Agitation sensor based on Facial Grimacing for improved sedation management in critical care

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Introduction

Agitation in Intensive Care Unit (disease, injury, life-support) → Sedation

Current methods to measure agitation are subjective (Hospital staff)

Under sedation
- Reduce patient recovery
- Risk of injury (staff, self extubation...) from agitation

Over sedation
- Longer weaning period
- Cardiovascular depression and death!

Increased length of stay and cost

Necessity of an accurate method to measure agitation
Previous work

A physiological model of agitation and sedation pharmacodynamics has been developed [Rudge et al.]

• Significant improvements in simulation → requires a sensor!!!

Current agitation sensors:

• Blood pressure/Heart rate variability [Chase, Starfinger et al.]
• Digital Imaging of whole body motion [Chase, Agogue et al.]
  • Medium to large overall average movement
  • Limited resolution (wide view, no detail)
A new approach towards Agitation Sensing

Motivation:
Higher resolution on face
Detect subtle facial change → early signs of agitation
Integrate with current sensors → more accuracy
Facial expression used in Visual Analog Scale (VAS)

Objectives:
Develop software for measuring the degree of facial grimacing, which clinical staff (and the literature) have noted as a distinct sign of emerging patient agitation.
Several simulations imitating a patient in Critical Care have been done

- A patient moving head with no expression
- A stationary patient with differing degrees of agitation
- A patient moving head and grimacing
Overview of proposed algorithm

Video acquisition

- Detect head position
- Put boundary around face

Segment the face

Evaluate grimacing
Reference point tracking

Detect head’s position:

• Place artificial marker point
  - e.g. on ventilator
• Convert image to grayscale
• Restrict region of interest
• Smoothing
• Normalization
• Thresholding
Reference point tracking

Clear unwanted object:

**Step 1**
Take image complement

**Step 2**
Makes all white area touching a border black
Reference point tracking

Unwanted objects (Case (d)):

First frame:
Delete all objects > or < size of dot

Following Frames:
Keep the dot that is within a predefined tolerance from the dot in the previous frame
Reference point tracking

Results:

Dot trajectory
Skin Recognition:

- Skin hue property
- Red/Green ratio
- Shown to be effective in literature
  - works on pale skin and dark skin equally effectively

- obtain features of face that represent grimacing ➔ with ventilator straight forward, without ventilator its harder!

⇒ use skin recognition to find face
Extracting contour of face

Contour extraction

- Initialization (requires check by user before proceeding)
- Contour defined with 50 points
- Plot for every point the Red/Green Ratio along the line A to B
- Distance A to B is defined

Simple fast method rather than e.g. snakes (computationally expensive)
Extracting contour of face

Detect the point along the line A to B that best meets the criteria for the border of the face.

![Graph showing skin detection](chart.png)

Patients stay on average 4 days in ICU ➔ Learning system could be used to improve the results.
## Results

<table>
<thead>
<tr>
<th>Position of the Head</th>
<th>Right</th>
<th>Front</th>
<th>Left</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Grimacing</td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
</tr>
<tr>
<td>Medium Grimacing</td>
<td>(4)</td>
<td>(5)</td>
<td>(6)</td>
</tr>
<tr>
<td>High Grimacing</td>
<td>(7)</td>
<td>(8)</td>
<td>(9)</td>
</tr>
</tbody>
</table>

- (1) Right No Grimacing
- (2) Front No Grimacing
- (3) Left No Grimacing
- (4) Right Medium Grimacing
- (5) Front Medium Grimacing
- (6) Left Medium Grimacing
- (7) Right High Grimacing
- (8) Front High Grimacing
- (9) Left High Grimacing
Facial grimacing – Stationary

Measure grimacing level:
- Segregate the face by two squares around the cheek
- Threshold the segregated area
- Count the number of extra pixels appearing due to grimacing

No grimacing
Frame Nº 6

Medium grimacing
Frame Nº 340

Grimacing
Frame Nº 361
Facial grimacing – Stationary

**Results**

Grimacing level as a function of the frame number after normalisation
Facial grimacing – Dynamic

Face Segmentation:

• Fixed section below dot

• Above the eyebrow and below the mouth

• Using dot position and contour of face
Facial grimacing – Dynamic

Measure Grimacing

- Extra wrinkles
- High-Pass filter
- Edge detection
- Counting edge pixels

Grimacing measure, which is normalized to calm state \( \Rightarrow \) relative change (important as a lot of patients are elderly)
Facial grimacing – Dynamic

**Angle correction calibration:**

- Sequence of frame moving the head with a calm face is used

\[
\bar{G} = G - a \times x
\]

- \( \bar{G} \): Grimacing measure
- \( G \): Corrected grimacing measure
- \( a \): Gradient of the line
- \( x \): Distance between the initial position and the current position of the dot
Facial grimacing – Dynamic

Results:

(1) (2) (3)
(4) (5) (6)
(7) (8) (9)
Facial grimacing –Dynamic

Results:

Manually normalized to a known calm state
(1st 80 frames of record here)
Future work

• Clinical validation of methods used

• Comparison of the computed agitation level based on grimacing with agitation graded by nursing staff using the Riker Sedation-Agitation Scale or similar clinically validated scale (e.g. VICS, Richmond, Glasgow COMA, ATICE, …)
Conclusions

- This research project has successfully investigated the image processing and software requirements for measuring the degree of grimacing and patient agitation in real-time.

- The goal is to develop methods for high resolution measurement of specific facial features that correlate to patient agitation and pain.

  → Sensitive, Quantitative, Objective, and Accurate agitation assessment for enabling better sedation management.