WOA 20th

20th WORKSHOP "FROM OBJECTS TO AGENTS" (WOA 2019)

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Towards a Logic-based Approach for Multi-modal Fusion and Decision Making during Motor Rehabilitation Sessions

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POR CAMPANIA FESR 2014-2020

AVATEA

Introduction

- **AVATEA:** Advanced Virtual Adaptive Technologies e-hEAlth
  - Aim: to develop an intelligent system for the **rehabilitation of children**
  - **Development Coordination Disorders** (DCD)

- Integration of several components:
  - **Adjustable seat**
  - **Sensors** (pressure, motion, cameras, EEG …)
  - **Visual interface** (games)

Challenges

- Need for developing personalised therapeutic scenarios
  - Adaptation techniques typically only focus on maximising effort during the rehabilitation session

- It is necessary to take into account parameters such as:
  - the **individual subject's capabilities**
  - the child's emotional response (**engagement**)

Challenges

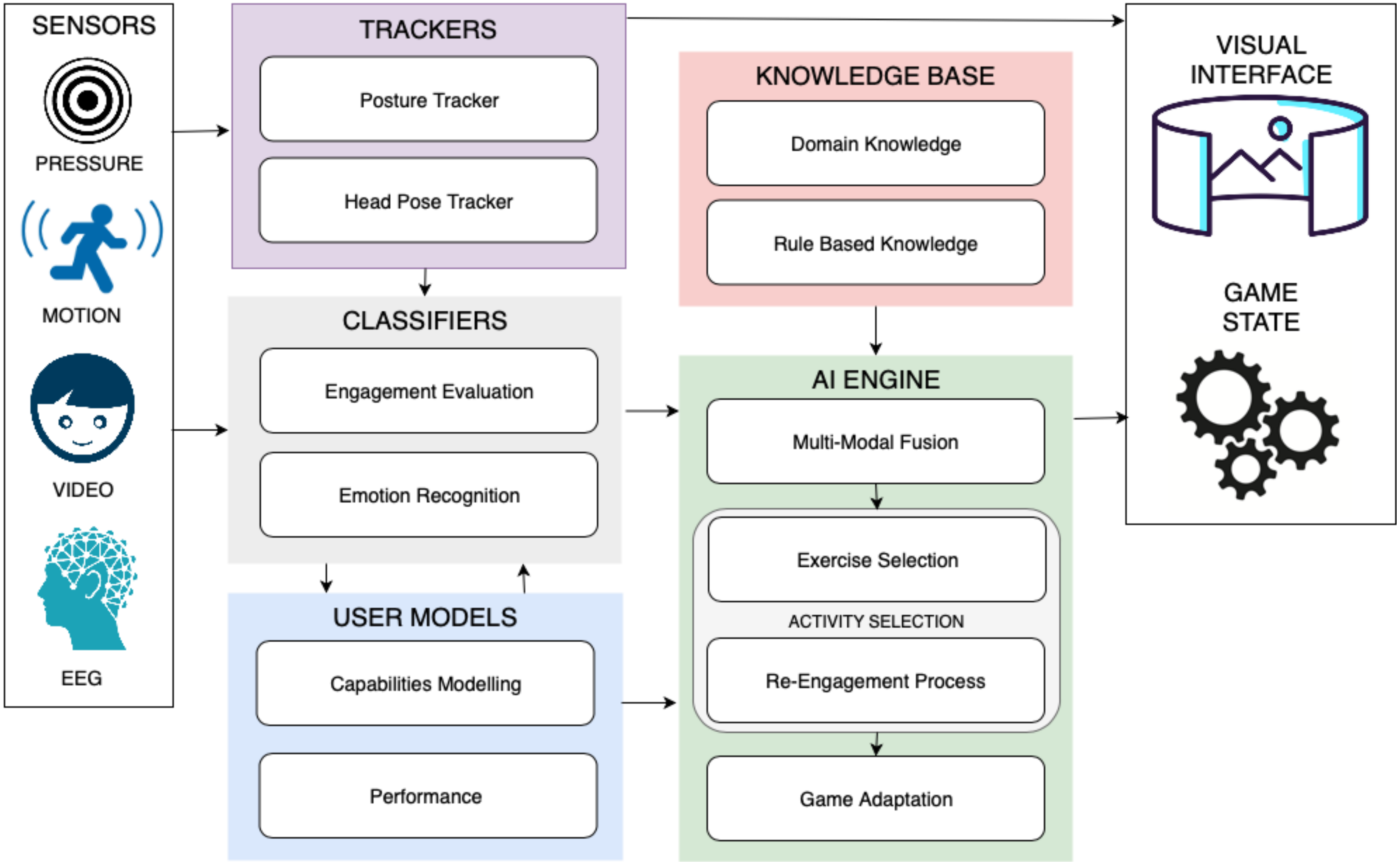
AVATEA requires facing a number of challenges, including:

- Deal with **sensor data from different sources**
    - (cameras, microphones, pressure sensors, EEG, …)
- **Machine learning** for data processing
    - Detect the user’s level of engagement
    - Profile and track the user’s progress
    - Support the therapists by providing them with detailed reports
- Provide an **adaptive rehabilitation and re-engagement strategy**
    - the rehabilitation procedure must remain safe and informative

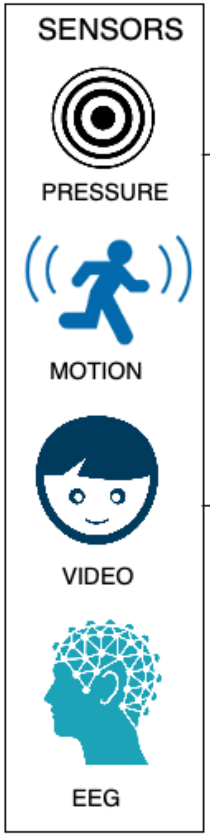
AVATEA Solution

- Handling data coming from different sources requires a complex system able to integrate them and take decisions accordingly,
    - **a multimodal system**
- **Logic-based systems**
    - are progressively becoming able to handle uncertain knowledge
    - offer a transparent way to look at the information in AI systems
        - To reconstruct the rationale behind the decisions taken
        - To provide explanations in human-readable terms

