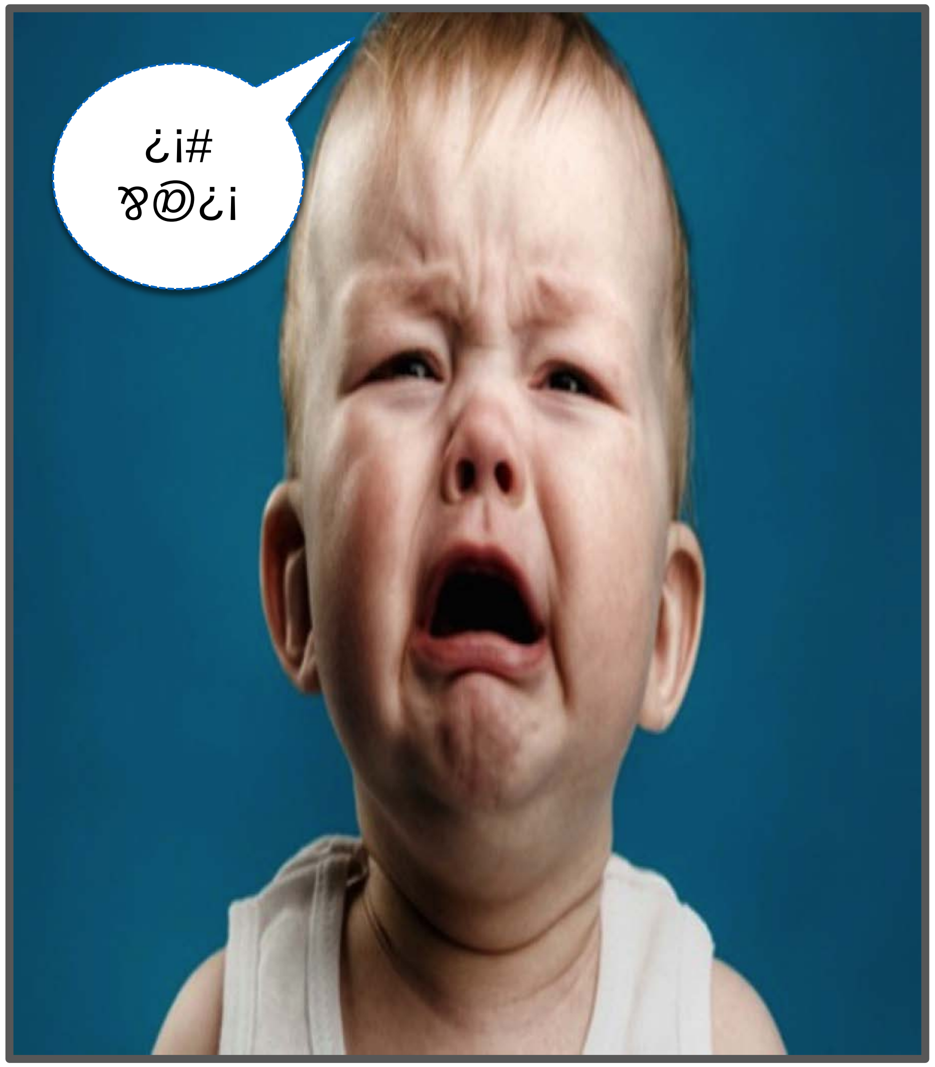
Towards Spotting Pain Expression Based on Facial Strain Analysis

Ghada Zamzmi[1], Gabriel Ruiz[1], Dmitry Goldgof[1], Rangachar Kasturi[1], Yu Sun[1], and Terri Ashmeade[2]

[1]Department of Computer Science and Engineering, University of South Florida, Tampa-FL, USA

[2]Department of Pediatrics, USF Morsani College of Medicine, Tampa-FL, USA

Why Infant Pain Assessment is Challenging?



Inability to Articulate

Personal Opinion Vs. Patient Self Report

Subjective Assessment

Good Assessment == Successful Management

Machine Based Infant Pain Assessment

- Potential **benefits** of building a machine based pain assessment tool include:
  - Reduce the assessment **subjectivity**
  - Reduce the costs of **monitor** infants continuously and **observe** signs of pain

NICU
(monitoring device)

Home
(application to help mothers)

Poor Countries
(lack of medical services)

Applications

Pain Indicators

- Infants' pain indicators are classified into 2 main categories, **behavioral** and **physiological** pain indicators:

Expression **Crying** **Body Motion** **Skin Color** **Vital Signs**

Behavioral (Expression, Crying, Body Motion)

