# Multi-Modal AI-Based Pain Detection in Intermediate Care Patients in the Postoperative Phase

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## Highlights

Automatic pain detection system

**Robust, Multi-modal, AI-based**

Trained on **multi-modal laboratory datasets**

Verified on **novel real-world dataset**

**Contributions:**

- Improvements on SOTA methods using novel approaches
- Creation of a novel real-world clinical dataset
- Verification of findings on real-world data
- Conducting a clinical acceptance trial

**Pain-detection Project Website:**

## Project Overview

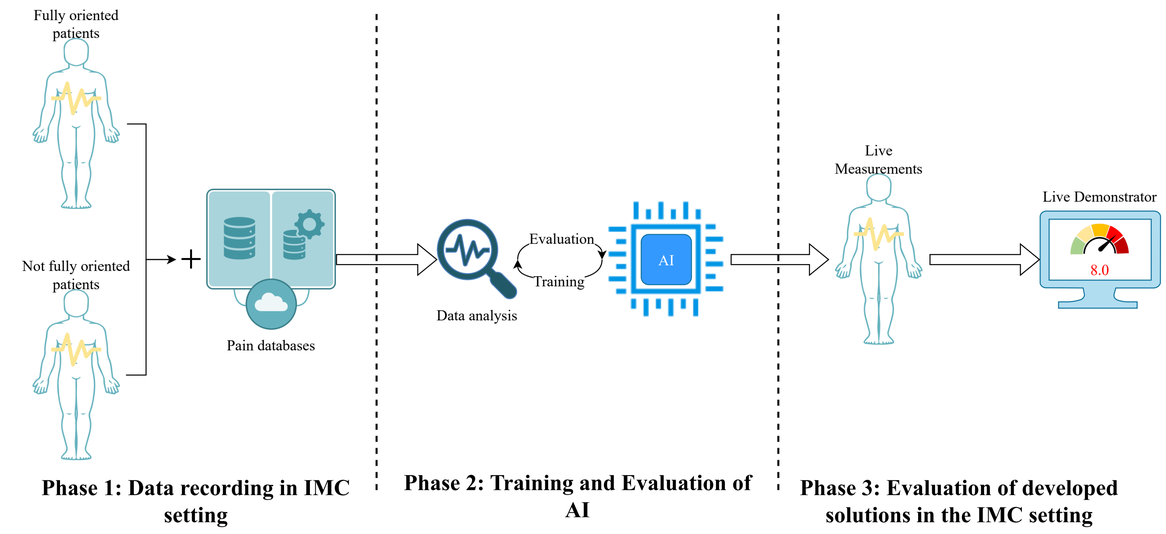



Figure 1. Overview of the IMC pain detection project.

## Introduction

**Problem:**

- Pain assessment in clinical settings is based on self-report or expert report
- Used pain assessment methods are subjective for every individual
- There is no unified automated system for pain assessment
- Patients who are not fully oriented have no method to communicate their pain

**Motivation:**

- Implement a robust and reliable system for pain intensity classification
- Evaluate the implemented system using a real-world dataset
- Perform a clinical acceptance trial

**Approach:**

- Recording a real-world dataset in an Intermediate Care Unit
- Improving the SOTA methods for real-time pain assessment
- Testing the developed methods using the newly recorded IMC data

## State-of-the-Art

- NIT recorded two multi-modal pain datasets including bio-signals and videos
  - BioVid
  - X-ITE
- Developed a multi-modal LSTM-based model
  - Based on handcrafted features for bio-signals
  - Based on Action Units and Landmarks for facial expressions

## Pain Datasets

| | | BioVid | X-ITE |
|---|---|---|---|
| bio signals | zEMG | ✓ | ✓ |
| | cEMG | ✓ | ✓ |
| | tEMG | ✓ | ✓ |
| | EDA | ✓ | ✓ |
| | ECG | ✓ | ✓ |
| video | frontal | ✓ | ✓ |
| | side | ✗ | ✓ |
| | body | ✗ | ✓ |
| | thermal | ✗ | ✓ |