The AVATEA Architecture



Sensors



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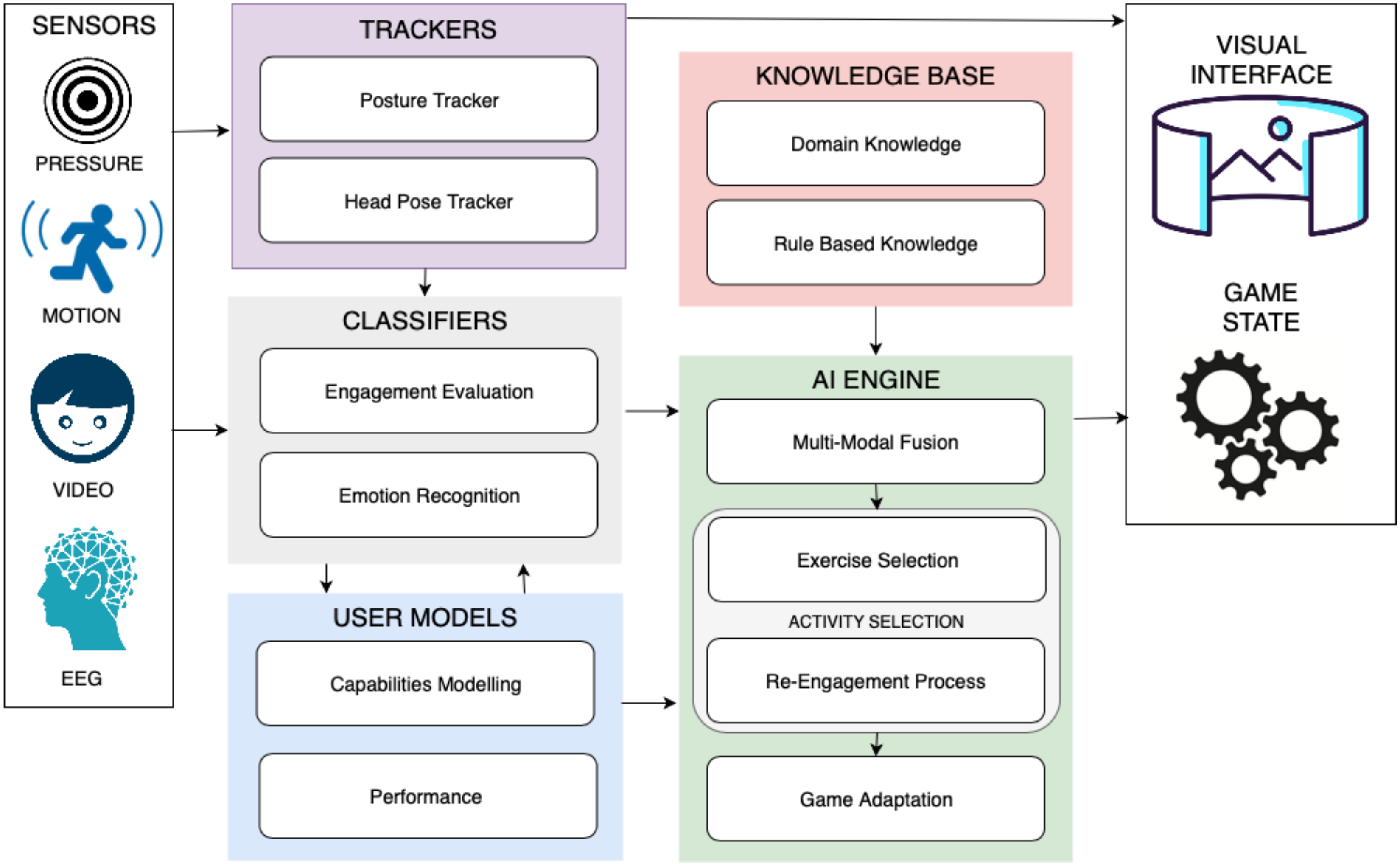
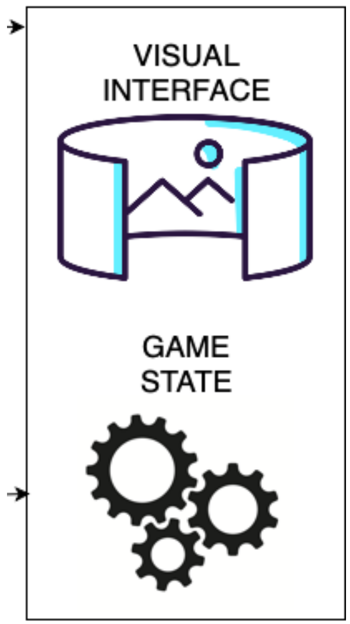
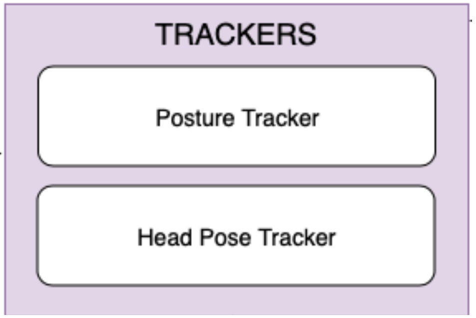
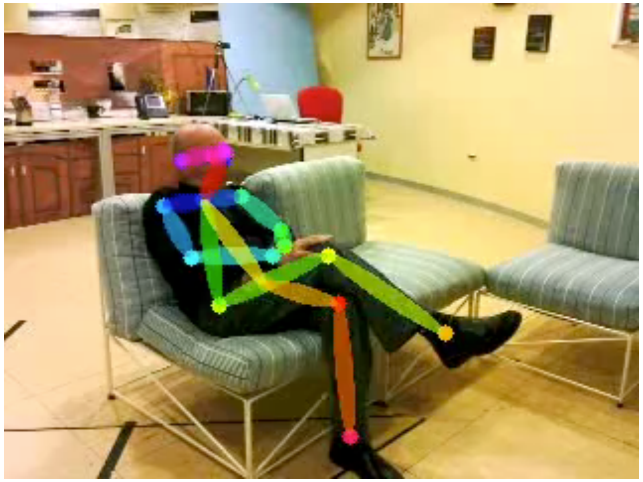


