12th European Conference on Software Architecture

24-28 September 2018, Madrid, Spain

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Architectural challenges on the analysis of human behaviour in synthetic environments

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Introduction

- **Synthetic Environment**: generic term
  - **Virtual Environment** (aka VR)
    - Computer generated environment that a user experience
  - **Immersive Virtual Environment** (IVE)
    - It surrounds the user
    - Have many sensors modalities
    - Rich representational capability

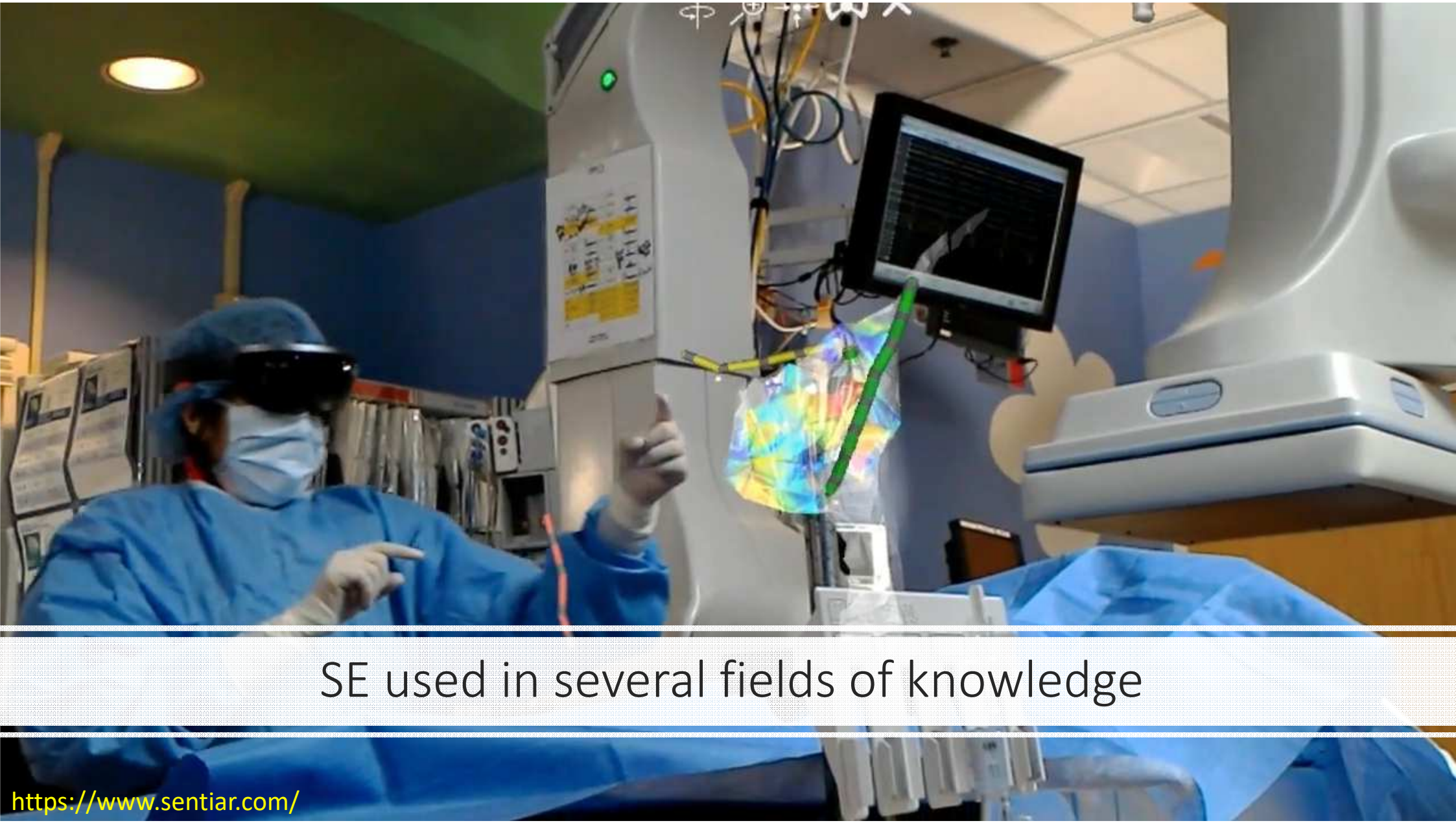
    } Causes the user feel sensations like in the real world
  - **Augmented Reality** (AR)
    - Computer assisted environment
    - User sees real world enhanced by overlying
      - Extended information
      - Computer-generated graphics
  - …

SE used in several fields of knowledge

https://www.cgsinc.com/blog/real-applications-ar-and-vr-learning

SE used in several fields of knowledge

https://www.realite-virtuelle.com/realite-virtuelle-sante#ftoc-heading-3



SE used in several fields of knowledge

https://www.sentiar.com/

Introduction

- **Presence**
  - Subjective experience of a person being in one place or environment
- **Virtual Body** (aka avatar)
  - Self-representation of the human participating in a SE