Table 1. Comparison BioVid & X-ITE

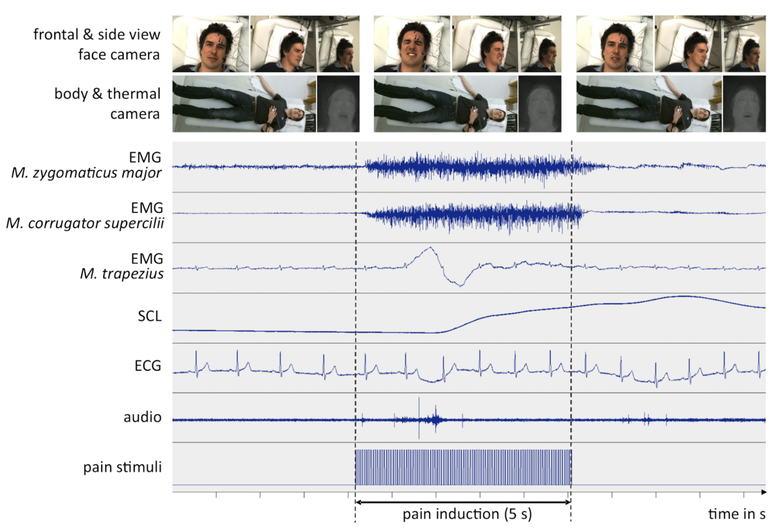
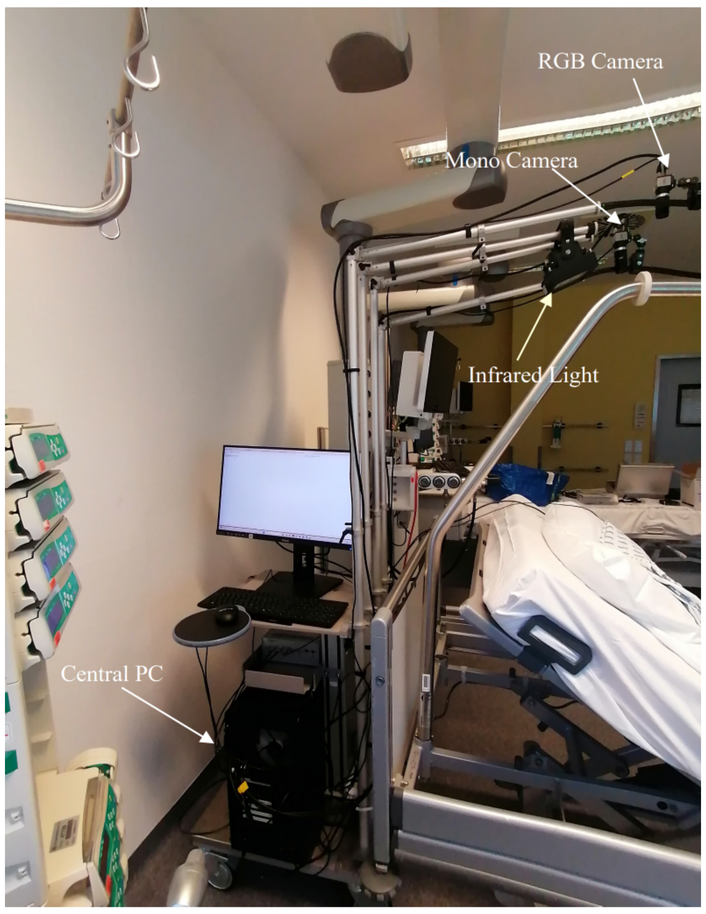