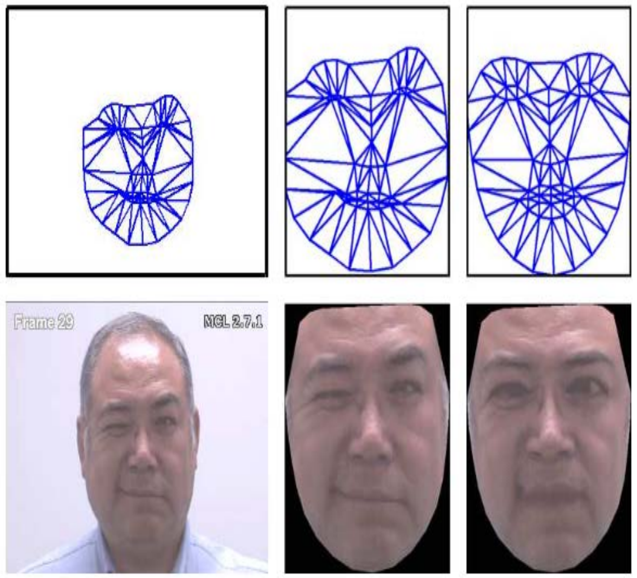
Physiological (Skin Color, Vital Signs)

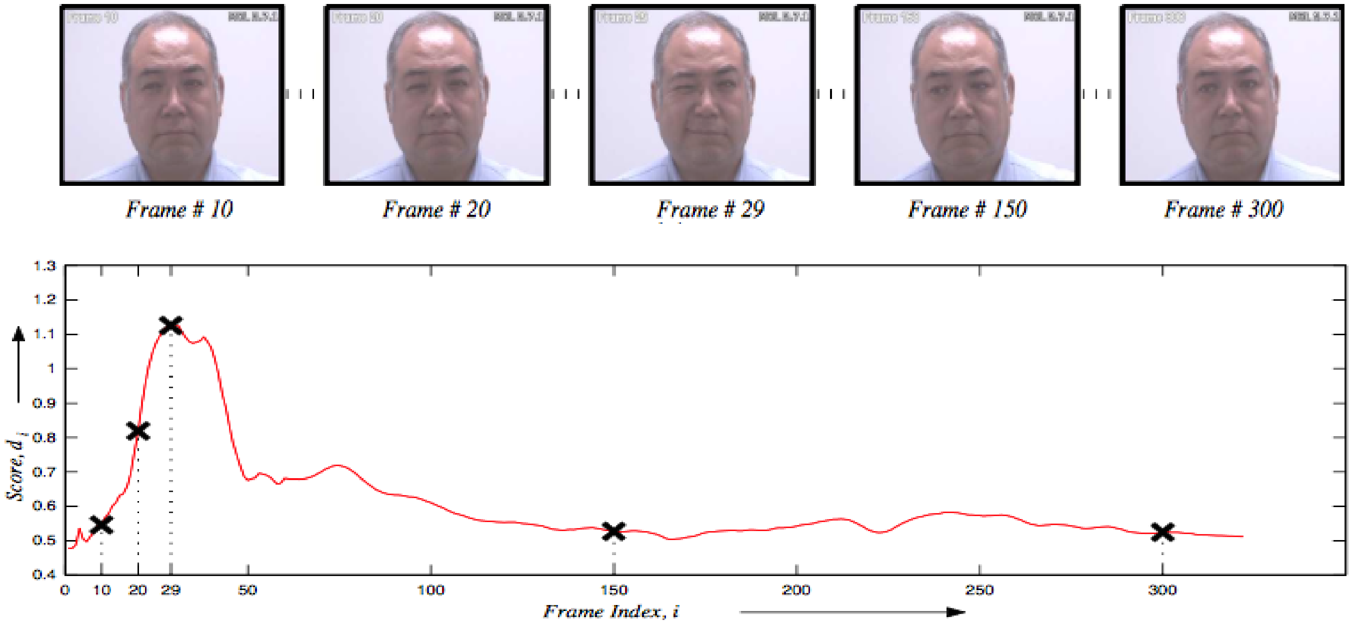
Our work utilizes the **facial expressions** as behavioral indicator of pain

Previous Work: The Painful Face

[AB Ashraf et al. 2009]

- **Dataset**: UNBC-McMaster Shoulder Pain Expression Dataset, which includes video clips for 129 subjects.
- **Pain Model**:
  - Active Appearance Model (AAM) for face representation.
  - Define three types of features based on the AAM model.
  - SVM for classification.





$$D_{sequence} = \sum_{i=1}^{T} d_i$$

$$D_{sequence} \underset{\text{no pain}}{\overset{\text{pain}}{\gtrless}} Threshold$$

Previous Work: COPE Project

- **Dataset**: COPE database contains a total of **204 static images** for 26 infants experiencing acute pain.
- Various works have used this dataset to recognize infants facial expression of pain.

