Infant Pain Assessment: Towards Spotting Pain Expression Based on Facial Strain Analysis

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Why Infant Pain Assessment is Challenging?

Inability to Articulate

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

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**Applications**

- NICU (monitoring device)
- Home (application to help mothers)
- Poor Countries (lack of medical services)
Behavioral 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  Physiological

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.

![Diagram showing Active Appearance Model and video frames with pain sequences]
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 Analysis

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)

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

**Race:** Asian, Black, White, Other  
**Ethnicity:** Hispanic, Non-Hispanic  
**Gender:** Male, Female

<table>
<thead>
<tr>
<th>Date of Enrollment:</th>
<th>BW:</th>
<th>GA:</th>
<th>DOB: 51</th>
</tr>
</thead>
</table>

**Start time for all recording:**  
**End time for all recording:**

### Normal/Hungry State Videos:

<table>
<thead>
<tr>
<th>State</th>
<th>Video #</th>
<th>Start Time</th>
<th>End Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal State</td>
<td>8-4</td>
<td>2/4/14 0944</td>
<td>15 min</td>
</tr>
<tr>
<td>Hungry State</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### NIPS - Neonatal Infant Pain Score

<table>
<thead>
<tr>
<th>Variable</th>
<th>Rating</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Facial Exp.</td>
<td>Relaxed</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Grimace</td>
<td>1</td>
</tr>
<tr>
<td>Cry</td>
<td>No Cry</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Whimper</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Vigorous Crying</td>
<td>2</td>
</tr>
<tr>
<td>Breathing</td>
<td>Relaxed</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Change in breathing</td>
<td>1</td>
</tr>
<tr>
<td>Arms</td>
<td>Relaxed</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Flexed/Extended</td>
<td>1</td>
</tr>
<tr>
<td>Legs</td>
<td>Relaxed</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Flexed/Extended</td>
<td>1</td>
</tr>
<tr>
<td>State</td>
<td>Sleeping/Awake</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Fussy</td>
<td>1</td>
</tr>
</tbody>
</table>
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]

For each frame, locate facial points, crop the face, align it, and divide it into 4 regions.
Results: Temporal Expression Segmentation

The diagram shows the results of temporal expression segmentation with strain and expression values plotted against frame number. Highlighted segments indicate specific strain values and expressions compared to 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%

<table>
<thead>
<tr>
<th></th>
<th>Pain</th>
<th>No-Pain</th>
</tr>
</thead>
<tbody>
<tr>
<td>N=67</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pain</td>
<td>28</td>
<td>1</td>
</tr>
<tr>
<td>No-Pain</td>
<td>2</td>
<td>36</td>
</tr>
</tbody>
</table>
Future Directions

✧ Develop a **multimodal objective measure of pain** using various behavioral 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?

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Extra Slides
Failure of Existing Face Tracking Algorithms

Viola-Jones

Mean Shift Tracker
Why this Dataset is Challenging?

Self-Occlusion | Toys | Pacifier | Tapes
---|---|---|---
Occlusion

Low Light Condition | Strong-Head Movements
**NIPS – Neonatal Infant Pain Scale**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Finding</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Facial Expression</td>
<td>Relaxed</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Grimace</td>
<td>1</td>
</tr>
<tr>
<td>Cry</td>
<td>No cry</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Whimper</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Vigorous crying</td>
<td>2</td>
</tr>
<tr>
<td>Breathing Pattern</td>
<td>Relaxed</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Change in breathing</td>
<td>1</td>
</tr>
<tr>
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<tr>
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<td>Flexed/extended</td>
<td>1</td>
</tr>
<tr>
<td>State of arousal</td>
<td>Sleeping/awake</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Fussy</td>
<td>1</td>
</tr>
</tbody>
</table>

Simply add up the total points.