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	**Over sedation**
• Reduce patient recovery • Risk of injury (staff, self extubation…) from agitation	• Longer weaning period • Cardiovascular depression and death!

↓

<u>Increased length of stay and cost</u>

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

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Motivation:

Higher resolution on face

Detect subtle facial change → *early signs of agitation*

Integrate with current sensors → *more accuracy*

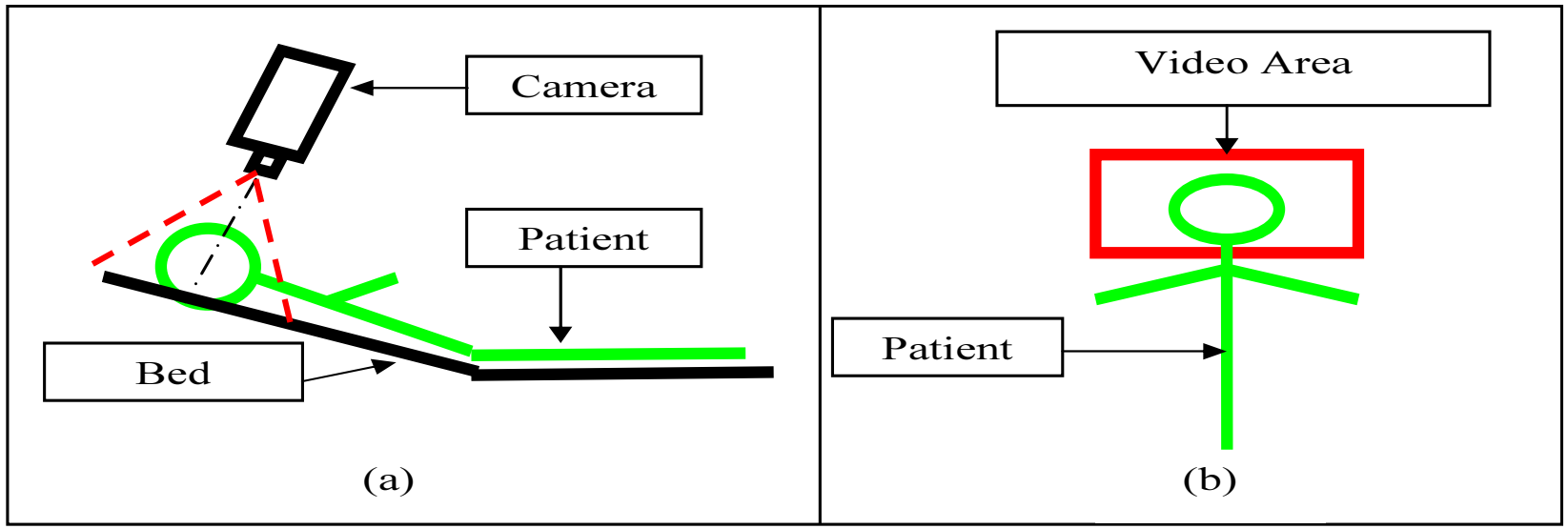
Facial expression used in Visual Analog Scale (VAS)

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.