[Sheryl Brahnam et al. 2006] (**PCA**, **LDA**, and **SVM**)
[Sheryl Brahnam et al. 2007] (**PCA**, **DCT**, **SFFS**, and **neural networks**)
[Benhood Gholami et al. 2009] (**RVM**)
[Loris Nanni et al. 2010] (**texture descriptor 'LBP'** , and **SVM**)

Our Work: Spotting Pain Expression Based on Facial Strain Analusis

The main contribution of this work can be summarized as follow:

Recognize **infant** pain expression **dynamically** for monitoring purposes based on analysis of facial strain

To the best of our knowledge, no work has employed existing face classification techniques to the task of monitoring infant facial expressions of pain

Dataset

- A total of **10** infants were videotaped under two pain procedures: **acute** or **chronic** in the presence of nurses who score the pain (i.e., mark and score moments of pain)

	Acute Pain	Chronic Pain
Definition	Intense pain	Less intense pain
Pain Trigger	Immunization/Heel Lancing	Post-op, G-tube
Ground Truth	State the pain score **prior** the acute procedure, at the **start** of the procedure, during and at **every minute** for around 5 minutes.	State the pain score **prior** the recording of the chronic pain (normal state), and every **15 minutes** during the chronic pain.

Monitoring System Setup

- ✧ Get parental Consent
- ✧ Prepare the recording equipment (e.g., Gopro camera, back up battery, scoring sheet, and subject's identifier sheet) to the subject room
- ✧ **Acute Procedure Recording**:

  Record the subject **5 minutes** prior the start of the procedure, **during** the procedure, and **5 minutes** after the procedure
- ✧ **Chronic Procedure Recording**:

  Record the subject in a normal state **prior the surgery**; then record the subject **after the surgery** for about 2 hours

A life-like infant doll

Camera on an enclosed incubator

Camera and the camera stand

Scoring Sheet

[redacted]

Date of Enrollment: ____________

BW: [redacted] GA: [redacted] DOL 5/

Start time for all recording: [redacted]

End time for all recording:

Race: Asian, Black, White, Other

Ethnicity: Hispanic, Non-Hispanic

Gender: Male, Female

Normal/Hungry State Videos:			
	Video #	Start Time	End Time
Normal State	B-11	2/4/14 0944	~5min. ~~hungry~~?
Hungry State			

ACUTE Procedure: Heelstick (lab) 1011	Video #:						
NIPS	5' Prior	Start of procedure	1'	2'	3'	4'	5'
Facial Expression	1	1	1	1	1	1	1
Cry	~~2~~ 1	2	2	1	1	1	1
Breathing Pattern	1	1	1	1	1	1	1
Arms	1	1	1	1	1	1	1
Legs	1	1	1	1	1	1	1
State of Arousal	1	1	1	1	1	1	1
NIPS score total	6	7	7	6	6	7	7

NIPS - Neonatal Infant Pain Score

Facial Exp.	Relaxed	0
	Grimace	1
Cry	No Cry	0
	Whimper	1
	Vigorous Crying	2
Breathing	Relaxed	0
	Change in breathing	1
Arms	Relaxed	0
	Flexed/Extended	1
Legs	Relaxed	0
	Flexed/Extended	1
State	Sleeping/Awake	0
	Fussy	1

Pain Expression Recognition Model

Pain expression recognition model consists of three main stages:

Stage 1*: Face Tracking*

- ✧ Locate the face in each frame and extract facial points

Stage 2*: Expression Segmentation*

- ✧ Segment expressions based on **analysis of facial strain**

Stage 3*: Expression Recognition*

- ✧ Classify the segmented expressions to pain/no-pain

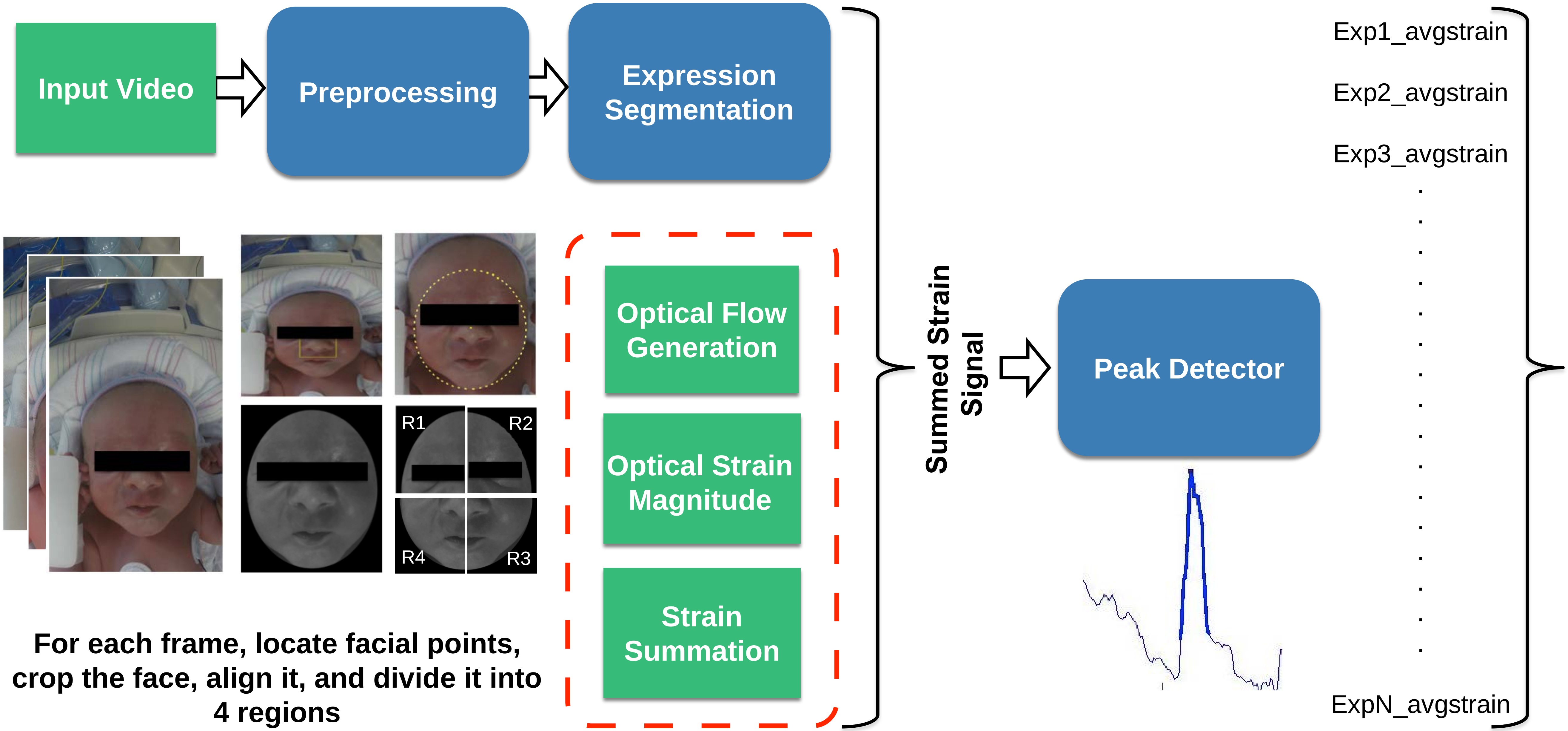
Stage 1: Face Tracking