Introduction

- User interacting in a Synthetic Environment
  - Sensors attached to the system
    - Gyroscope, accelerometer…
    - Full-body motion tracking
    - Voice
    - …
  - Huge amount of data to be processed
    - Behaviours
    - Intents
    - …
    - Knowledge
- Example: Educational Data Mining (EDM)

Introduction - EDM

- Extract knowledge from VR data
- Requires:
  - Strong human interaction model defined: **behaviours**
    - Interactions possible and meaningful ← through use of sensors
  - Appropriate sensors deployed
  - Mapping from behaviours to **relevant knowledge** in the domain of the study

Introduction

- **Behaviour**
  - Any basic action a user performs in a SE
  - Counterpart of a physical action in the real world

grab
(with both hands)

walk

look at

touch
(with a hand)

speak

Introduction

- Disparity of Synthetic Environments types
- Huge number of sensors available
- Each specific domain has its own high-level concepts

- There is the need for a **framework**
  - A creation tool: VR, AR, etc.
  - A way to create human interaction models
    - integrated with previous artefacts
  - A way to define domain knowledge to be extracted from behaviours
  - A common high-level view of all previous in an integrated way

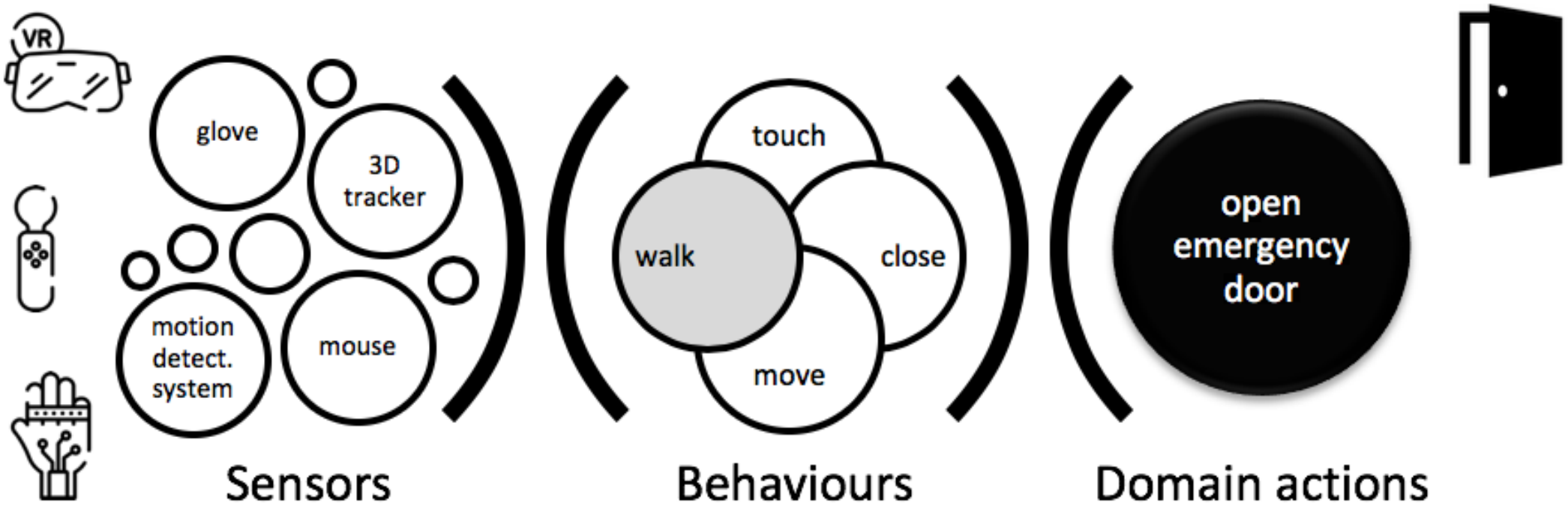
Introduction

- There are frameworks, but
  - Constrained to *in-lab* experimentation
- Lots of new VR/AR platforms are arising
  - Massive, distributed use
  - Multi-purpose: streaming video, tele-collaboration, immersive games…
- Success of those platforms → number of SE environments will grow

Introduction

- Thus:
  - SE human interaction framework → reutilization?
  - SE human interaction framework → move from in-lab to out-lab
    - New limitations: bandwidth, processing power, battery…
    - Distributed, massive use
    - Commercial use
    - Privacy?
  - Third party platform → metadata management