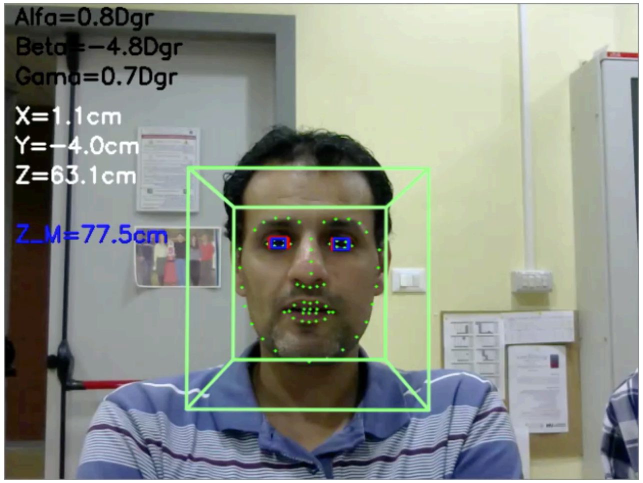
Games



Input Trackers







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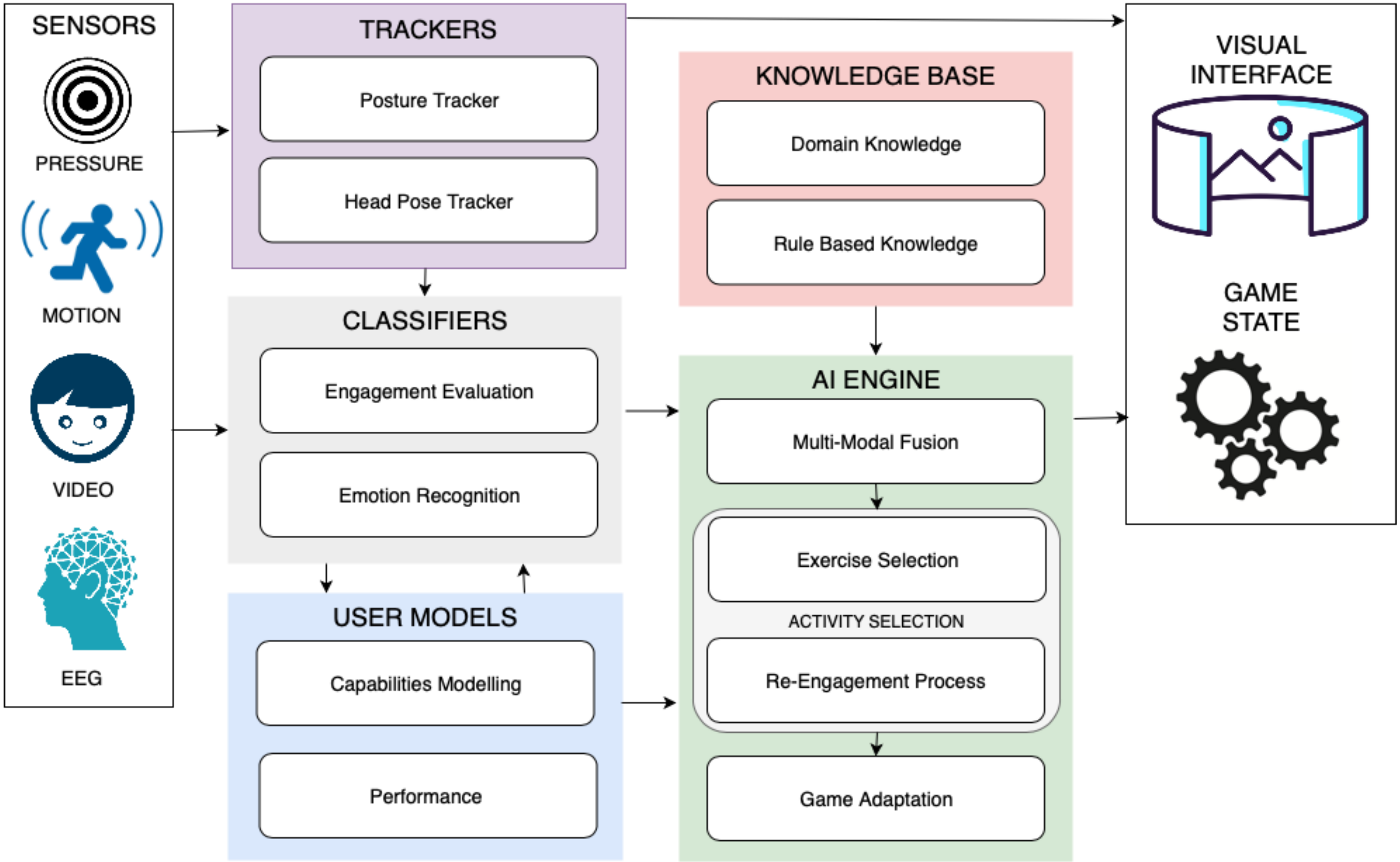

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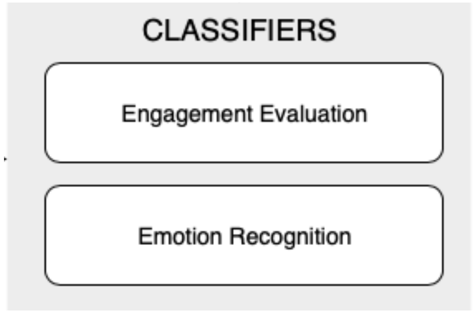

