Digital Twin for Drone Control through a Brain-Machine Interface

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Agenda

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- The Decision Component

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01. Introduction

01 Introduction

- There has been an increase of interest on the drone sector
- The usage of drones is particularly important for the execution of <u>high-risk operations</u>
- Dangerous operations require that the operator is <u>fully focused</u> to deliver a <u>reliable control</u>

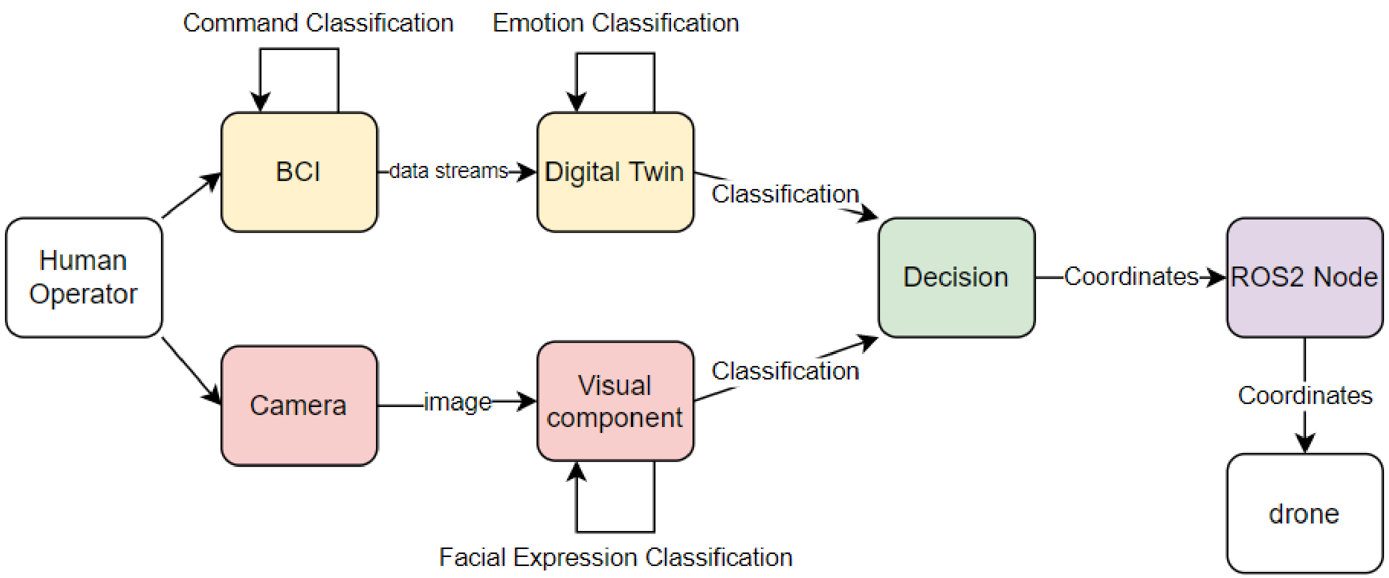
02. Implementation

02 Implementation

Proposed Solution Overview

- **Digital Twin**: virtual representation of the operator; BCI data streams input; classifies the cognitive emotional state;
- **Visual Component**: facial expressions footage input; classifies the visual emotional state[1] ;
- **Decision Component**: decides whether the operator is in a suitable emotional state to send commands and computes necessary information;
- **ROS2 Client node**: communication between the *base station* that manages the drones and this system; client node is connected to the server node to send information.