Human interaction models in a SE - Authoring



1. Select and configure sensors

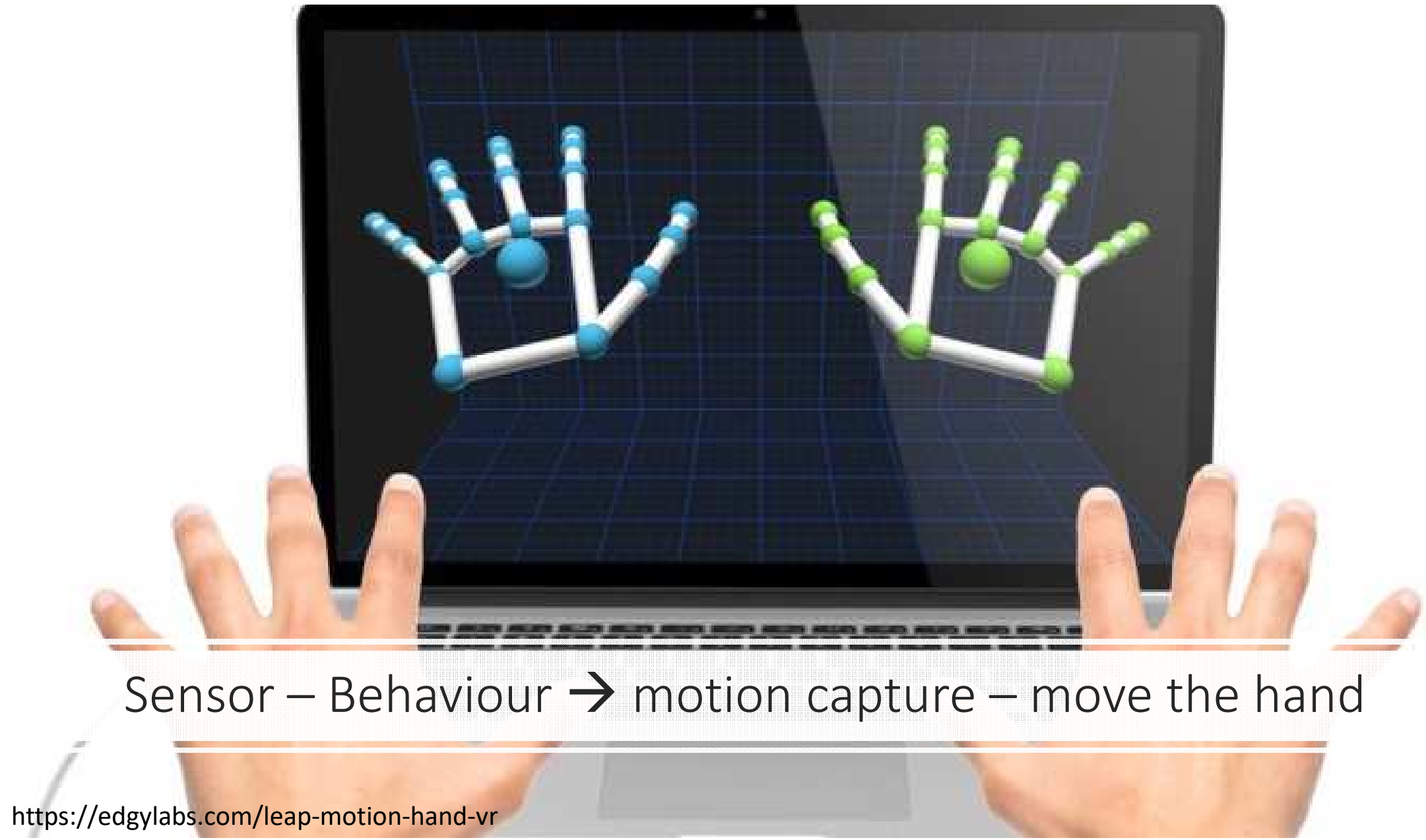
2. Map sensors data to behaviours
3. Compose to form complex ones

4. Map [complex] behaviours to high-level concepts in the domain

Human interaction models in a SE - Authoring

- **Sensor – Behaviour** mapping
  - Allow the user to use any peripheral or mechanism present in the SE
  - Perform behaviours in a **flexible** and **extensible** way

- Example: **move the hand** by…



Sensor – Behaviour → motion capture – move the hand

https://edgylabs.com/leap-motion-hand-vr

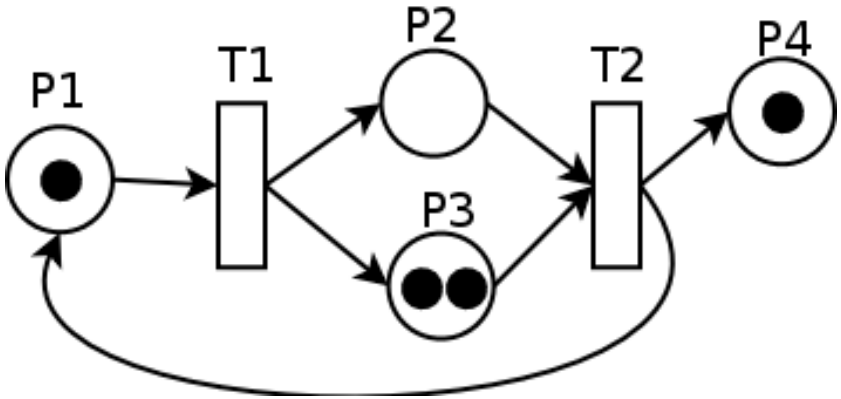
Sensor – Behaviour → 3D mouse – move the hand

https://www.3dconnexion.es/products/spacemouse/spacemouse-enterprise.html

Human interaction models in a SE - Authoring

- **Behaviour – Domain** mapping
  - Allow the author to define any kind of human interaction model
  - Combining a set of behaviours conducted by the user
    - With a specific set of constraints

- Examples:
  - SE 1: Detect fear by a combination of **head** and **gaze movements**
  - SE 2: Detect the intent of running through an emergency exit by analysing how a user **walks**, or **runs**