- Existing state-of-the-art algorithms perform poorly in case of infants due to:
  - Occlusion and unpredictable movements
  - Existing algorithms are trained based on adult faces
- Face tracking was an issue!
  - Manual extraction of facial points
- Haar cascades training model specifically for infant dataset

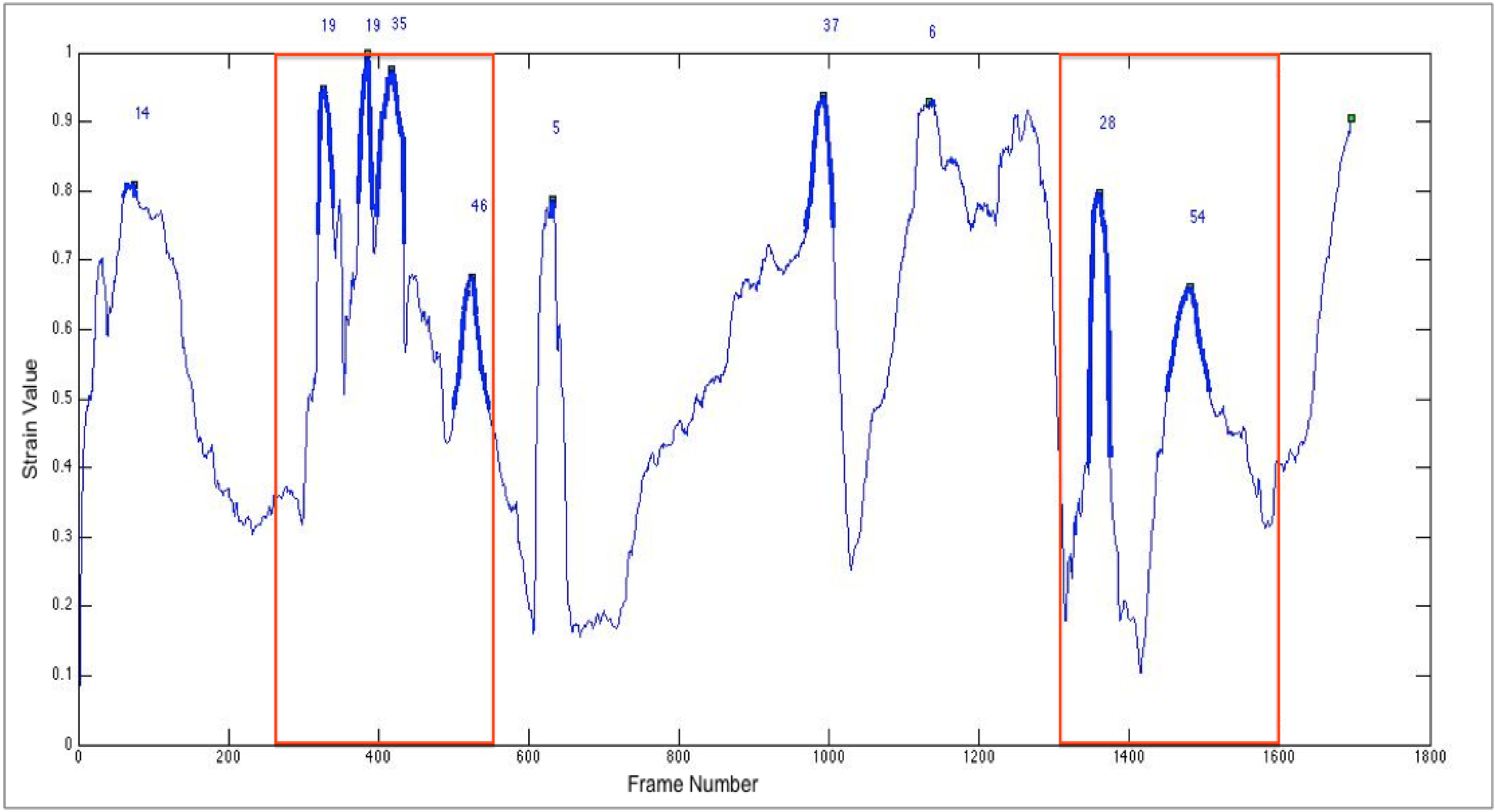
Stage 2: Temporal Expression Segmentation