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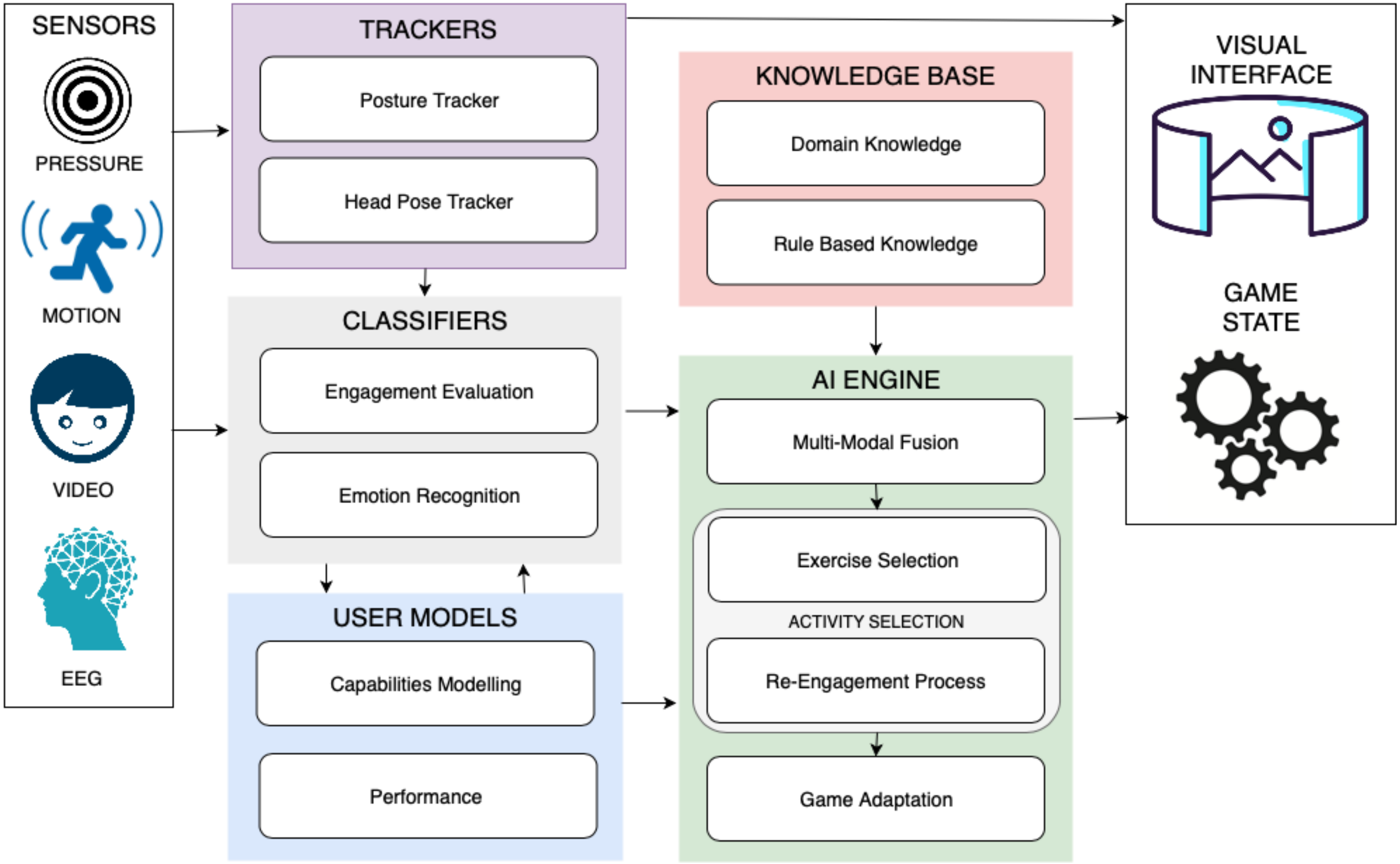
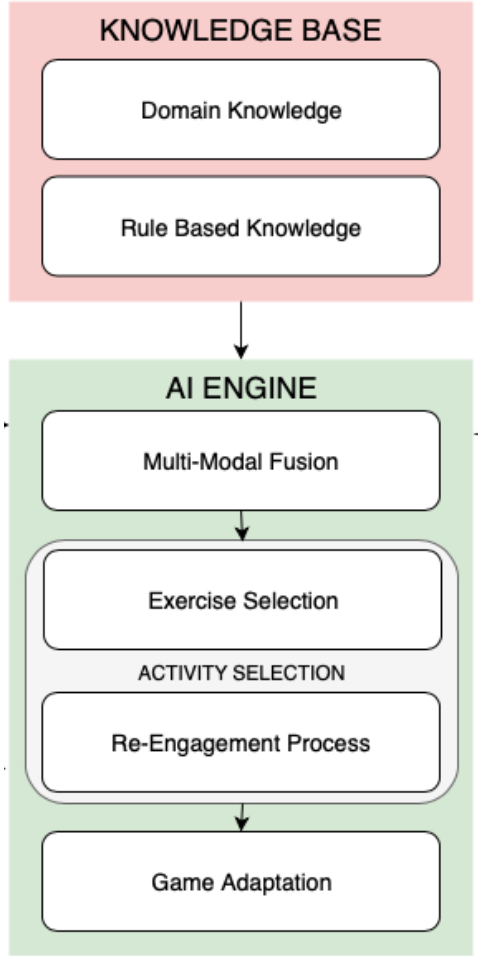


AI Engine


KNOWLEDGE BASE
Domain Knowledge
Rule Based Knowledge
AI ENGINE
Multi-Modal Fusion
Exercise Selection
ACTIVITY SELECTION
Re-Engagement Process
Game Adaptation

Multimodal fusion

As an illustration, consider the task of detecting the child's level of engagement w.r.t. the exercise s/he's performing:

Multimodal fusion

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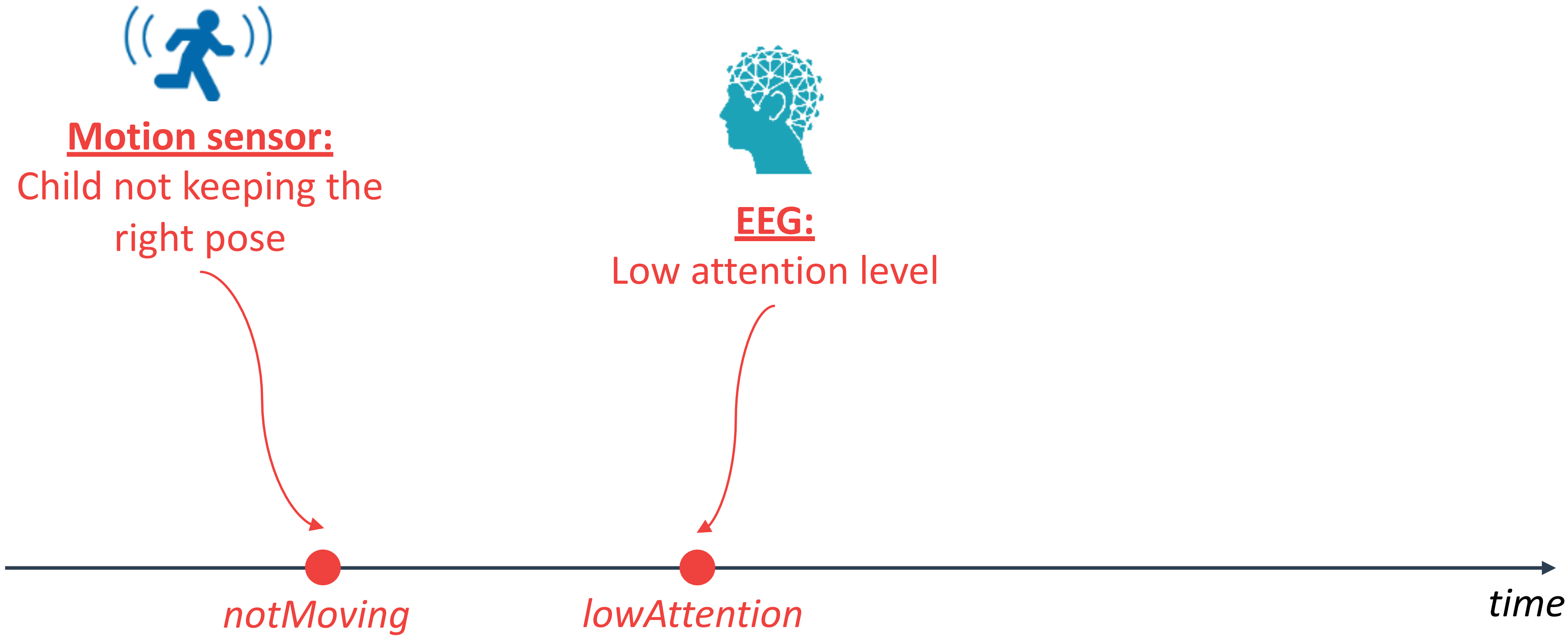

Multimodal fusion

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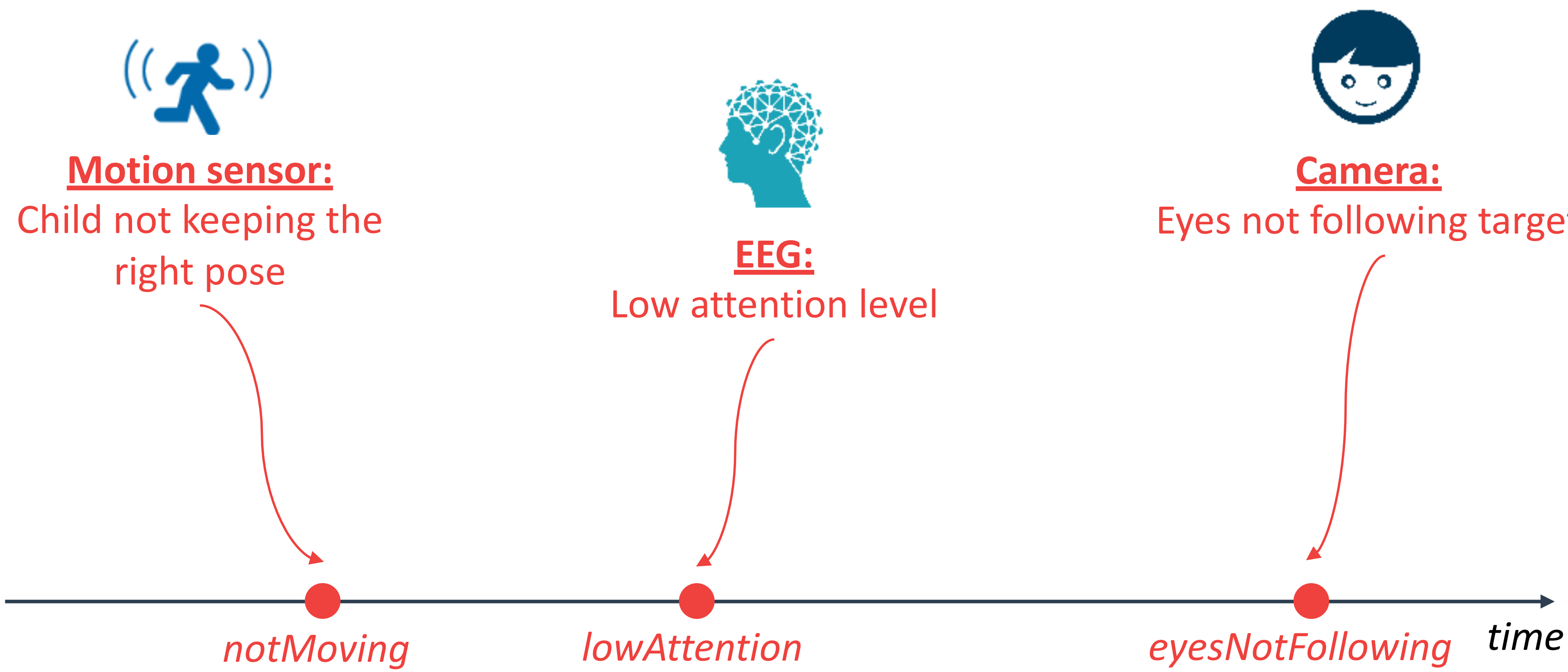