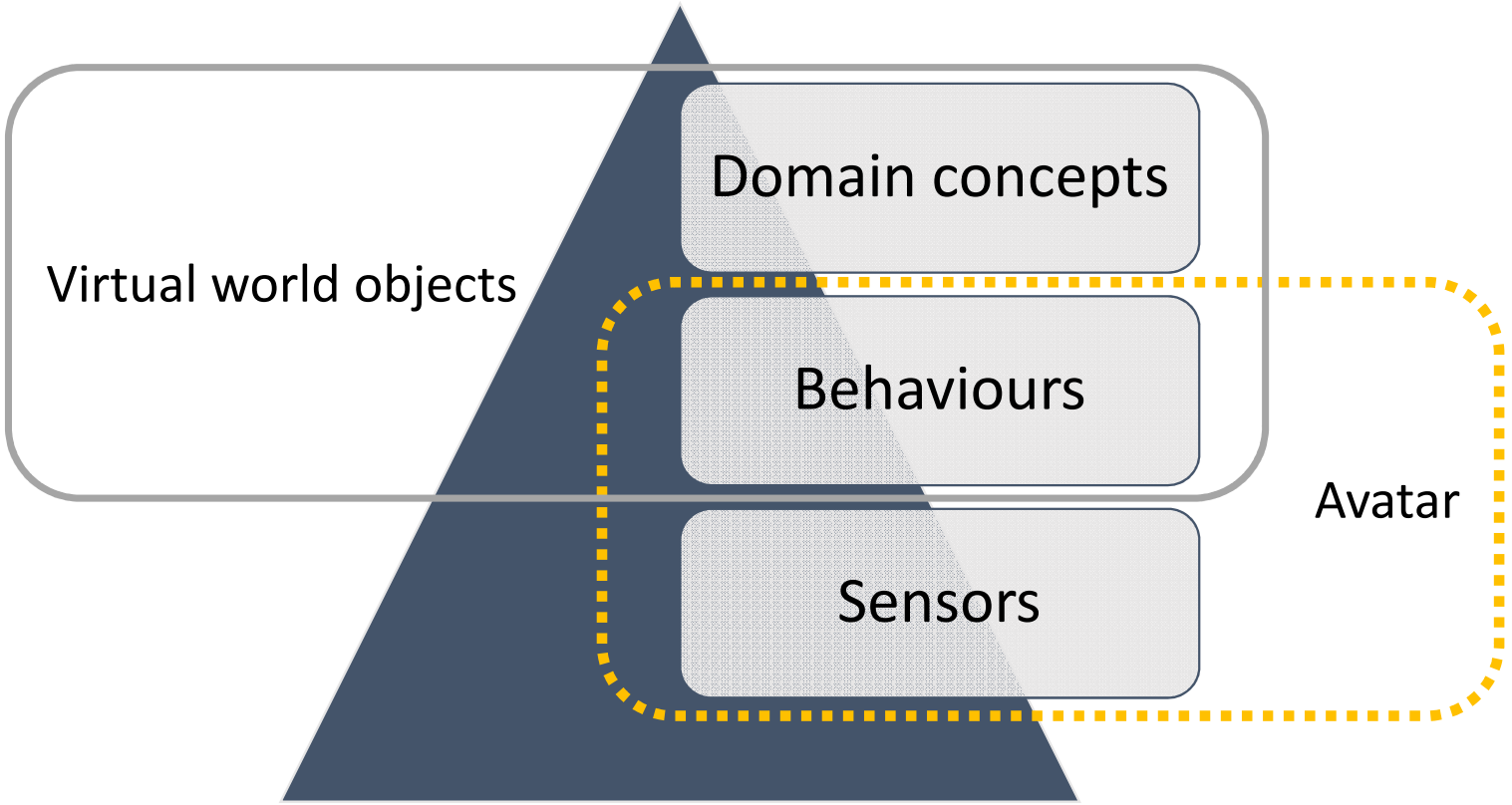
https://en.wikipedia.org/wiki/Petri_net

Human interaction models in a SE - Authoring

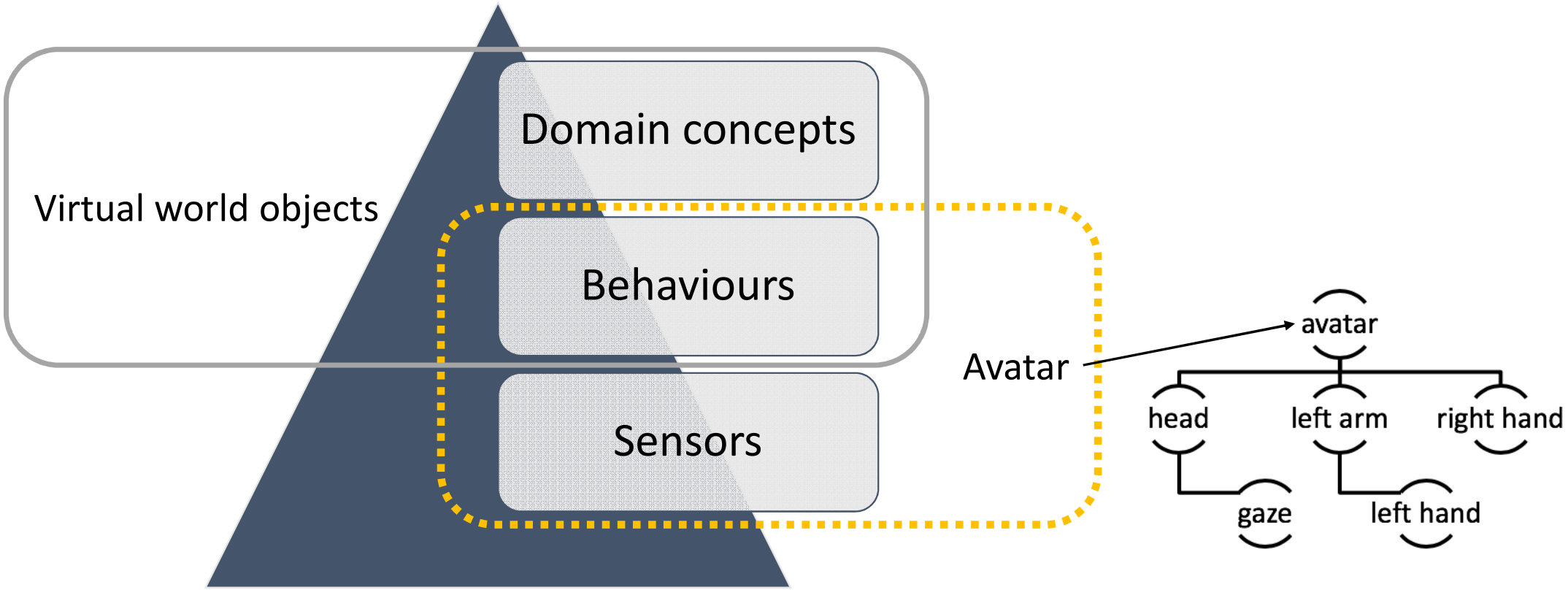
- Each domain is different
  - **Behaviour – Domain** mapping: try to maximise reuse
- Out-of-lab implementation means great variety of sensors
  - **Sensor – Behaviour** mapping: try to adapt to variety

- Both are needed for an industrialization of the authoring process

Human interaction models in a SE - concepts



Human interaction models in a SE - concepts



Issues – Data gathering and processing

- *In-lab* studies
  - High-spec hardware and sensors
  - Local area networks
  - Sensors emitting data at high rates
- *Out-of-lab*
  - Personal devices: mobile, etc.
  - Limited resources:
    - Memory
    - Processing power
    - Network connectivity
    - Battery

Issues – Data gathering and processing

- *In-lab* studies allows…
  - Power processing (CPU, RAM), even near the user
  - Transferring most sensors' raw data to a server
  - More static configuration (less changing environment)

- *Out-of-lab* constraints
  - **Lightweight** real-time processing in user's device
  - Transfer only processed data to server (i.e. summarized snapshots)
  - Configurable, changing over time…
    - User preferences (privacy) affecting transmission, processing, etc.
    - Device capabilities
    - Environment or device status changes: connectivity, etc.

Issues – Data gathering and processing

- *In-lab* sensors data:
  - High available
  - Precise, high data-rate
  - All raw data processed and stored
- *Out-lab* sensors data:
  - Missing data (due to connectivity problems, etc.)
  - Inaccurate data, noise (due to device capabilities, etc.)
  - Summarized data (due to optimizations, restrictions, etc.)