The Strain Algorithm

[Matthew Shreve et al. 2014]

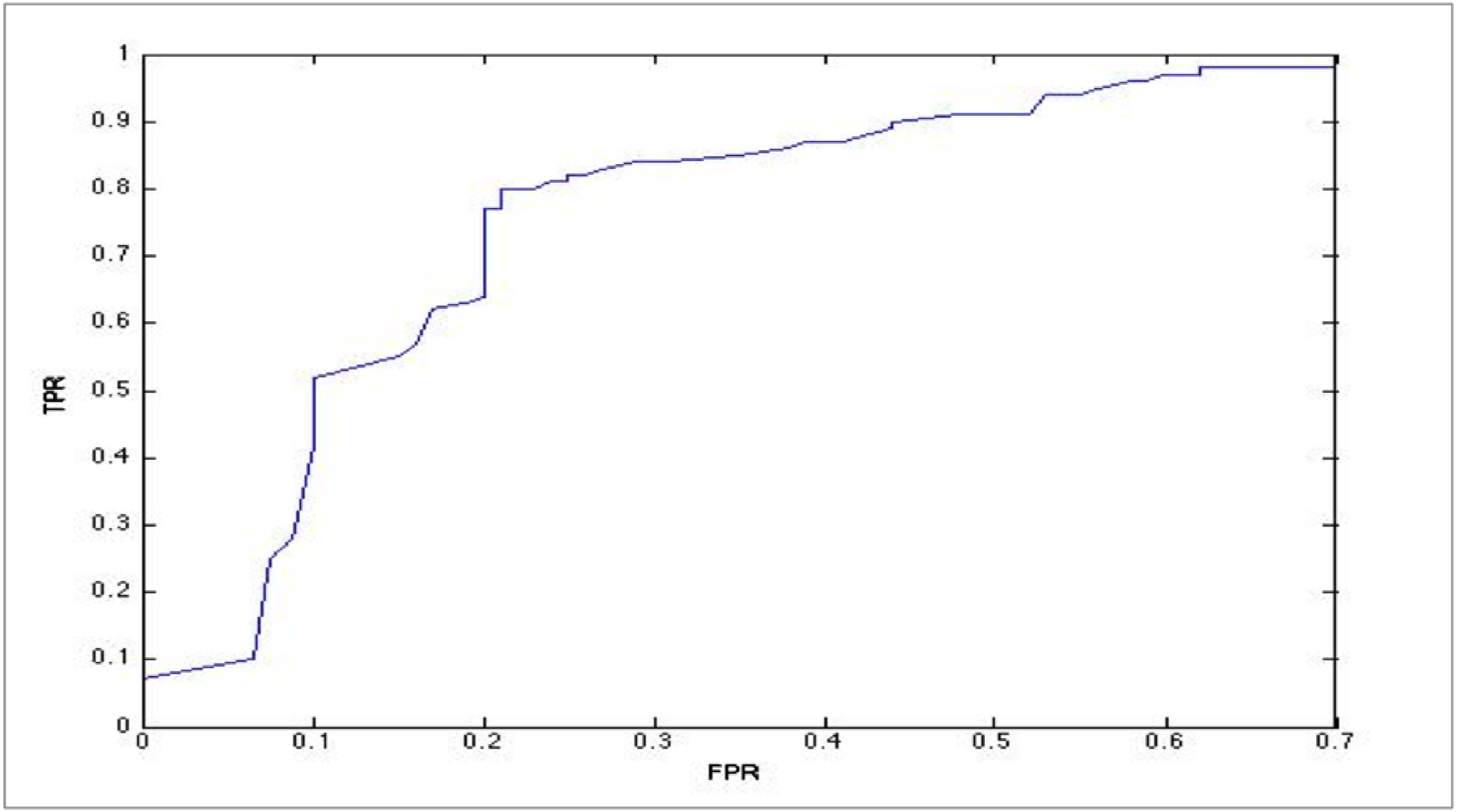


Results: Temporal Expression Segmentation



Strain **Expression** **Ground Truth**

Results: ROC Curve for Segmentation Algorithm



ROC achieves 80% TPR with 20% FPR

Stage 3: Expression Recognition

Pain vs No-Pain

- ✧ Seven subjects are used for training (i.e., 56 pain expressions and 67 other expressions); three subjects are used for testing (i.e., 29 pain expressions and 38 other expressions)
- ✧ Two state-of-the-art classifiers are used; 10-fold cross validation is used for both classifiers.
- ✧ The accuracy of binary classification for KNN was around 96%

N=67	Pain	No-Pain	
Pain	28	1	29
No-Pain	2	36	38

Future Directions

✧ Develop a **multimodal objective measure of pain** using various behavioral and and physiological pain indicators in addition to the facial expression

✧ Extend the binary model of pain classification into **multi-level** pain classification

✧ Evaluate our method on **other datasets** and compare the results

✧ Evaluate our method with larger dataset:

- This work: 10 infants; video sequences
- Currently: more than 40 infants; video/audio/vital signs data
- Future: up to 90 infants; video/audio/vital signs/body motion data

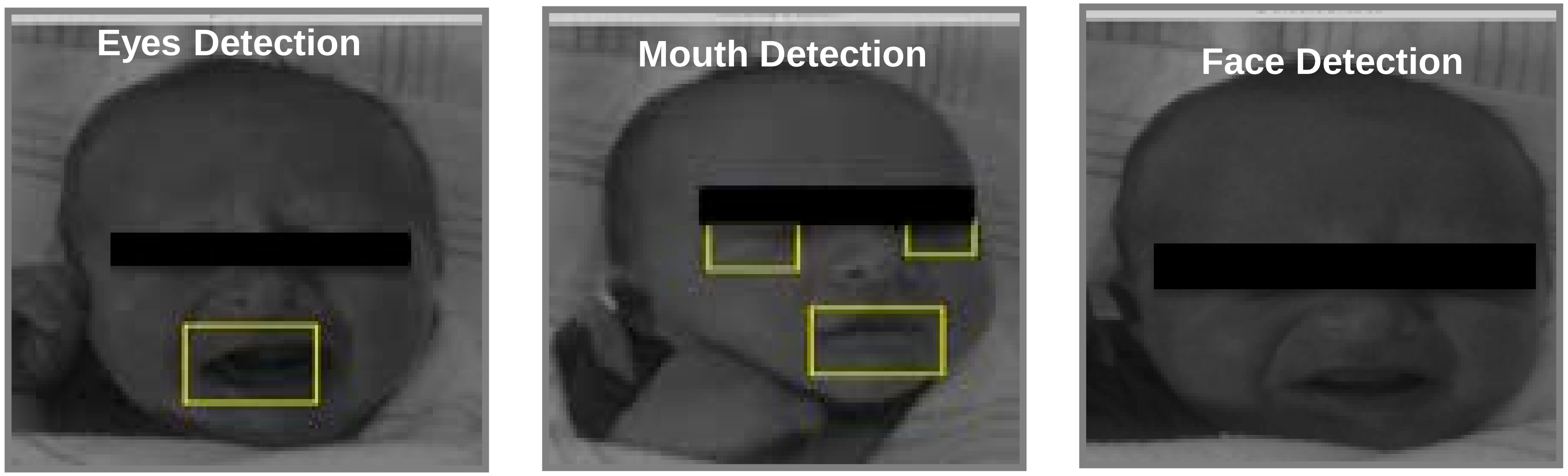
Thanks for listening!

Questions?