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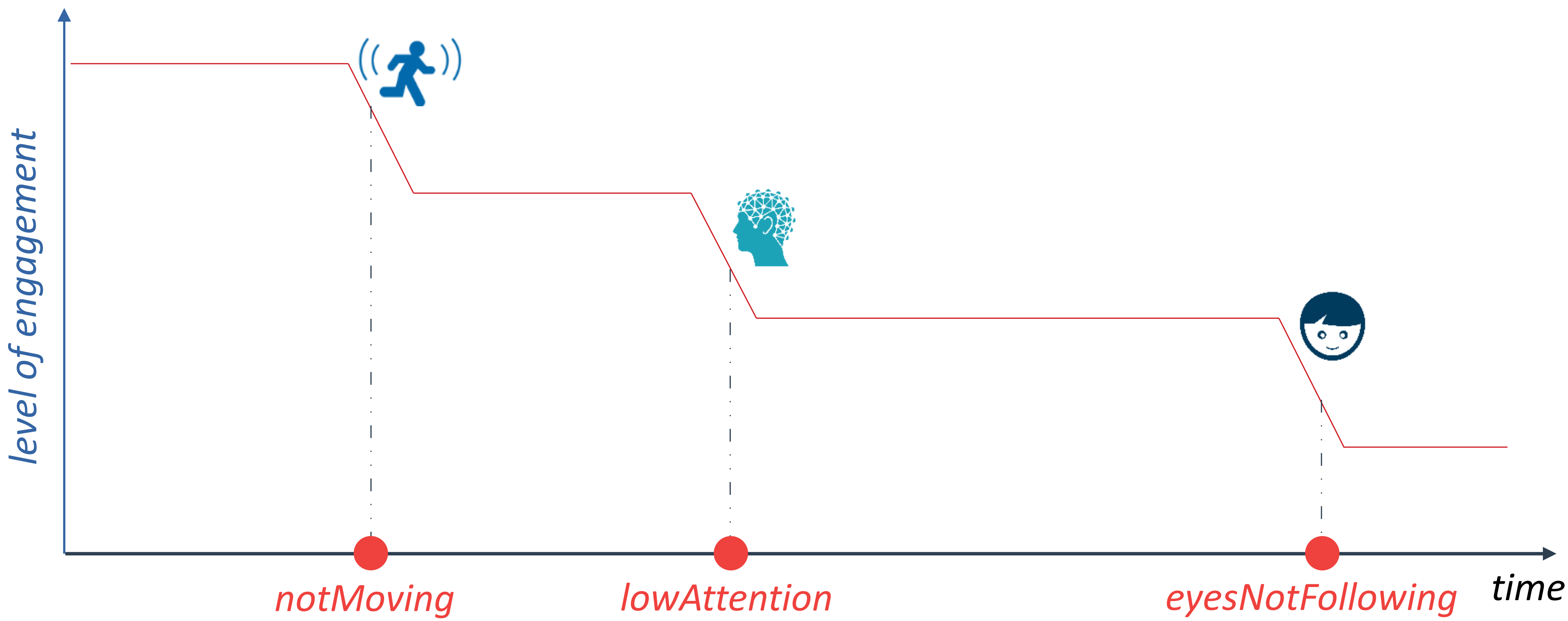

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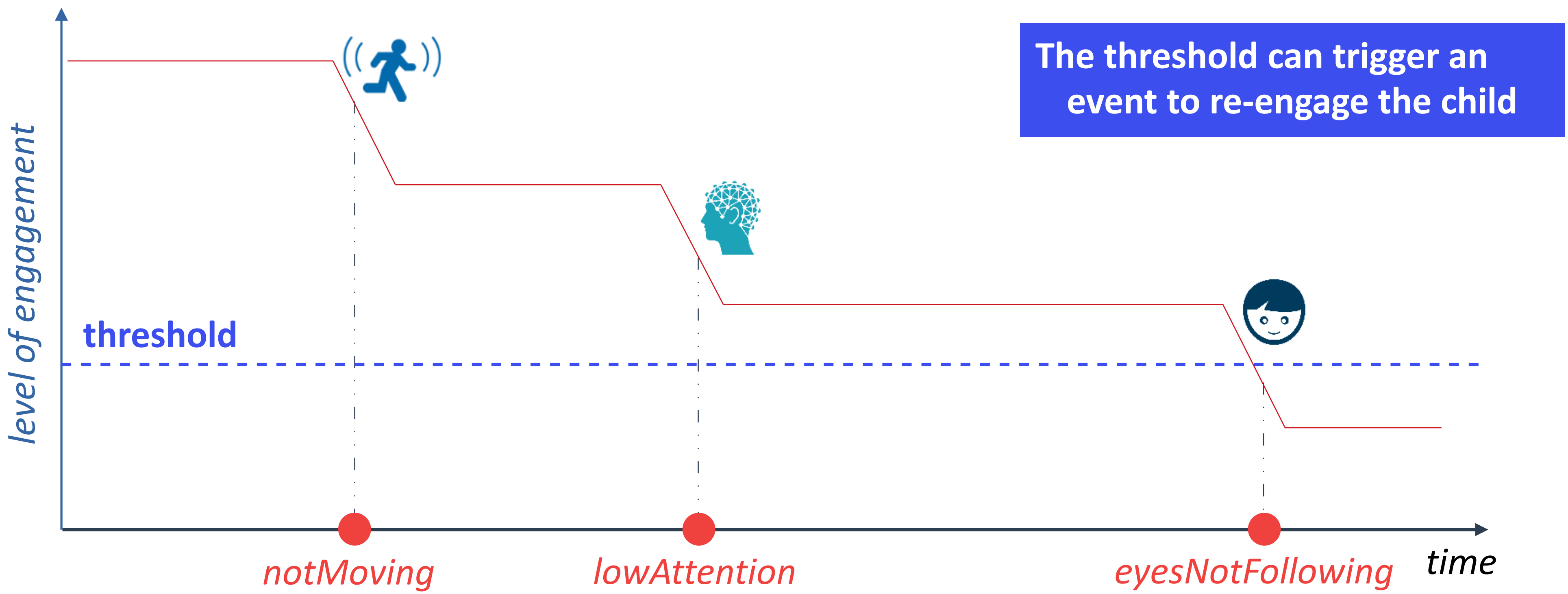

EPEC: Overview

For this task we use **EPEC**, a modern logical probabilistic logic-programming language for representing events occurring along a timeline, reason about their effects, and plan to achieve a goal:


```
notMoving causes-one-of {({¬Engangement},0.3),
(Ø,0.7)}
eyesNotFollowing causes-one-of {({¬Engangement},0.5),
(Ø,0.5)}
notMoving occurs-at Friday, 21-Jun-2019 14:07:52
GMT+0000
eyesNotFollowing occurs-at Friday, 21-Jun-2019
14:09:58 GMT+0000
```

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notMoving **occurs-at** Friday, 21-Jun-2019 14:07:52 GMT+0000
eyesNotFollowing **occurs-at** Friday, 21-Jun-2019 14:09:58 GMT+0000

∀*I*, *cutScene* **performed-at** *I* **if-believes** (*Engangement*,[0,*threshold*])

EPEC: Language

For completeness, we give a full description of EPEC's language and syntax. EPEC's language consists of:

- A finite set ***F*** of *fluents*
- A finite set ***I*** of *instants*, ordered with a least element
- A finite set $\underline{\mathbf{A}}=\underline{\mathbf{A}}_e \cup \underline{\mathbf{A}}_a$ of (*environmental*, *agent*) *actions*
- A finite set ***V*** of *values*

A *literal* is an expression of the form *X*=*V*, a *formula* is a combination of literals using connectives, a (*partial*) *fluent state* is a set of literals that mention each *(*resp. some*)* fluent exactly once, and an *outcome* is a pair (*S*,*P*) for some partial fluent state *S* and real value *P* in [0,1].