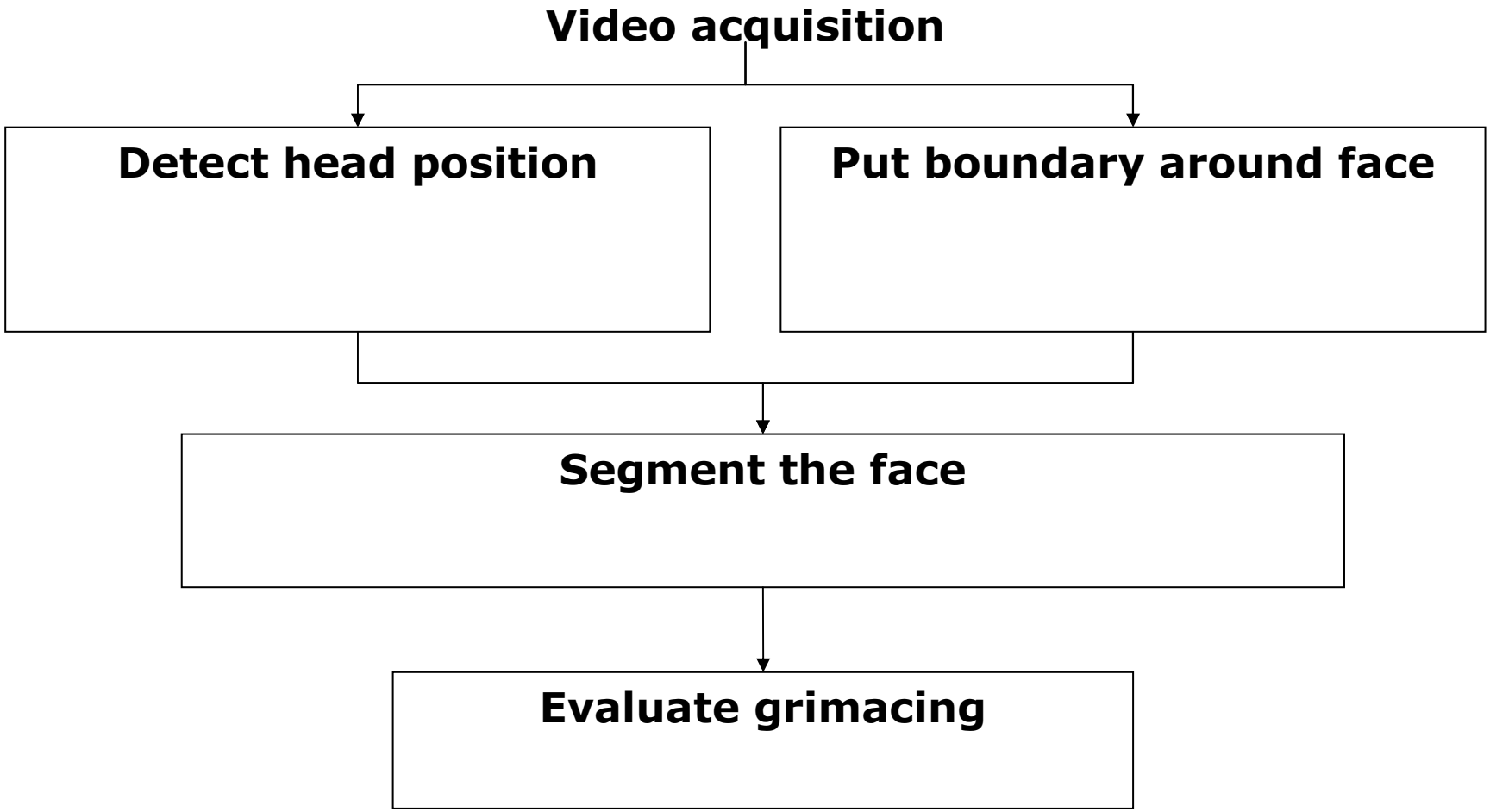
Experimental Setup

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



Reference point tracking

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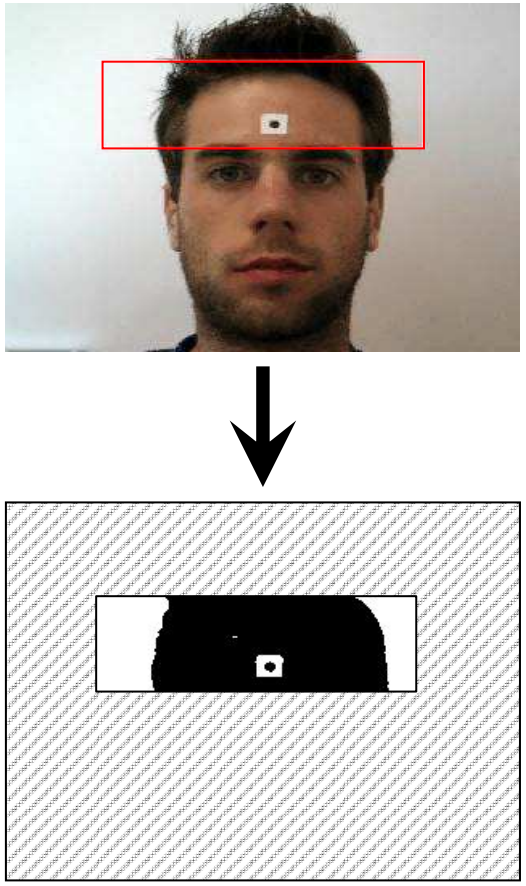
Detect head's position:

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



Reference point tracking

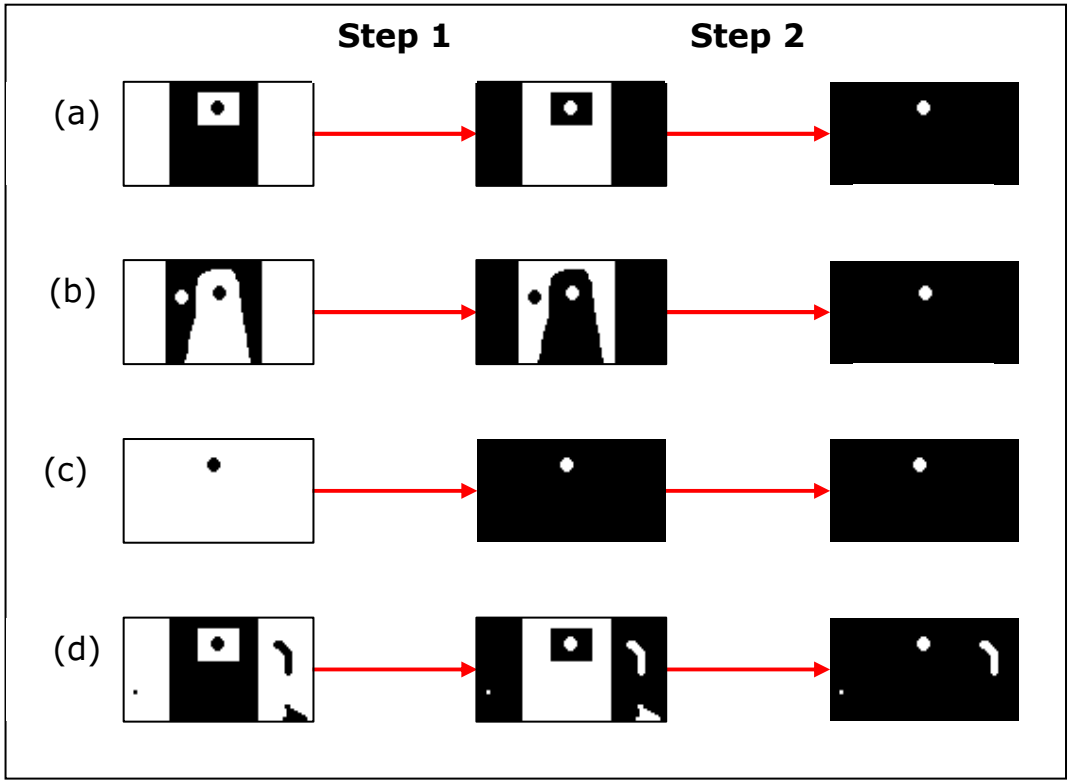
Clear unwanted object:

Step 1

Take image complement

Step 2

Makes all white area touching a border black



Reference point tracking

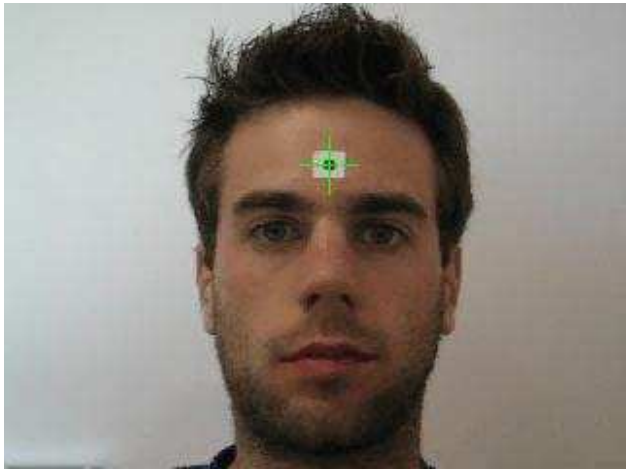
Unwanted objects (Case (d)):