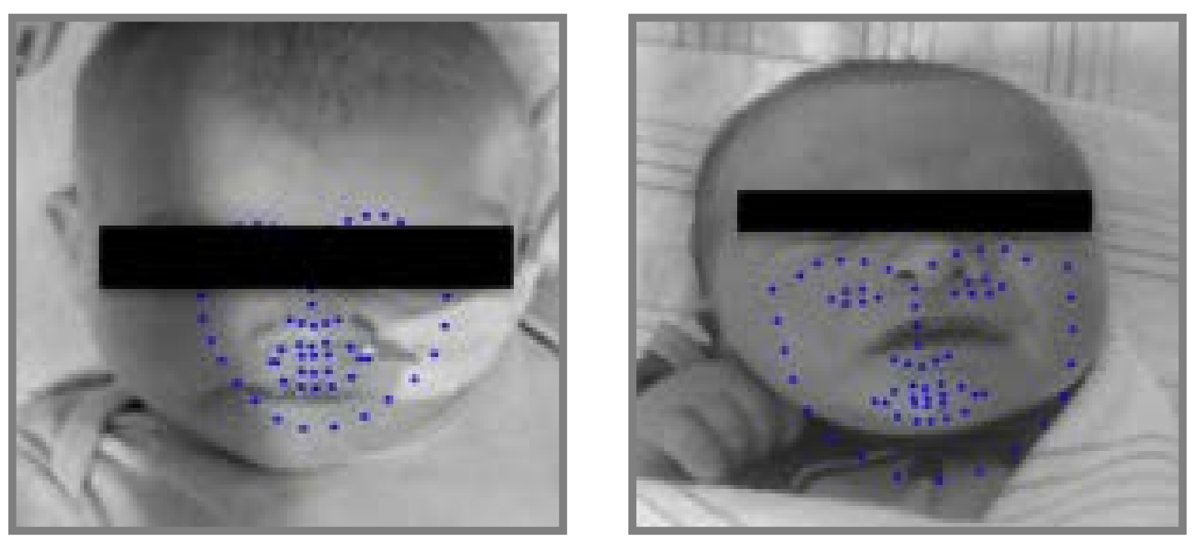
ghadh@mail.usf.edu

Extra Slides

Failure of Existing Face Tracking Algorithms

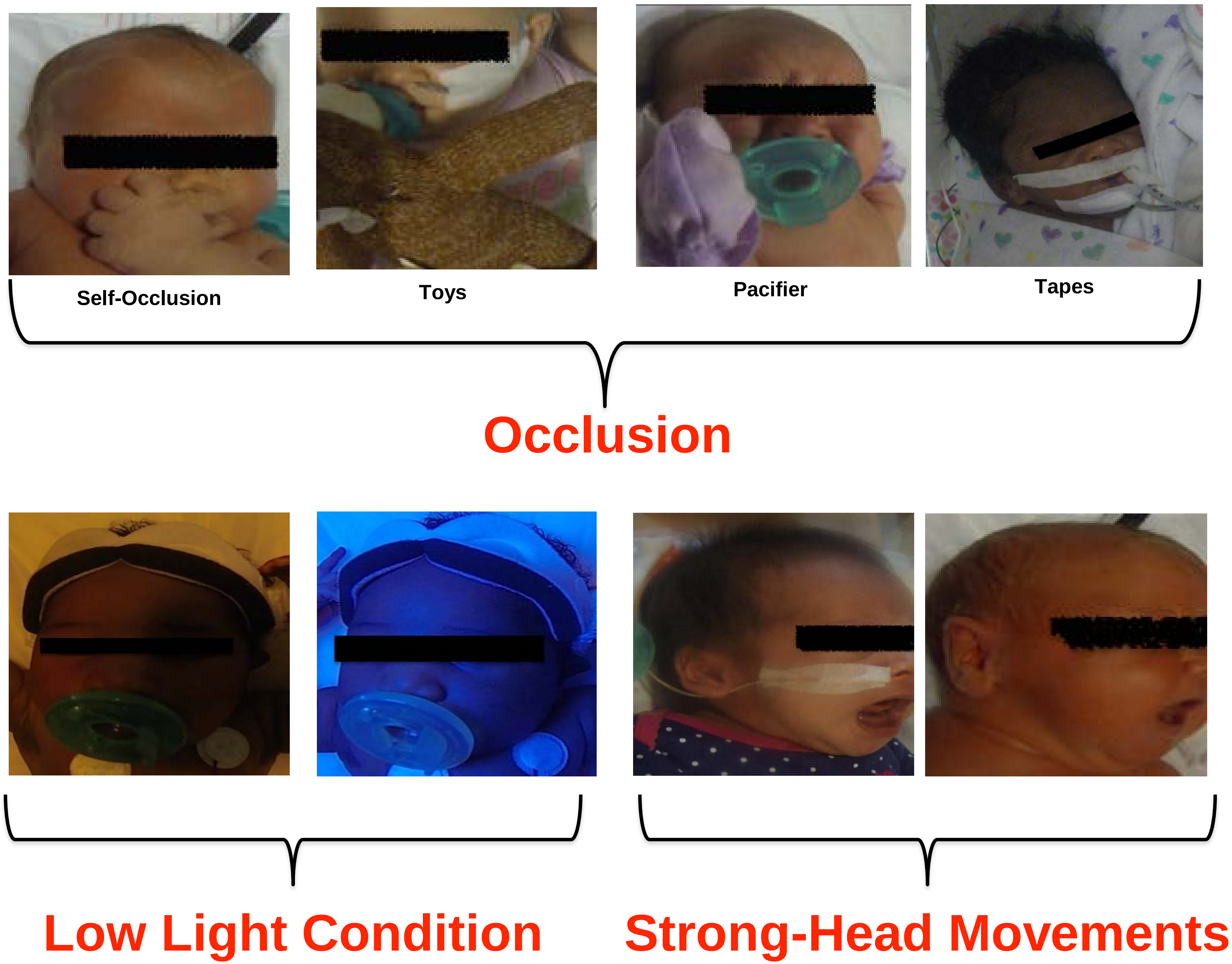


Viola-Jones



Mean Shift Tracker

Why this Dataset is Challenging?