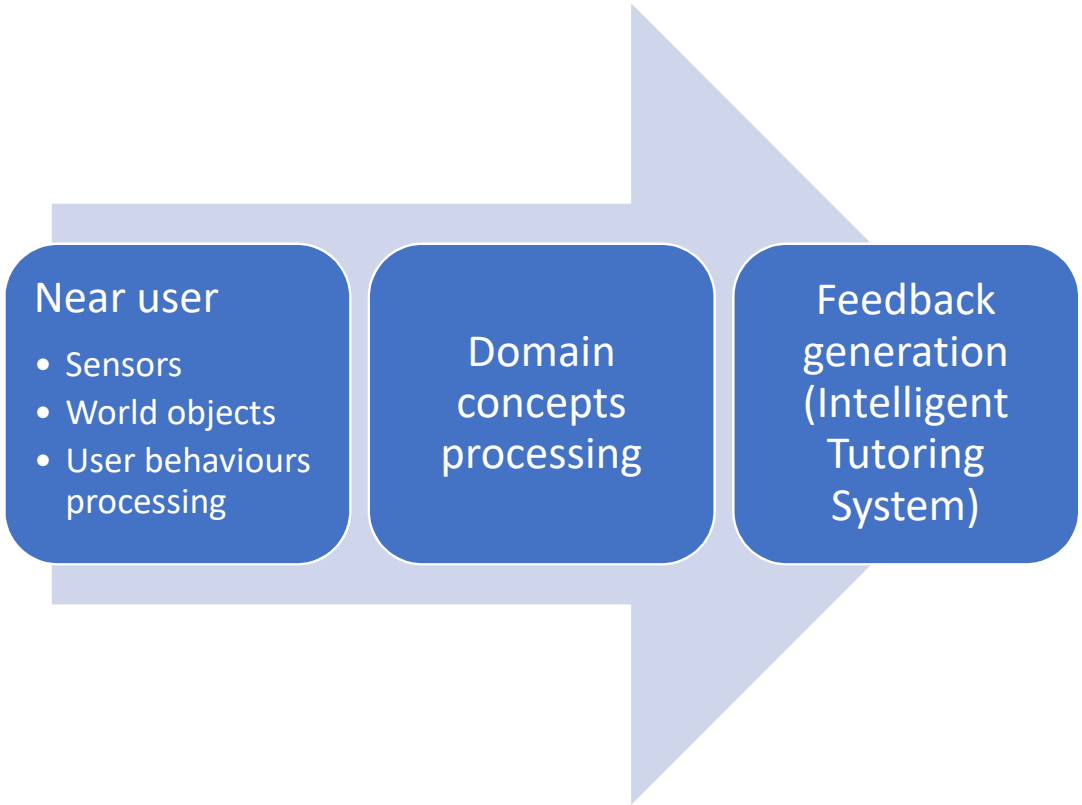
Behaviour processing

- Behaviours are conducted by the user
- We detect them by analysing sensors data
- Out-of-lab: sensors data quality is lower
  - Remember (sensors): missing data, accuracy, summarized data…

- Behaviours processing creates new data (digested from sensors)
- quality(behaviour data) **depends on** quality(sensors data)
  - Remember (sensors): missing data, accuracy, summarized data…

Data processing

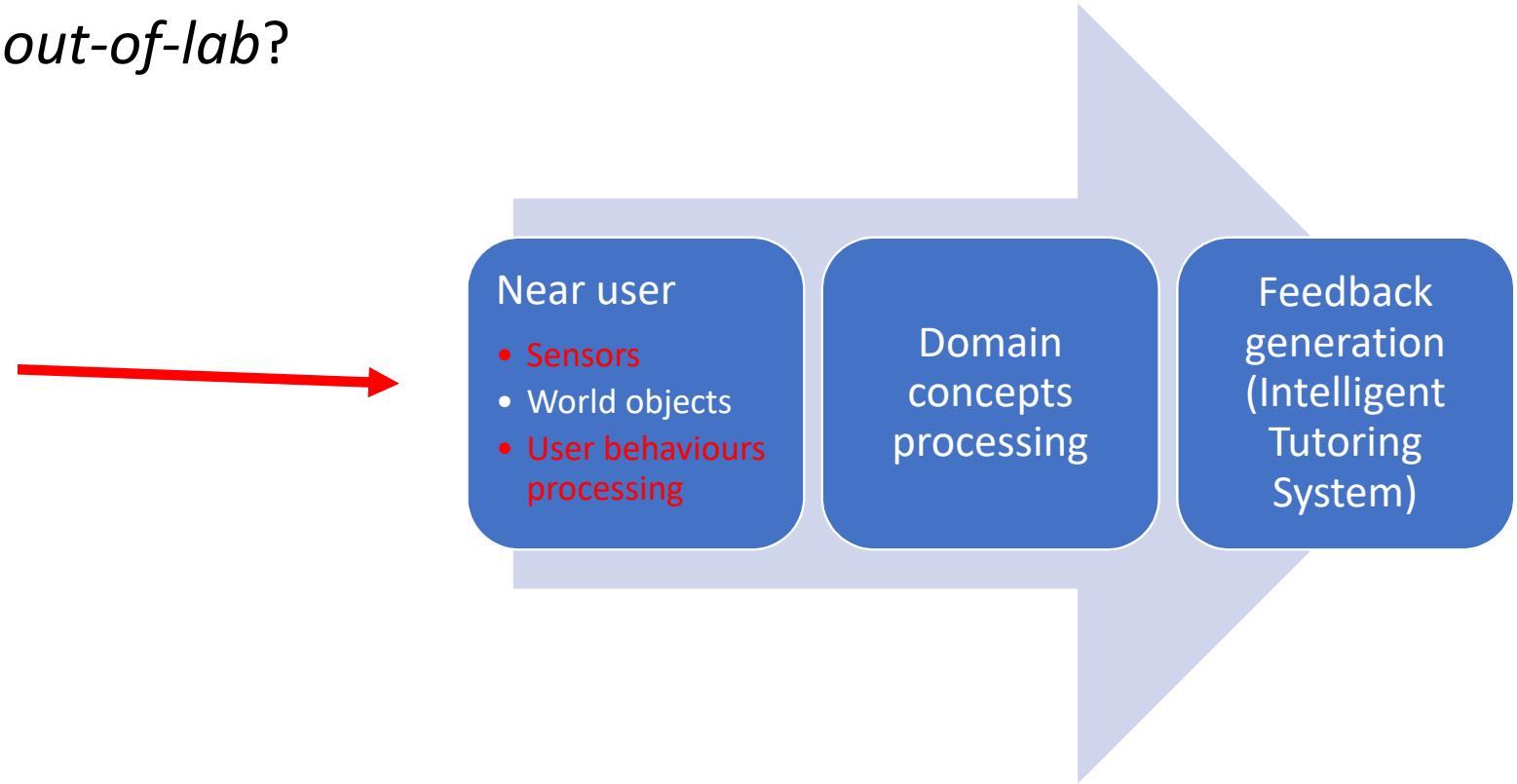
- Our previous architecture allowed only for real-time processing
  - We were *in-lab*



