First Investigation Into the Use of Deep Learning for Continuous Assessment of Neonatal Postoperative Pain

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Automatic Face and Gesture Recognition (FG 2020)
Overview of the Work

• First investigation into the use of fully deep learning framework for assessing neonatal postoperative pain

• Present a neonatal pain dataset
  • Collected from premature and newborns while they are undergoing postoperative pain

• Propose a new deep learning framework
  • Combining spatial and temporal information
  • Estimate intensity of neonatal postoperative pain
Motivation

• Postoperative pain, or pain after surgery, occurs as a result of a tissue injury
  • Usually lasts for up to seven days

• Inadequate treatment of postoperative pain leads to
  • Chronic pain
  • Increases the financial burden
  • Serious physiological outcomes such as changes in respiratory, cardiovascular, and immune functions
  • Impaired sleep, depression, and anxiety
Research Goal

• Current standard for pain assessment
  • Pain scale such as N-PASS and PIPP
  • Manual, Inconsistent, subjective, and intermittent

• Goal?
  • Postoperative pain assessment and management providing
    • Maximum pain relief with minimum side effects
    • Proposed automated system for continuous monitoring
Data Collection

• Visual, vocal, and physiological
• Procedural pain dataset
  • 36 subjects
  • GA 30-41 weeks
• Postoperative pain dataset
  • 9 subjects
  • GA 32-39 weeks
• Pain scale
  • NIPS
  • N-PASS
Samples from Postoperative Dataset
Proposed Framework
Spatial Feature

• Bilinear CNN
  • Popular solution for fine grained image classification
  • Effectively collect local pairwise information and
  • Produce orderless texture feature
  • Merge two CNNs
  • Robustly handle intra-class variations caused by large pose, lighting, and background variations

• Pretrain – VGG-16 architecture
  • VGGFace2 dataset – 3.3M faces of 9K identities
  • ImageNet dataset – 14M images of 21K classes
Temporal Feature

- **RNN**
  - Suffers from lack of preserving long-term dependencies

- **LSTM**
  - Solves the problem of long-term dependency

### Table I
**Details of LSTM Architecture**

<table>
<thead>
<tr>
<th>Layer Type</th>
<th>Configurations</th>
</tr>
</thead>
<tbody>
<tr>
<td>RNN</td>
<td>LSTM 16, Activation = Tanh, Recurrent Activation = Hard Sigmoid</td>
</tr>
<tr>
<td>RNN</td>
<td>LSTM 16, Activation = Tanh, Recurrent Activation = Hard Sigmoid</td>
</tr>
<tr>
<td>FC</td>
<td>Time Distributed Dense 16, Relu</td>
</tr>
<tr>
<td>FC</td>
<td>Time Distributed Dense 16, Relu</td>
</tr>
<tr>
<td>FC</td>
<td>Time Distributed Dense 1, Linear</td>
</tr>
</tbody>
</table>
Experimental Evaluation

• Datasets
  • Procedural (acute) pain
  • Postoperative (prolonged acute) pain
  • COPE
    • 26 subjects
    • GA 18 hours - 3 days
    • Total 204 static images

• Evaluation protocol
  • Leave-one-out-subject

<table>
<thead>
<tr>
<th>Pain intensity</th>
<th>Number of images</th>
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<tbody>
<tr>
<td>0</td>
<td>1728</td>
</tr>
<tr>
<td>1</td>
<td>160</td>
</tr>
<tr>
<td>2</td>
<td>512</td>
</tr>
<tr>
<td>3</td>
<td>352</td>
</tr>
<tr>
<td>4</td>
<td>928</td>
</tr>
<tr>
<td>5</td>
<td>960</td>
</tr>
<tr>
<td>6</td>
<td>352</td>
</tr>
<tr>
<td>7</td>
<td>992</td>
</tr>
<tr>
<td>Total</td>
<td>5984</td>
</tr>
</tbody>
</table>
## Experimental Results

**Neonatal post-op assessment (facial pain intensity [0-1])**

<table>
<thead>
<tr>
<th>Approach</th>
<th>Pretrain</th>
<th>Retrain</th>
<th>MSE</th>
<th>MAE</th>
</tr>
</thead>
<tbody>
<tr>
<td>VGG16</td>
<td>VGGFace2</td>
<td>COPE</td>
<td>0.4170</td>
<td>0.5412</td>
</tr>
<tr>
<td>VGG16</td>
<td>VGGFace2</td>
<td>Acute</td>
<td>0.1979</td>
<td>0.4035</td>
</tr>
<tr>
<td>VGG16</td>
<td>VGGFace2</td>
<td>Post-Op</td>
<td>0.3606</td>
<td>0.5155</td>
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<tr>
<td>VGG16</td>
<td>Acute</td>
<td>Post-Op</td>
<td>0.3716</td>
<td>0.5211</td>
</tr>
<tr>
<td>Bilinear VGG16</td>
<td>VGGFace2, ImageNet</td>
<td>COPE</td>
<td>0.4272</td>
<td>0.5208</td>
</tr>
<tr>
<td>Bilinear VGG16</td>
<td>VGGFace2, ImageNet</td>
<td>Acute</td>
<td>0.1917</td>
<td>0.3458</td>
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<tr>
<td>Bilinear VGG16</td>
<td>VGGFace2, ImageNet</td>
<td>Post-Op</td>
<td>0.2955</td>
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<tr>
<td>Bilinear VGG16</td>
<td>Acute</td>
<td>Post-Op</td>
<td>0.2695</td>
<td>0.4173</td>
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</tbody>
</table>

**Neonatal post-op assessment (pain intensity [0-7]) using LSTM**

<table>
<thead>
<tr>
<th>Approach</th>
<th>MSE</th>
<th>MAE</th>
</tr>
</thead>
<tbody>
<tr>
<td>VGG16 + LSTM</td>
<td>4.8612</td>
<td>1.7274</td>
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<tr>
<td>Bilinear VGG16 + LSTM</td>
<td>3.999</td>
<td>1.5565</td>
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Summary

• Conclusion
  • Present a collection of neonatal postoperative pain dataset
    • Real clinical environment
    • Multimodal data (i.e. visual, vocal, and vital signs)
  • Fully automated deep learning-based framework
    • Aims to mitigate the limitations of the current assessment practice
    • Uses spatial and temporal feature

• Future work
  • Collection of larger postoperative pain dataset (on going effort)
  • Incorporating other pain modalities (i.e. body, crying sound, vital signs)
Thank you for listening!

For more information please visit our project webpage at https://rpal.cse.usf.edu/project_neonatal_pain/