DEVELOPMENT OF A MULTISENSORY ACQUISITION SYSTEM FOR FLS TRAINING ASSESSMENT

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Laparoscopy is a minimally invasive surgical procedure used to examine the organs inside the abdomen. It can be used for both diagnostic and operational purposes.

- Less pain and scaring
- Reduced recovery time
- Reduced intraoperative blood loss
- Reduced infection and complications

- Loss of tactile feedback
- Fulcrum effect
- Lower mobility, no wrist-like movement
- The lack of depth perception

SPECIAL TRAINING REQUIRED

“The Fundamentals of Laparoscopic Surgery” (FLS) is an educational program created by SAGES and aimed to teach the fundamental knowledge and skills required in a basic laparoscopic surgery.

The FLS program is:
• a joint educational offering of SAGES and ACS.
• a standard of validated surgical training for residency education in America (CME accredited)

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5 tasks of increasing complexity:
A. Peg Transfer
B. Precision Cutting
C. Ligating Loop
D. Suture with Extracorporeal Knot
E. Suture with Intracorporeal Knot

Evaluation criteria:
- Time
- Accuracy

Stress impact on the performance

**SURGICAL FIELD**

- Laparoscopy is more stressful than open and robotic surgery

**MILITARY AND CIVIL AVIATION FIELDS**

- Stress has effect on decision making (e.g. attentional tunnelling)

**Best way to proceed:**
- Non-invasive and unobtrusive sensors
- More than one source of information
- Don’t disregard an evaluation of the subject performance

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Aim of the project

Setup of the acquisition system

Algorithm for blinking detection
- Validation

Algorithm for the 2D reconstruction of the movement of the tool
- Validation

Data acquisition

Preliminary analysis

4 video cameras
- 2 Trocar’s camera
- Laparoscopic camera
- Face camera

EEG
- Offline extraction and synchronization

Hexoskin

Eye Tracker
Workflow

Setup of the acquisition system

Algorithm for blinking detection
Validation

Algorithm for the 2D reconstruction of the movement of the tool
Validation

Data acquisition

Preliminary analysis
Setup of the acquisition system
Setup of the acquisition system

PARTICIPANT SIDE

OPERATOR SIDE

Quick-20 Dry EEG Headset
Trigger Box
Beacon
Setup of the acquisition system

- Abdomen and thorax belts
- Hexoskin shirt
- Recording device
- USB cable
Setup of the acquisition system

Video-camera
Resolution: 1024x768
Workflow

1. Setup of the acquisition system
   - Algorithm for blinking detection
     - Validation
   - Algorithm for the 2D reconstruction of the movement of the tool
     - Validation
2. Data acquisition
3. Preliminary analysis
Algorithm for blinking detection

Blinking is a semi-autonomic, reflexive, rapid closing of both the eyes.

Eye Tracker Gaze analysis: ET blink candidates

EEG analysis on Fp1 and Fp2: EEG blink candidates

Candidates comparison: Final blinks
Algorithm for blinking detection

M. Haak et al., “Detecting stress using eye blinks and brain activity from eeg signals.”, 2014

GAZE ANALYSIS

Detection criteria:
intervals of eyes not captured < 400 ms

Intervals of eyes not captured by the ET
Algorithm for blinking detection

AMPLITUTE ANALYSIS – PEAK ESTIMATION

M. Haak et al., “Detecting stress using eye blinks and brain activity from eeg signals.”, 2014
Algorithm for blinking detection

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Algorithm for blinking detection

M. Haak et al., “Detecting stress using eye blinks and brain activity from eeg signals.”, 2014
Algorithm for blinking detection

Validations:
100% of blinking detection (little and slow movements of the subject during the performance)

Main limits:
• Fast and rough movements of the subject (lots of motion artifacts)
• Subject on the edge of the tracker volume of the ET

M. Haak et al., “Detecting stress using eye blinks and brain activity from eeg signals.”, 2014
Workflow

1. Setup of the acquisition system
   - Algorithm for blinking detection
     - Validation
   - Algorithm for the 2D reconstruction of the movement of the tool
     - Validation

2. Data acquisition
3. Preliminary analysis
Algorithm for 2D reconstruction of the movement of the tool

i-th FRAME ANALYSIS
Flat patterns on the ceiling

Identification criteria:
• # circles close to 1 vertex
• # circles close to 2 vertexes
• Presence of circle in the center of the square

e.g. feature vector [2 0 1]
Algorithm for 2D reconstruction of the movement of the tool

1. i-th Frame
2. Fill and candidate labeling
3. HSV – V channel
4. Features detection
5. Thresholding
6. Pattern extraction
7. Square labeling
Algorithm for 2D reconstruction of the movement of the tool

Frame by frame additive error
Algorithm for 2D reconstruction of the movement of the tool

Frame (i)  \[ \text{Model}^{T}_{\text{Data}} \]  Frame (i+1)

Registration error: M = 0.81px  Std = 0.67 px
Max registration error: 4 pixel
Error depends on image’s quality.