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

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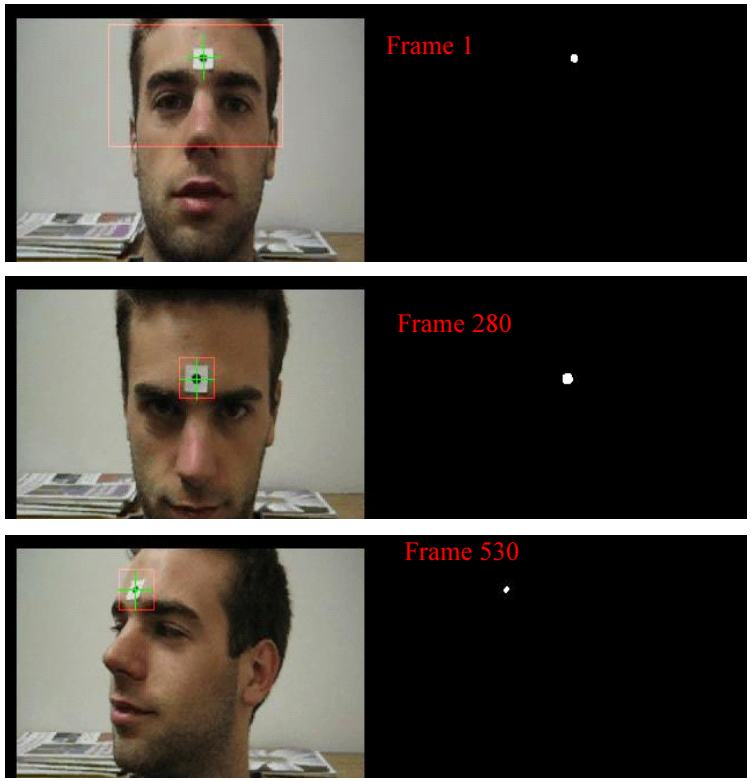
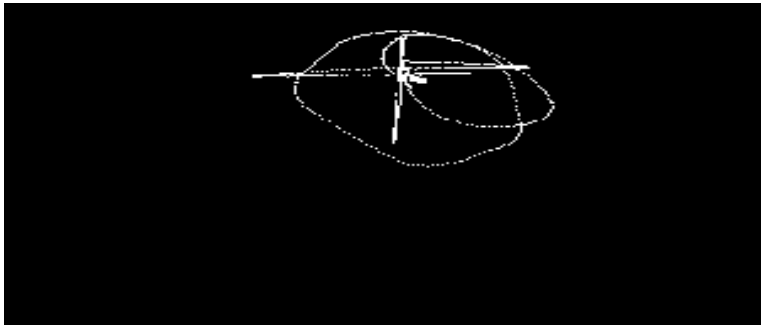
Results:



Dot trajectory



Extracting contour of face

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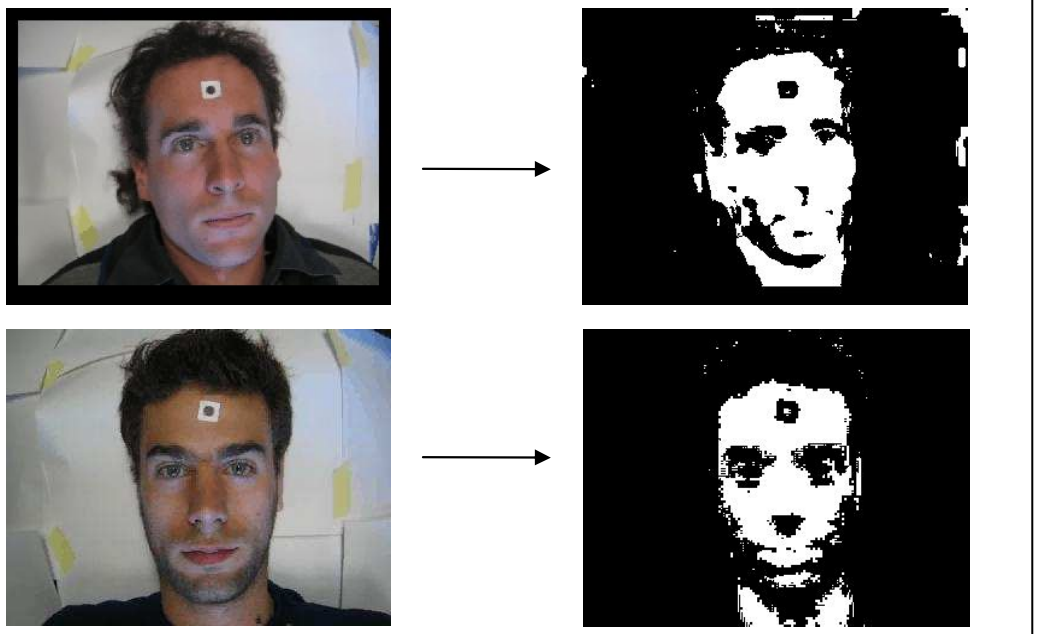
Skin Recognition:

- 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!