Proposed Solution Architecture



[1] Open-source project was integrated in the solution: Emotion Recognizer

02 Implementation

The Digital Twin

Data Aquisition

- Emotiv Epoc+

- Subscription to *motion*, *facial expressions* and *band power* data streams

Data Format

- Handling raw data by assigning each value to the corresponding feature

Data Integration

- Observations are matched with the values of the nearest point in time

Data Cleaning and Feature Engineering

- *Arousal* and *valence* are computed for each observation
- Categorical features are binary encoded
- Single-value features and other irrelevant ones are eliminated

Modeling

- 4 classes: positive classes (*calm* and *focused*) and negative classes (*distracted* and *stressed*)
- 70% for modeling and 30% for validation
- Algorithms: Decision Tree, k-NN, LDA, Naïve Bayes, Random Forest, SVM (linear and rbf kernel) and Neural Networks
- Random Forest is selected

02 Implementation

The Decision Component

- Receives input of the same period of time of the digital twin, visual component and the command;
- Approves a command under an overall positive classification:

Group	Classes	
	Digital Twin	**Visual Component**
Positive	*Focused* and *Calm*	*Happy* and *Neutral*
Negative	*Distracted* and *Stressed*	*Angry*, *Disgust*, *Fear*, *Sad* and *Surprise*

Decision	Detections	
	Digital Twin	**Visual Component**
Not send	Positive	Negative
Not send	Negative	Positive
Not send	Negative	Negative
Send	Positive	Positive

- Computes coordinates after the command is approved:

$$distance = (command\ confidence\ * increment) * cognitive\ emotion\ confidence$$

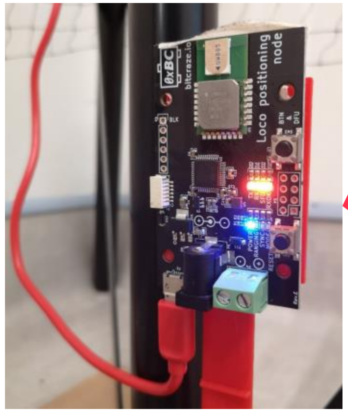
03. Validation

03

Validation

Experimental Setup

Anchor[1]



Arena

Crazyflie Quadcopter[2]

[1] Anchor part of the positioning system by *Bitcraze* company: Loco Positioning system

[2] Crazyflie 2.1 quadcopter by *Bitcraze* company: Crazyflie 2.1

Validation

Experiments

- ***Baseline Test:*** no emotion classification and commands are directly sent to the drone (only a ROS2 client node is established);
- ***Level 1 Test:*** only the digital twin is added and decision will be accomplished according to the predictions (core functionality);
- ***Level 2 Test:*** digital twin and computation of coordinates are added;
- ***Full Test:*** digital twin, visual component and computation of coordinates are added (all functionalities).

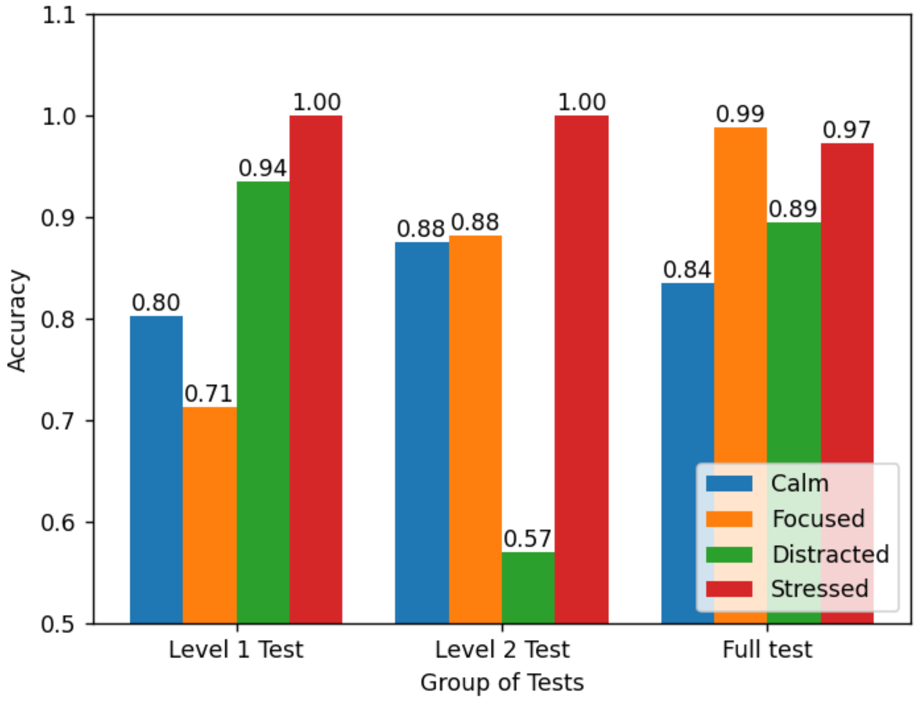
Increasing level of the solution's robustness

