

Recognition of Human Activity Based on Probabilistic Finite-State Automata



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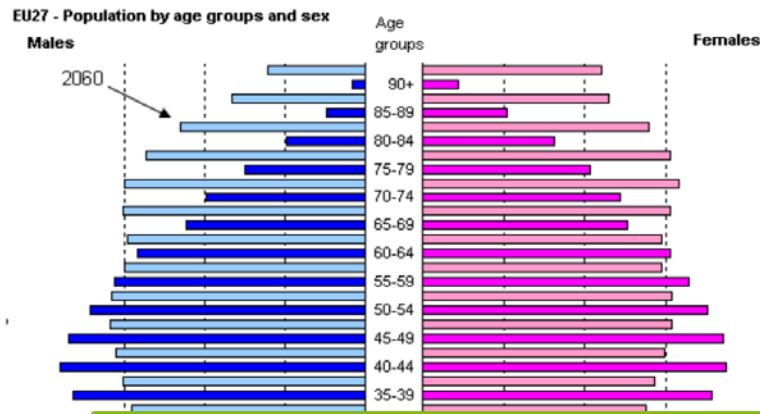
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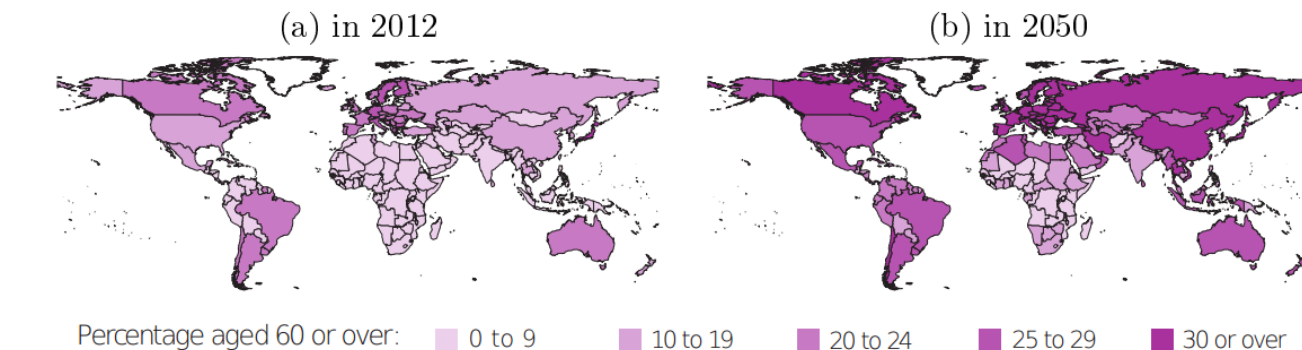
Laboratory of Control
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Societal Context



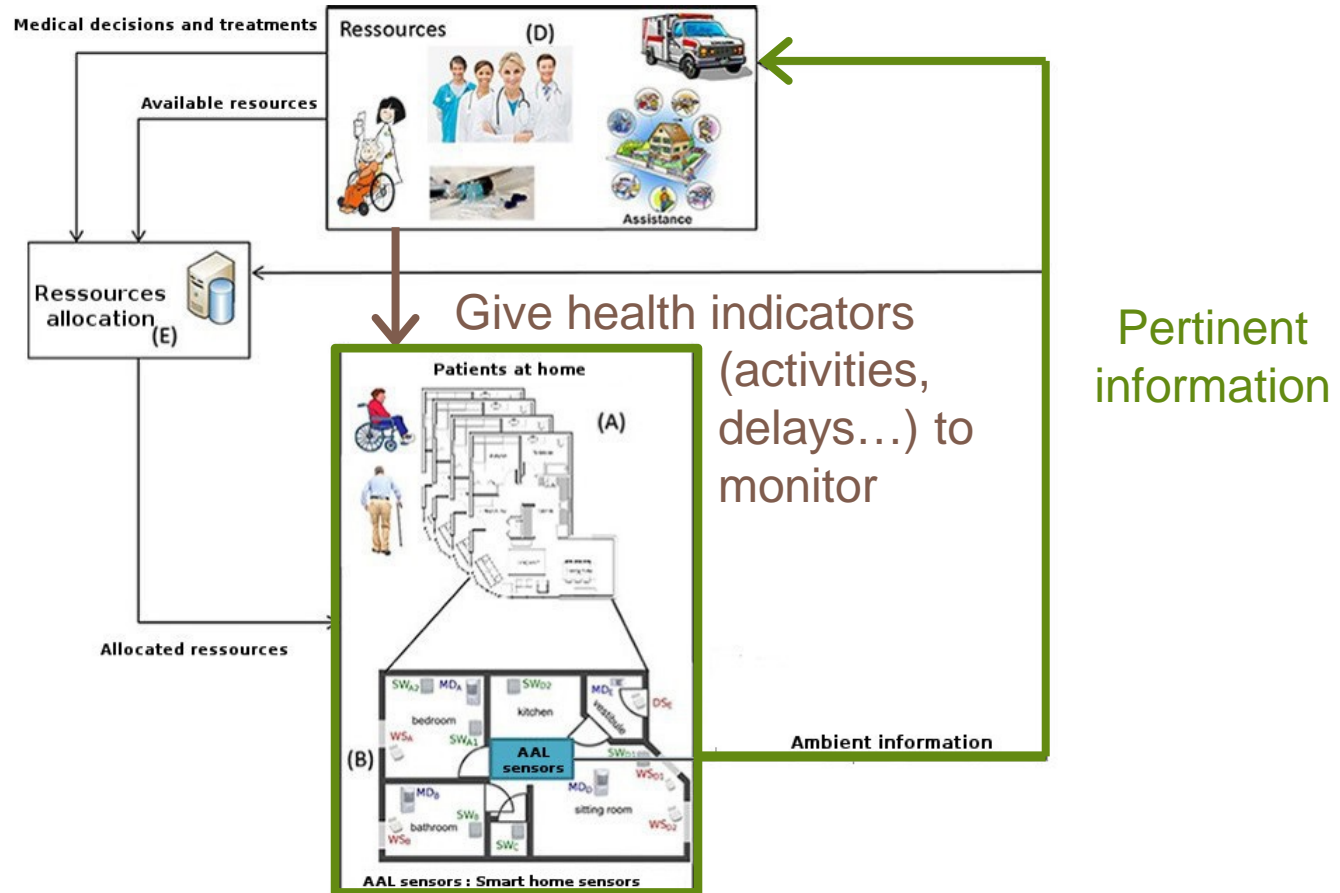
49,6% of the EU population is depending in 2011,
77,9% projected in 2060.