Data processing

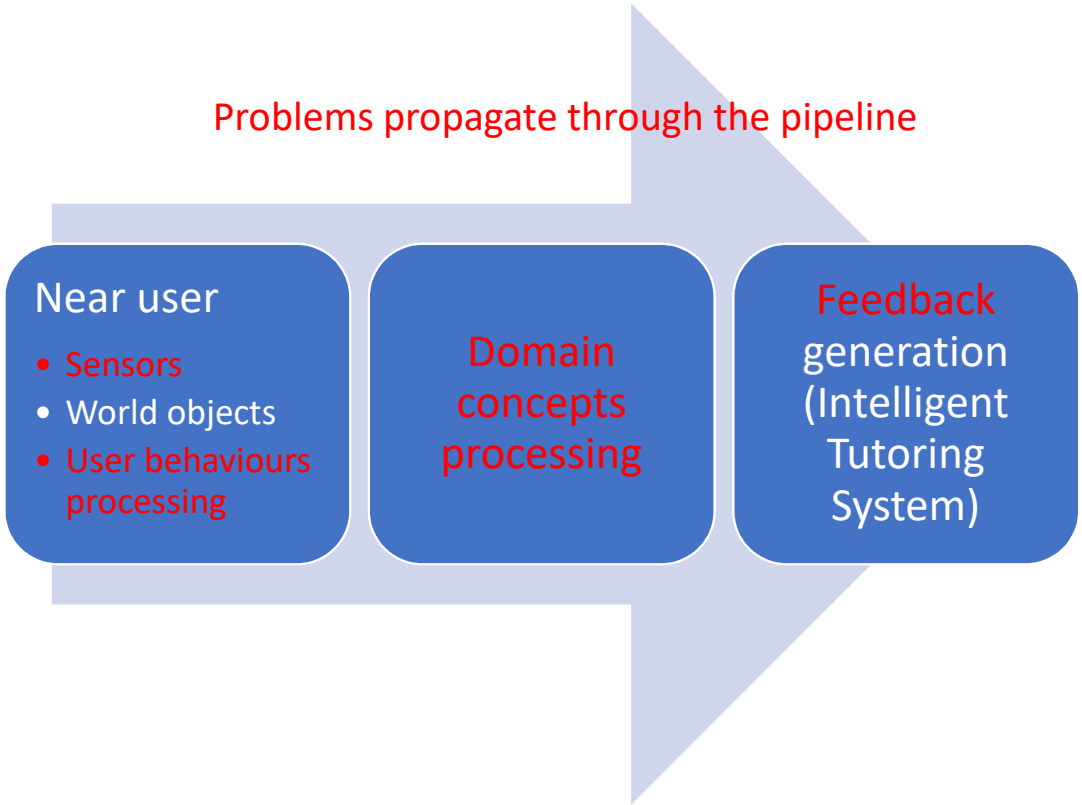
- What happens *out-of-lab*?