03

Validation

Results

Success Rate of the digital twin per emotional state and per test level



Distracted Emotion Recognition

Positive Detections	Level 1 Test	Level 2 Test	Full Test
Total number	6	11	10
Nº neutral commands	4	7	6
Nº of sent commands	2	4	1
BCI positive and visual negative	N/A	N/A	3

Stressed Emotion Recognition

Positive Detections	Level 1 Test	Level 2 Test	Full Test
Total number	0	0	2
Nº neutral commands	0	0	1
Nº of sent commands	0	0	0
BCI positive and visual negative	N/A	N/A	1

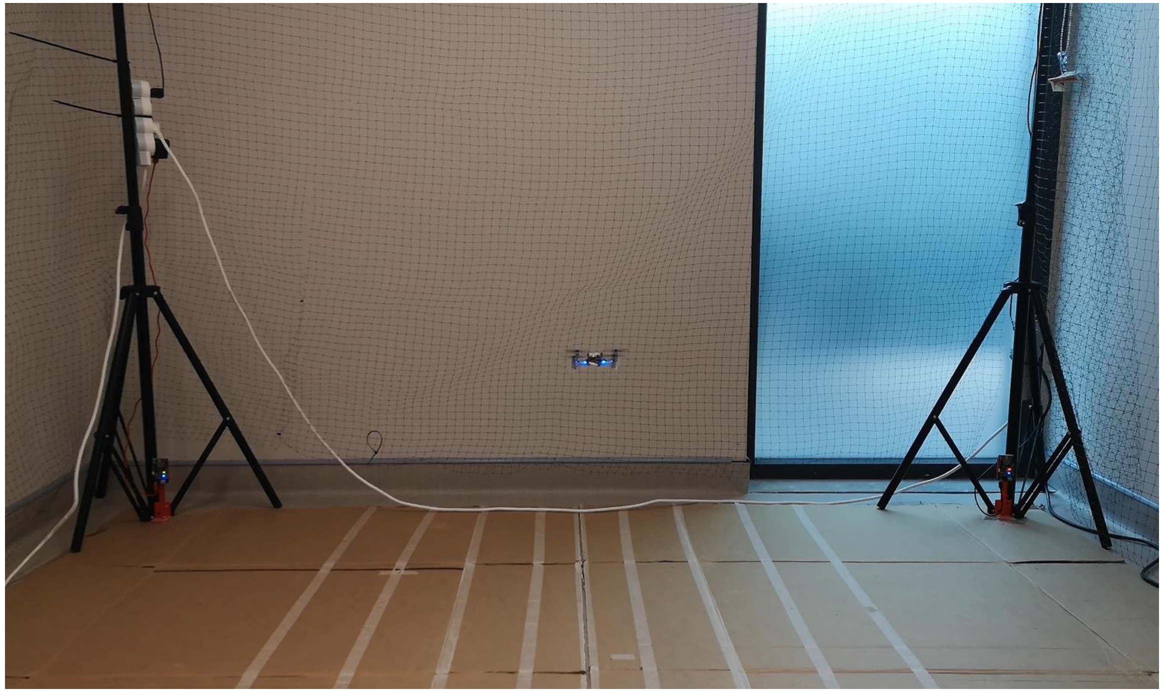
Prevented commands to be sent under a cognitive negative emotion

04. Conclusion

04 Conclusion

- We were able to demonstrate that a digital twin of an operator can discriminate his multiple, positive and negative, emotional states;
- The conjunction of a digital twin (cognitive classifier) and a visual component (visual classifier) improve the system's overall reliability;
- We were able to demonstrate that drones can be managed through a ROS 2 client and server nodes.

Drone position after take-off



04

Conclusion

Demonstration

video

Thank you!

video

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