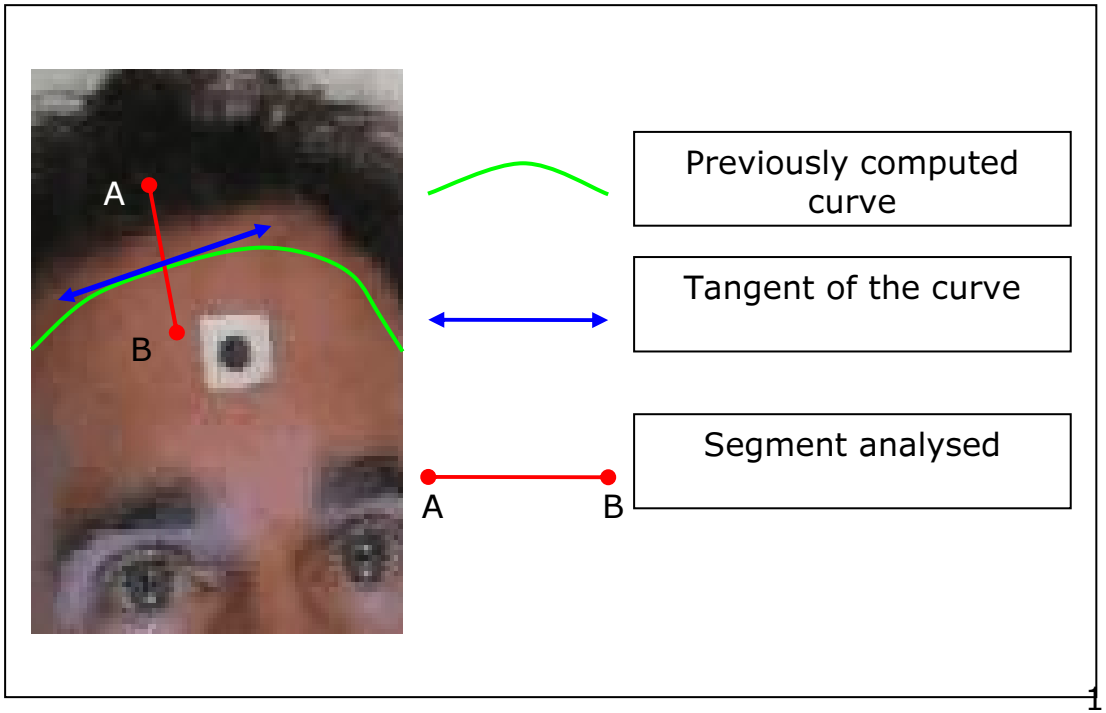
➔ use skin recognition to find face



Extracting contour of face

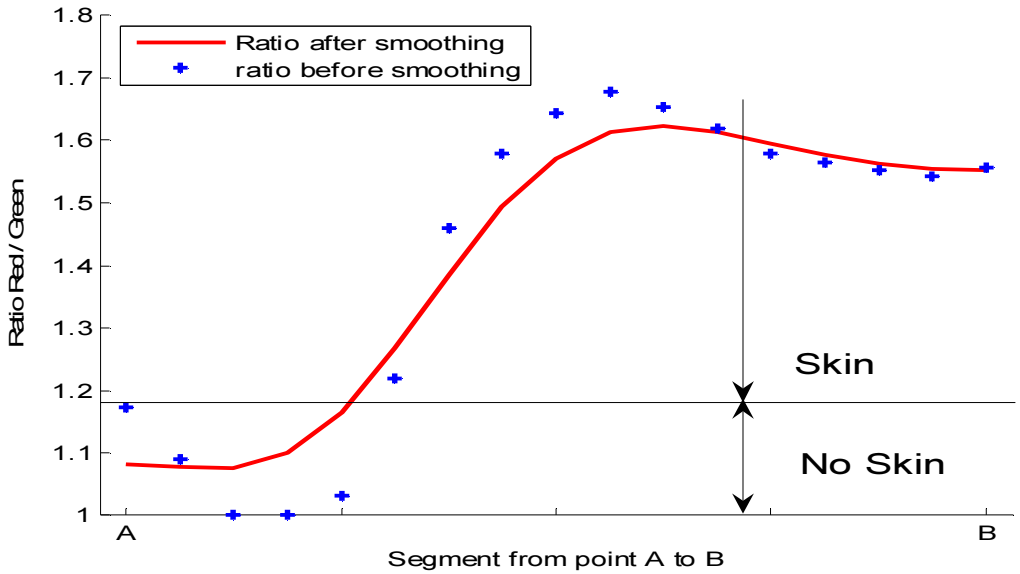
Contour extraction ➔ Simple fast method rather than e.g. snakes (computationally expensive)