Lightweight processing
Missing sensors data
Insufficient accurate data



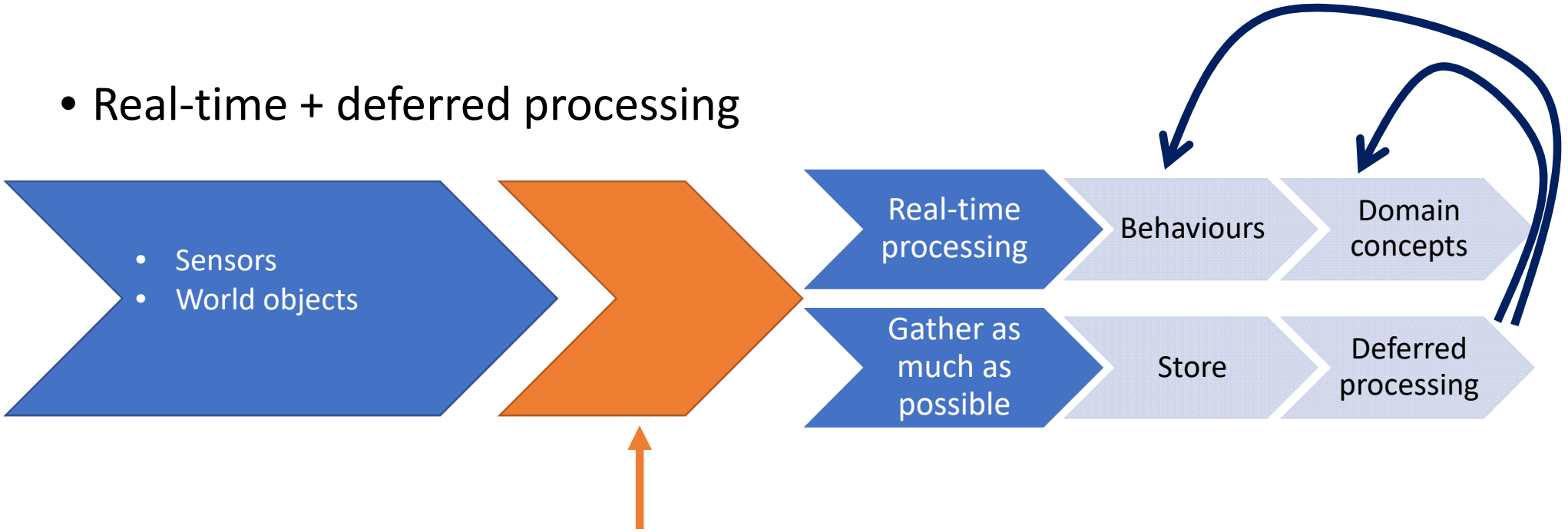
Data processing

- What happens *out-of-lab*?
  - Real-time processing may not be possible
- Solution?
- Allow for deferred processing
- Behaviours / Domain Concepts
  - Some processed real-time
  - Some inferred in a latter processing



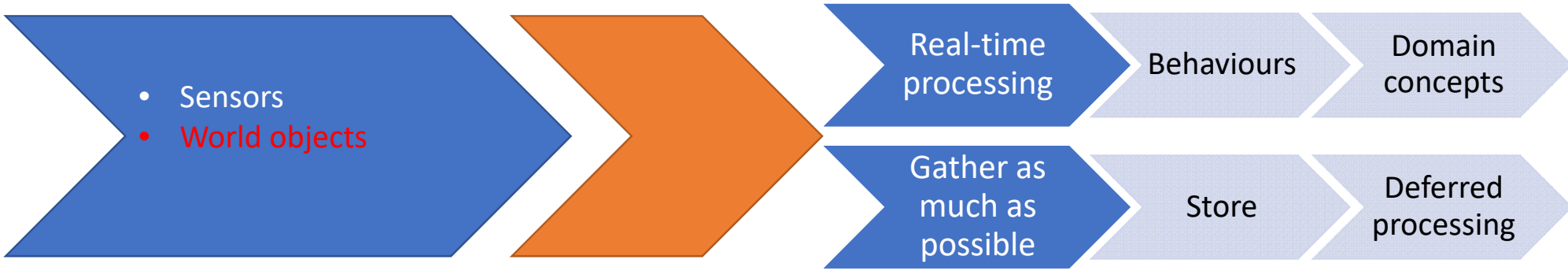
Data processing

- Real-time + deferred processing



Virtual world objects we interact with…

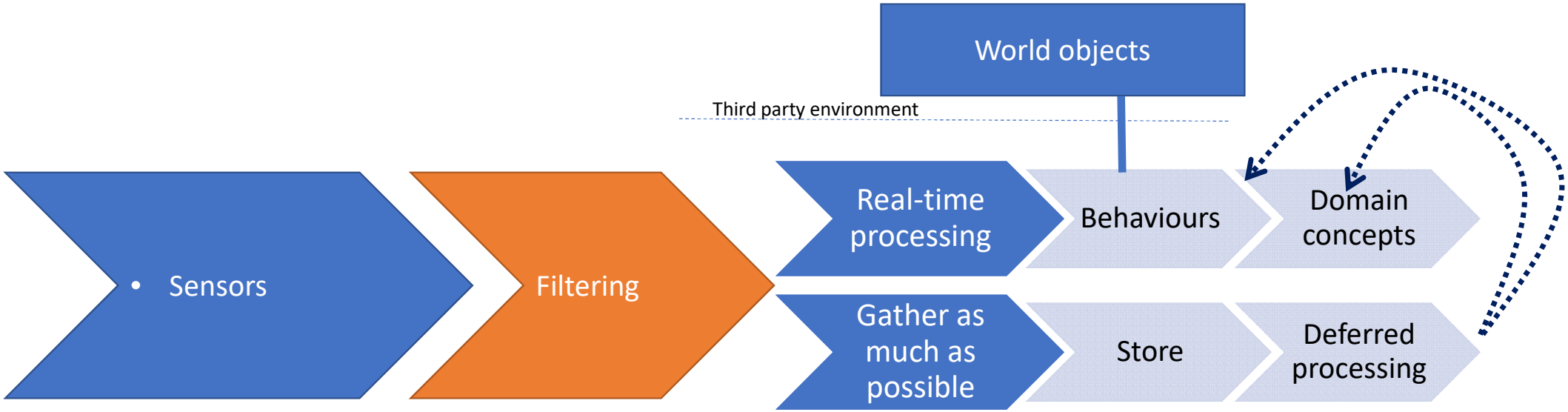
- 3D representation, objects metadata…



- *Out-of-lab* using a 3rd party platform → missing objects metadata !
  - Example: *grab* behaviour of a hand requires a reference to the **object** grabbed

Behaviours as an integration concept

- Objects metadata owned by a 3rd party
- Avatar centred design of human interactions
- Make Behaviour the integration concept in the architecture



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Thank you