→ We have to find alternative ways to take care of elderly and disabled persons to assume a **continuity** between hospital and personal home



Population aged 60 and over in 2012(a) and 2050(b) [World Health Organization, 2012]

Health at Home



Fried Frailty Criteria

The presence of 3 or more of the following symptoms

1) Unintentional weight loss (4–5 kg in 1 year)

2) Self reported exhaustion

3) Weakness (grip strength < 20% in the dominant hand)

4) Slow walking speed (< 20% for time to walk 4.5 m)

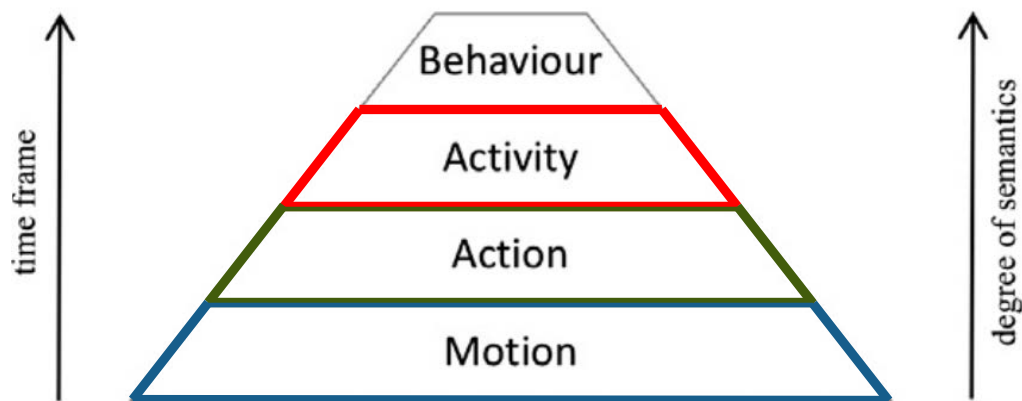
5) Low physical activity (< 20% for calorie expenditure)

Activity Daily Living monitoring

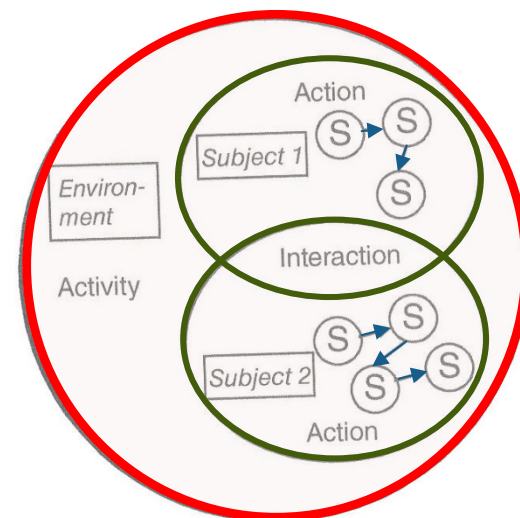


Activity of Daily Living (ADL)

[Chaaroui12]



Human behaviour analysis tasks – classification.