- 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



Extracting contour of face

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



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

Extracting contour of face

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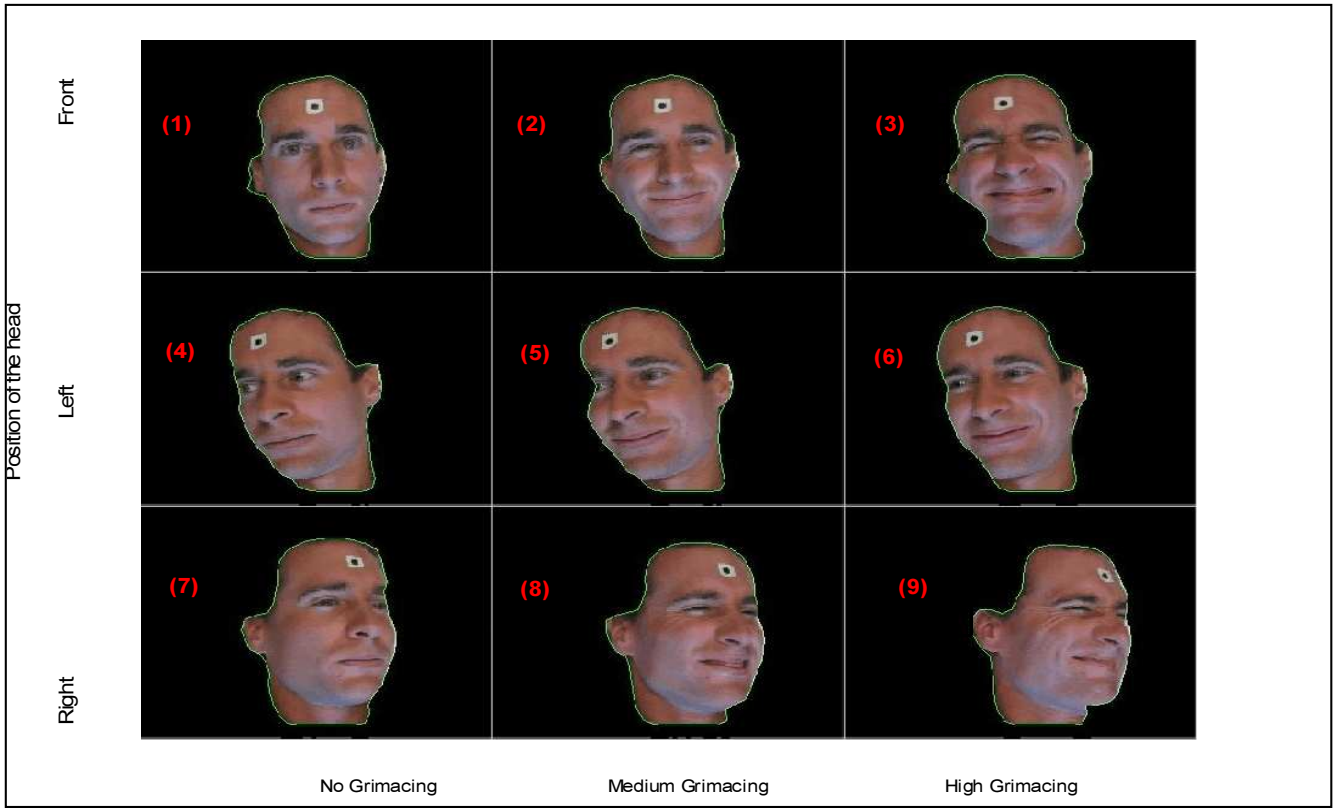
Results



Facial grimacing – Stationary

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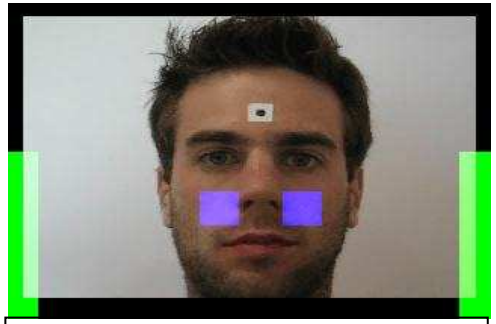
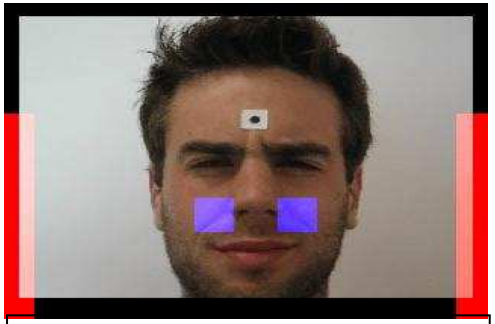
Measure grimacing level:

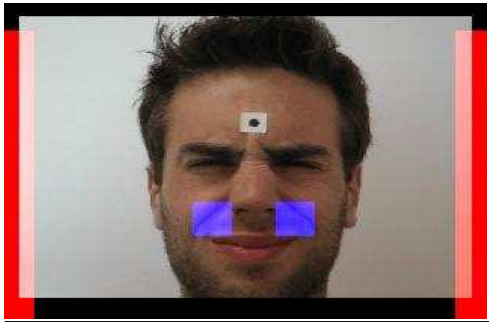
- Segregate the face by two squares around the cheek
- Threshold the segregated area
- Count the number of extra pixels appearing due to grimacing



No grimacing
Frame Nº 6



Medium grimacing
Frame Nº 340



Grimacing
Frame N º 361

Facial grimacing – Stationary

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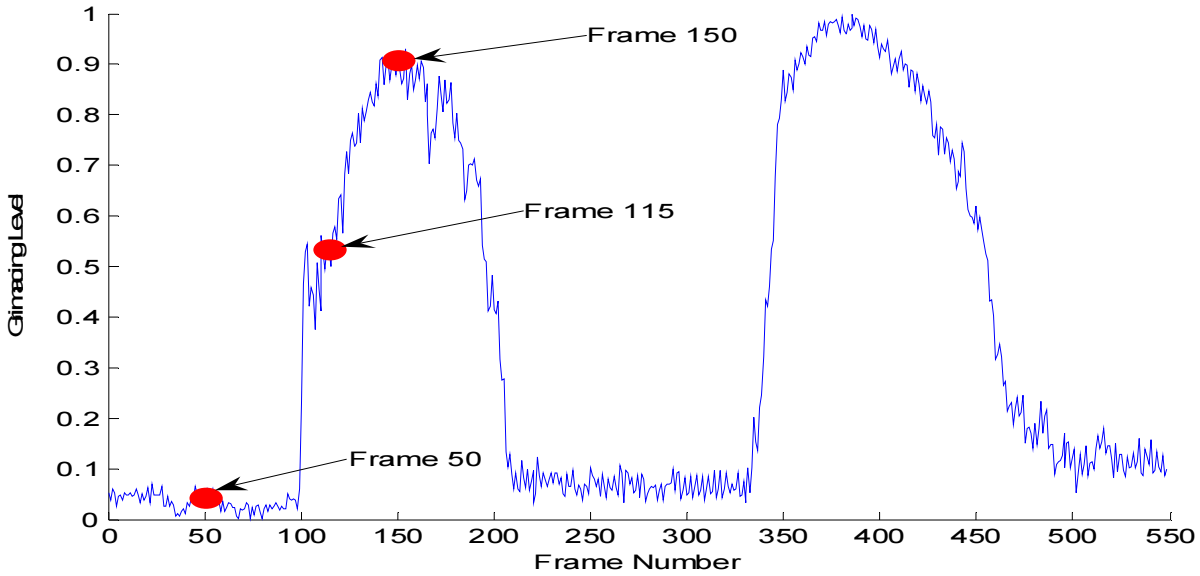
Results

Grimacing level as a function of the frame number after normalisation



Facial grimacing –Dynamic

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Face Segmentation:

•Fixed section below dot

•Above the eyebrow and below the mouth

• Using dot position and contour of face

Facial grimacing –Dynamic

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Measure Grimacing

Extra wrinkles

High-Pass filter

Edge detection

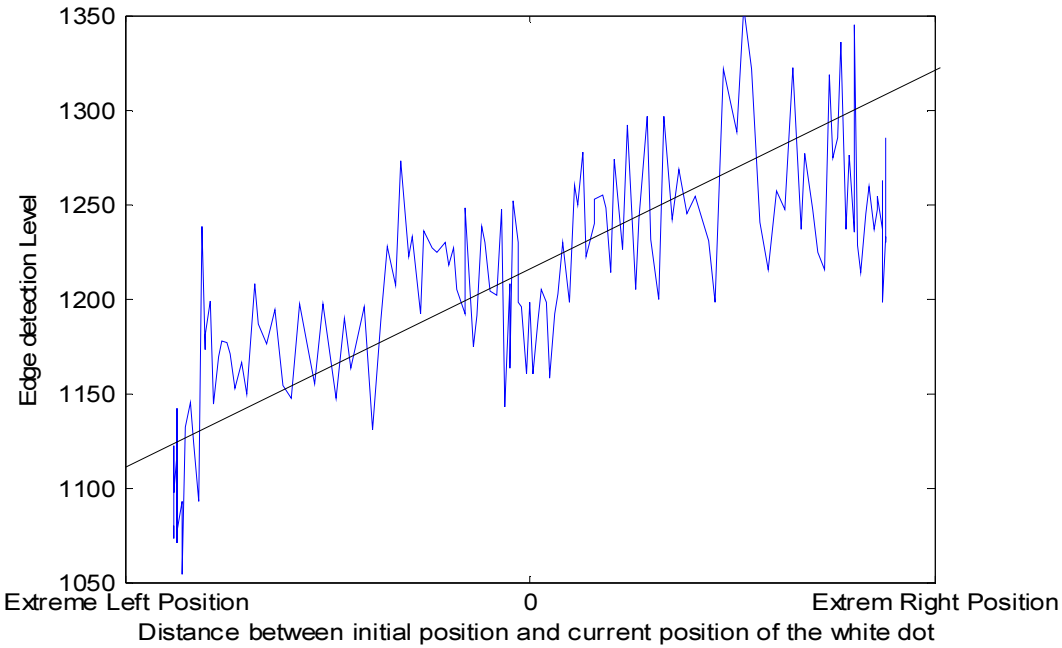
Counting edge pixels

Grimacing measure, which is normalized to calm state ➔ 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



$$\overline{G} = G - a * x$$

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

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Results:

Facial grimacing –Dynamic

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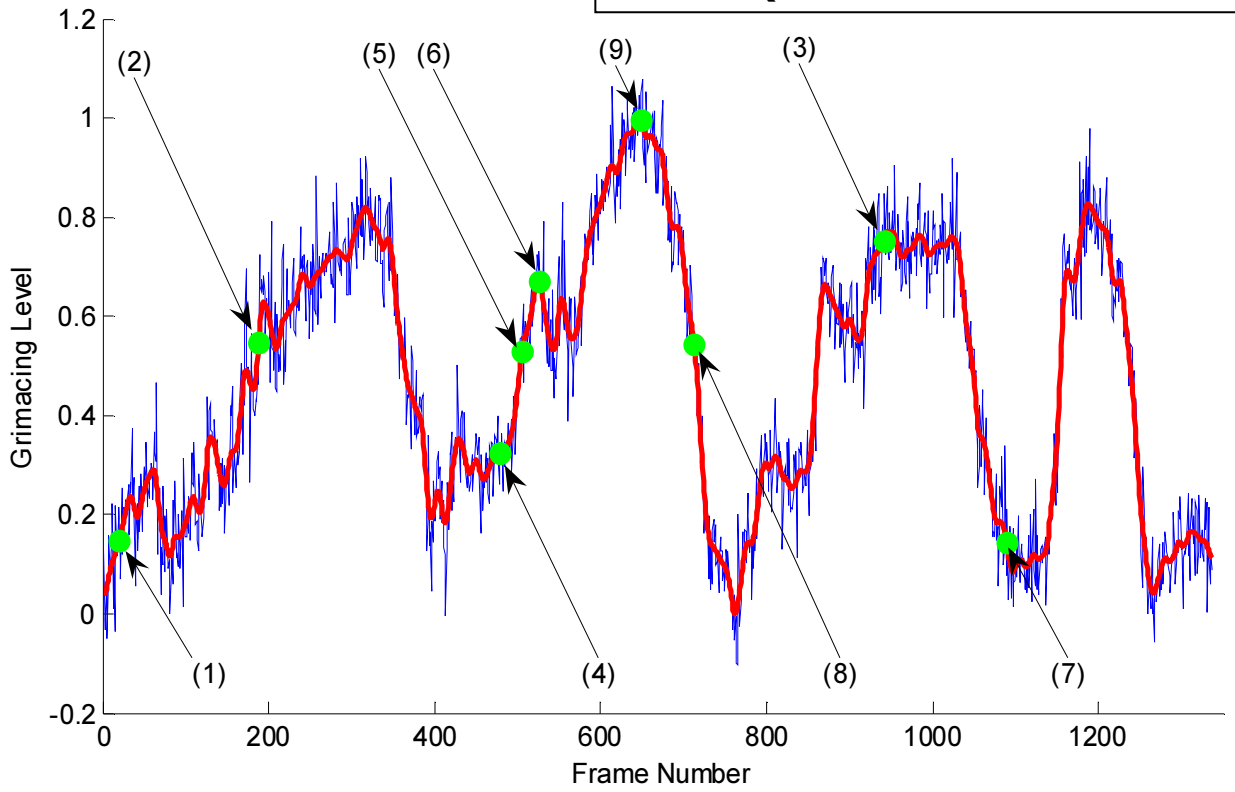
Results:

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

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- 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.