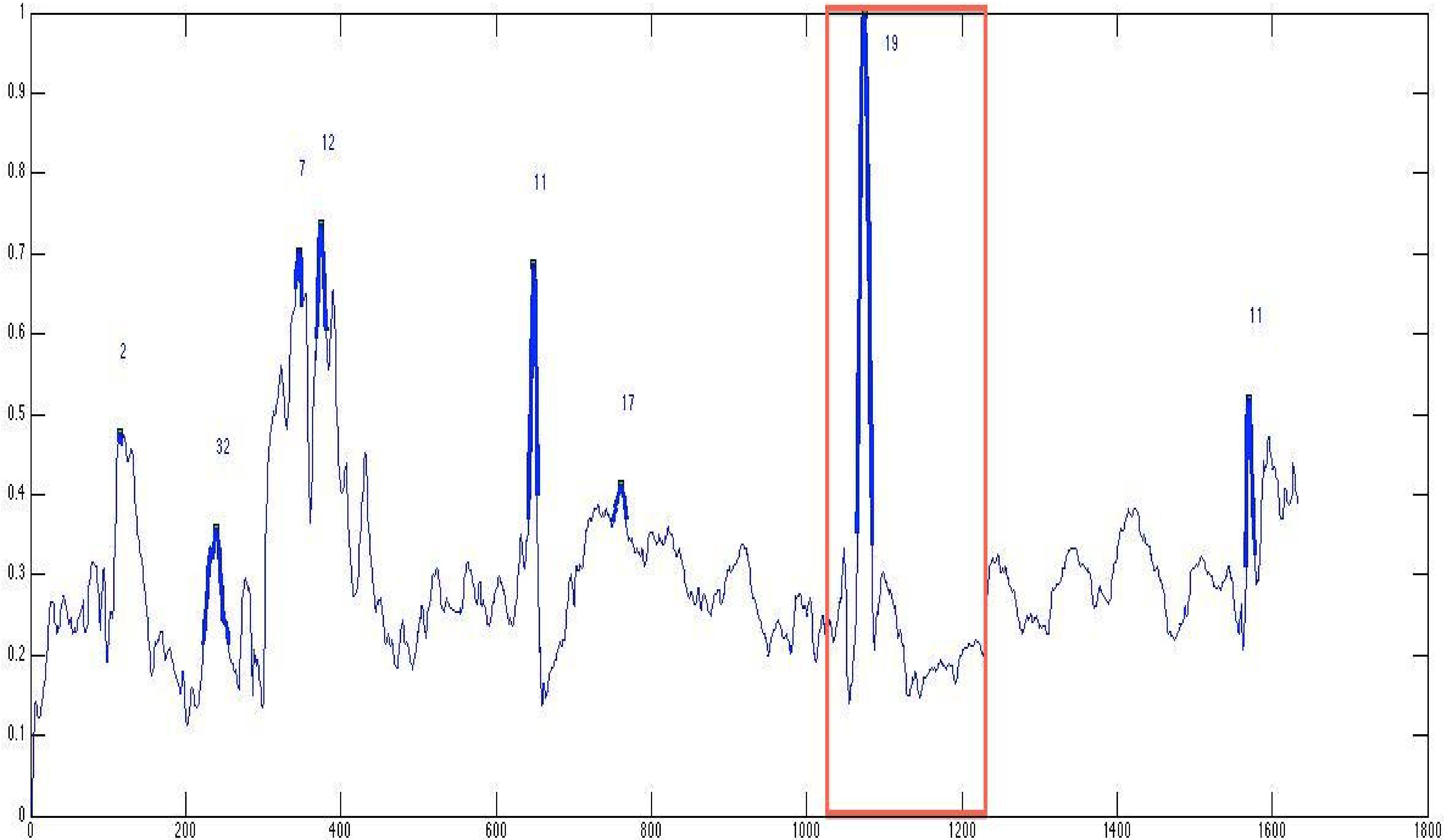


[Ghada Zamzmi et al. EmoSpace/FG1915]

NIPS – Neonatal Infant Pain Scale

Parameter	Finding	Points
Facial Expression	Relaxed	0
	Grimace	1
Cry	No cry	0
	Whimper	1
	Vigorous crying	2
Breathing Pattern	Relaxed	0
	Change in breathing	1
Arms	Relaxed	0
	Flexed/extended	1
Legs	Relaxed	0
	Flexed/extended	1
State of arousal	Sleeping/awake	0
	Fussy	1

Simply add up the total points.



1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
200
400
600
800
1000
1200
1400
1600
1800
2
32
7
12
11
17
19
11