Main Limit:
• Blurring introduced by fast movements
Workflow

Setup of the acquisition system

- Algorithm for blinking detection
  - Validation

- Algorithm for the 2D reconstruction of the movement of the tool
  - Validation

Data acquisition

- Preliminary analysis
Acquisition

Participants:
- 4 Beginners (B)
- 5 Residents (R)
- 3 Experts (E)

Acquisition Protocol:
1. Calibration
2. Signals quality check
3. Acquisitions
   - Task 0: Rest
   - Task 1: Peg Transfer
   - Task 2: Circle Cut
   - Task 3: Intracorporeal Knot (only R and E)
Workflow

Setup of the acquisition system

Algorithm for blinking detection
Validation

Algorithm for the 2D reconstruction of the movement of the tool
Validation

Data acquisition

Preliminary analysis
Performance evaluation

Criteria:
- Task’s initial score = 700 pts
- Subtract the % of completion time required to complete the task
- Penalties for each not completed phase
- Penalties for errors (small, big, very big)
Performance evaluation

Task 1:

Task 2: main discriminative task among B and R,E

Task 3: main discriminative task among R and E
Preliminary analysis – Gaze observations (ET)

Correlation with events

Task 1

Gaze coordinates \((x,y)\) over time – Peg Transfer (task 1)

- **Beginner**
  - Reaction to error
  - Loss of attention

- **Resident**
  - Initial difficulty

- **Expert**
  - Reaction to error

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Preliminary analysis – Gaze observations (ET)

Task 3

Smoother signals → better performance
Preliminary analysis – Gaze observations (ET)

Level of focus

Task 2:

Higher dispersion

Gaze (x,y) on monitor – task: 2
Preliminary analysis – Gaze observations (ET)

Level of focus

HIGH DISPERSION

Resident

Expert

T start

T end

Gaze (x,y) on monitor – task: 3

Gaze (x,y) on monitor – task: 3

Task 3:
Preliminary analysis – Gaze observations (ET)

Level of focus - Analysis on Gaze displacements vectors’ module

<table>
<thead>
<tr>
<th>Name</th>
<th>Category</th>
<th>Task 2: Circle Cut</th>
<th>Task 3: Intracorporeal Knot</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>mean [px]</td>
<td>std [px]</td>
</tr>
<tr>
<td>Subj1</td>
<td>B</td>
<td>5.5</td>
<td>29.6</td>
</tr>
<tr>
<td>Subj2</td>
<td>B</td>
<td>2.1</td>
<td>15.1</td>
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<tr>
<td>Subj3</td>
<td>B</td>
<td>3.8</td>
<td>24.7</td>
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<tr>
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<td>B</td>
<td>4.0</td>
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<td>R</td>
<td>3.0</td>
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<td>R</td>
<td>1.9</td>
<td>12.9</td>
</tr>
<tr>
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<tr>
<td>Subj12</td>
<td>E</td>
<td>1.8</td>
<td>10.1</td>
</tr>
</tbody>
</table>

Outliers:
- High: Subj1, Subj2, Subj11
- Low: Subj5, Subj7, Subj12

Tasks:
- Task 2
- Task 3

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Preliminary analysis – Hexoskin, Blinking, Pupil observations

Hexoskin:
- Heart activity: almost 1/3 of the data present errors
- Respiratory activity: irregular respiration during hard phases

Blinking Rate:
- Drop from rest to exercise
- In some, it increases in hard phases

Task 3
Preliminary analysis – Hexoskin, Blinking, Pupil observations

**Hexoskin:**
- Heart activity: almost 1/3 of the data present errors
- Respiratory activity: irregular respiration during hard phases

**Blinking Rate:**
- Drop from rest to exercise
- In some, it increases in hard phases

**Tunnel Effect (sound):**
No impact on the performance
Conclusions

The goals achieved:
• Creation of a multisensory platform for signals acquisition during FLS training
• Algorithm for blinking detection
• Algorithm for 2D reconstruction of the tool motion
• Observations on preliminary analysis on subset of signals: ET, respiration and Blinking represent signals of interest

Future development:
• Include a new device for heart monitoring and enlarge the number of participants
• More in depth analysis for all the other signals to find relevant parameters for a wider performance evaluation
• Add external events such as the rotation of the laparoscopic view and the appearance of smoke in the FOV
Thank you for your attention

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