EPEC: Syntax

<u>v-propositions</u>: *F* **takes-values** $\{V_1, \ldots, V_n\}$

<u>i-propositions</u>: **initially-one-of** $\{S_1, \ldots, S_n\}$

<u>c-propositions</u>: θ **causes-one-of** $\{O_1, \ldots, O_n\}$

<u>o-propositions</u>: A_e **occurs-at** *I* **with-prob** *P* **if-holds** θ

<u>p-propositions</u>: A_a **performed-at** *I* **with-prob** *P* **if-believes** $(\theta, \dot{P})$

<u>s-propositions</u>: θ **senses** *F* **with-accuracies** *M*

where *F* is a fluent, V_i is a value, S_i is a state, θ is a formula, O_i is an outcome, A_e, A_a are (environmental, agent) actions, *P* is a real value in [0,1], $\dot{P}$ is a sub-interval of [0,1], *I* is an instant, *M* is a matrix.

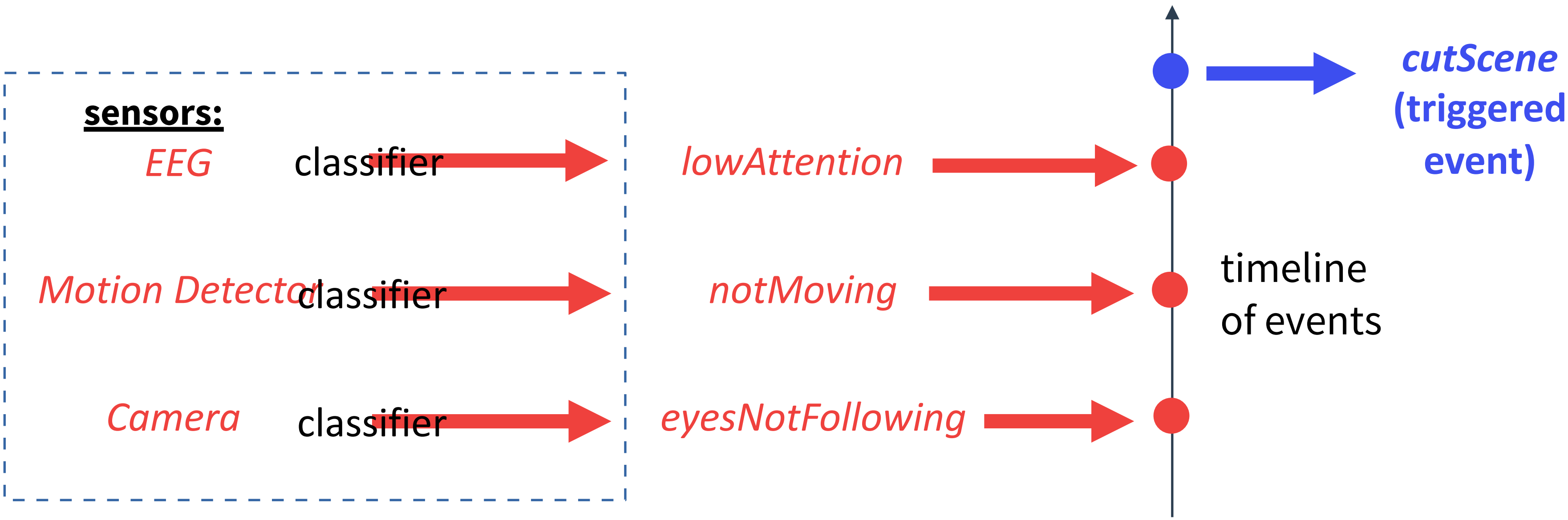
EPEC: Implementation

There are several existing implementations of EPEC, which can reason **offline** about a knowledge base consisting of sets of (v-, i-, c-, o-, p-, s-) propositions.

These implementations are:

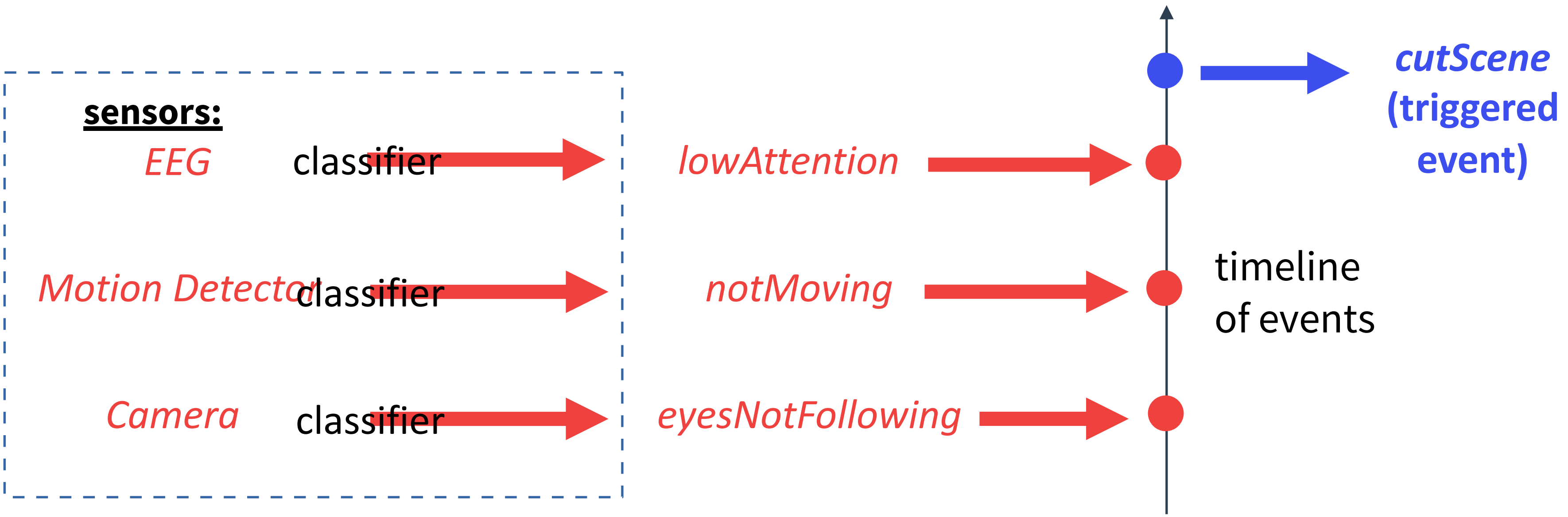
- **PEC-ASP**: for exact computation of probabilities (non-epistemic fragment of EPEC)
- **PEC-Anglican**: for approximate computation of probabilities (non epistemic fragment of EPEC, uses MCMC techniques)
- **EPEC-ASP**: for exact computation of probabilities (full EPEC)