Figure 2. Example of pain data from the X-ITE pain database

## IMC Recording Setup



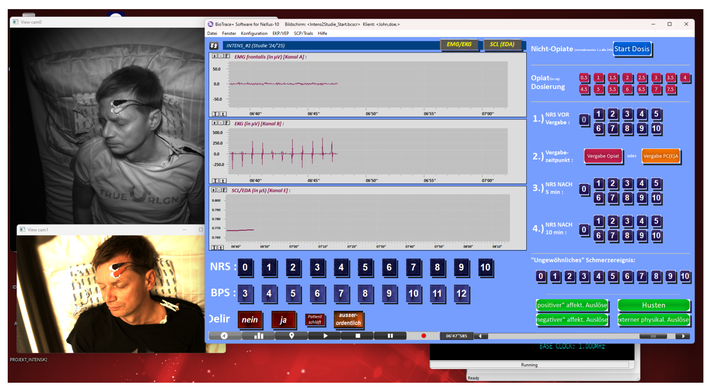



Figure 3. Recording Setup in the IMC of the University Hospital of Ulm, Germany

## IMC Recording Setup

**Setup was installed in the IMC of the University Hospital in Ulm, Germany**

- Recording of patients recovering from abdominal surgery
- Controlled environment with constant supervision of recorded patients
- Recording of frontal camera and bio-signals
  - EMG
  - EDA
  - ECG
- Usage of infrared filtered mono camera with infrared light to ensure continuous recording independent of environmental lighting

## Attention

! Due to privacy concerns, the IMC data will not be published. The data will only be used to evaluate the methods, to determine if pain can be correctly classified without extensive re-training, while also making sure that no sensitive data can be found within a public model.

## Planned Steps in the Project

- Recording data of real patients in the IMC
- Improvements on the SOTA Methods
  - Improved feature selection
  - Improved more powerful models
- Training on BioVid and X-ITE
- Evaluation on IMC Data
- Implementation of a live test for clinical evaluation

## Recent Model Architecture

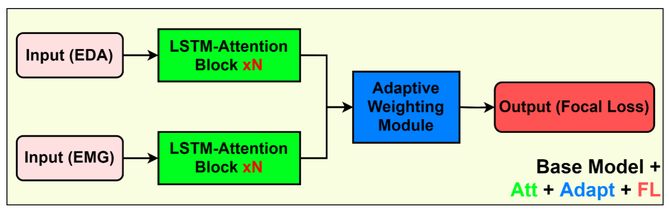



Figure 4. Current model architecture for continuous pain intensity classification

## Tested model improvements

- Creating a more powerful model by adding attention and model depth
- Improving multi-modal capabilities by introducing an adaptive weighting module for late fusion
- Introducing focal loss and reduction strategies to improve imbalanced data
- Introducing an improved, more powerful feature set with full multi-modality

## Current video-based pain detection approach

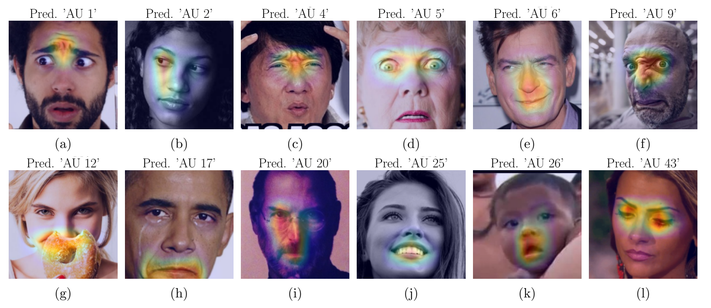



Figure 5. Heatmaps of action units, commonly used in video-based pain detection

## Conclusion

- Setup recording of a new real-world pain dataset
- Improved model architecture for continuous pain classification
- Introduced a full multi-modal feature set for pain classification on bio-signals

## Future Work

- Improvements in pain detection through facial expressions
- Evaluation between laboratory data and real-world data
- Implementation of a live demonstrator
- Conducting a clinical acceptance trial

## Acknowledgment

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