EPEC



In our architecture, all the modalities are **jointly** represented on EPEC's timeline in the form of **events**. These are then reasoned about, together with the causal rules and conditional plans, to infer high-level facts about the environment (e.g., the current level of engagement) and possibly trigger other events (e.g., play a cut scene).

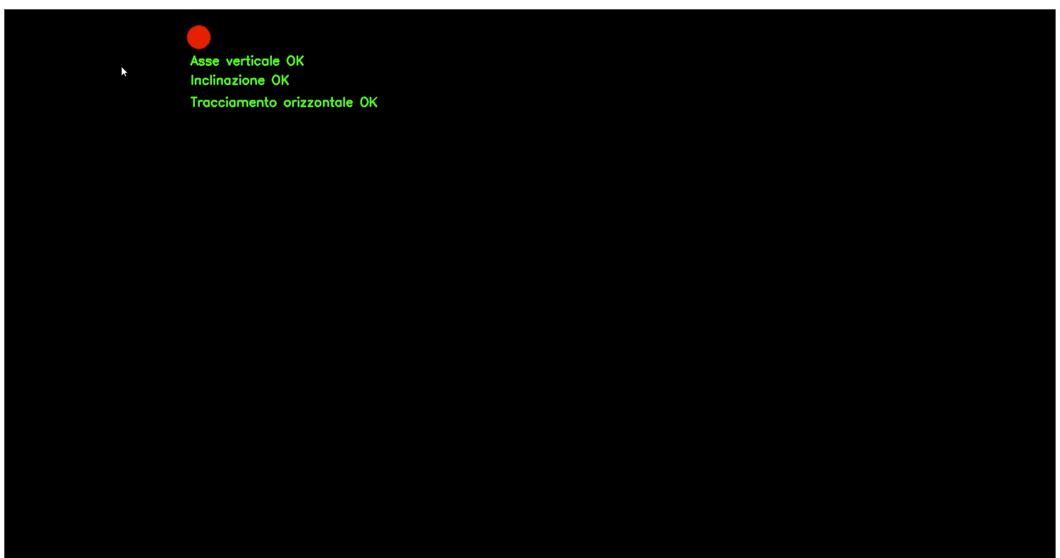
EPEC

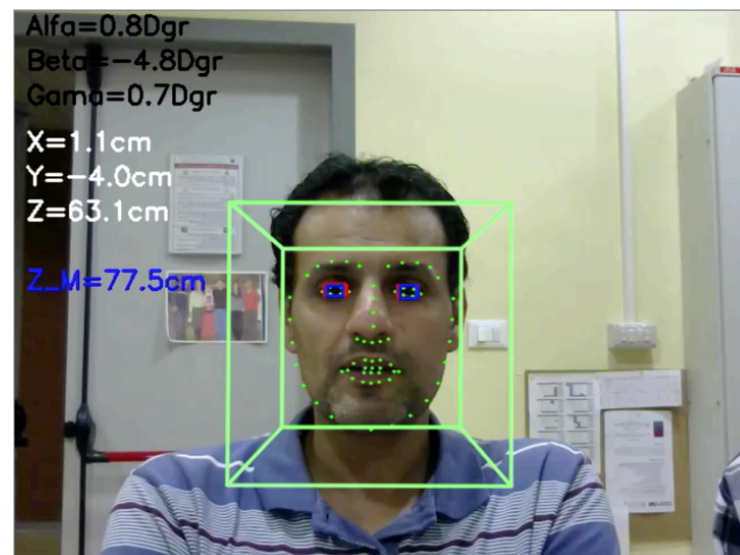


Notice that if the classifiers are noisy with a known degree of uncertainty, EPEC also supports the specification of confusion matrices associated with them, e.g.:

EEG **senses** *Engagement* **with-accuracies** $\begin{pmatrix} 0.15 & 0.85 \\ 0.99 & 0.01 \end{pmatrix}$

First Demo


Asse verticale OK
Inclinazione OK
Tracciamento orizzontale OK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Beta=−4.8Dgr
Gama=0.7Dgr
X=1.1cm
Y=−4.0cm
Z=63.1cm
Z_M=77.5cm

Explanation in EPEC

EPEC can be used to assist the therapists by providing **explanations** (e.g., for inferences and the decisions taken)

For instance, in the previous example it is possible to (automatically) provide an explanation for triggering *cutScene*:

> *"Given the belief that the child was initially fully engaged, and that s/he wasn't moving at time* 1*, his/her attention was low at time* 3 *and wasn't following the target at time* 4*, I have worked out that his/her level of engagement was 0.1 at time* 5*, which is below the threshold for triggering a cutScene action."*

Conclusions and future work

This work provides an overview of the challenges posed by the AVATEA project and how we are going to tackle them using a logic-based approach to multimodal fusion.

- Since the existing implementations of EPEC work **offline**, we are working on an **online** implementation which can receive events (from trackers and classifiers) and take decisions at **runtime**.
- Another important challenge is to “extract” domain knowledge from the experts in the field, and translate it to EPEC domains.
- Finally, translating explanations in EPEC to **natural language** would also be helpful to therapists and is planned for future work.