[Cook15]

Classification of tasks according to the degree of semantics (DoS) involved.

DoS	Time lapse	Description
Motion	frames, seconds	Movement detection, background subtraction and segmentation; gaze and head-pose estimation
Action	seconds, minutes	Establish with which objects the person is interacting. Recognise simple human primitives (sitting, standing, walking, etc.)
Activity	minutes, hours	Tasks that consist of a sequence of actions in a particular order. ADLs are recognised (e.g. cooking, taking a shower or making the bed)
Behaviour	hours, days, ...	Highly-semantic comprehension comes into play (ways of living, personal habits, routines of ADLs)

Activity of Daily Living study

[Cook15]

Discovery

Recognition

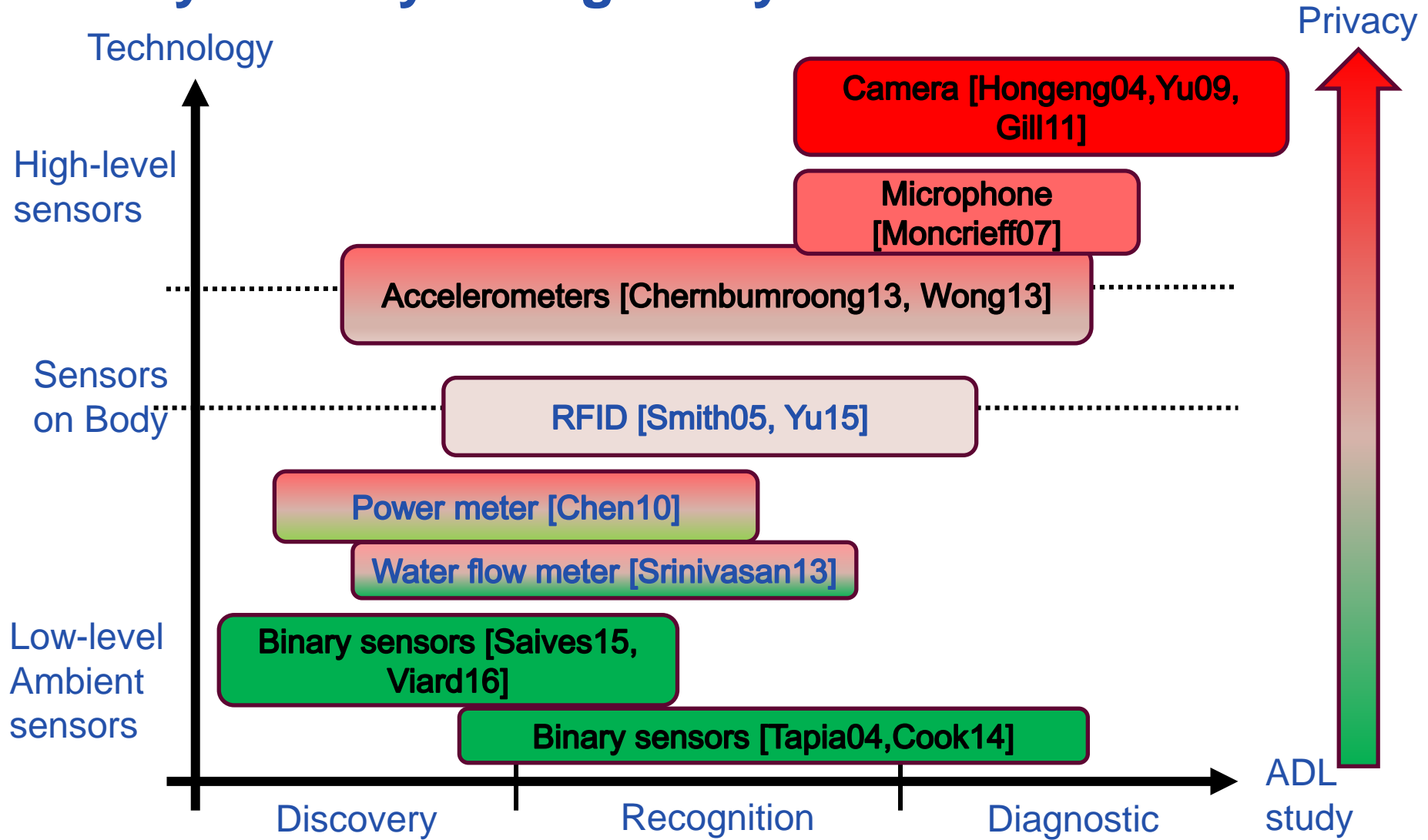
Diagnostic

Ability to know what is ADL

Ability to detect a performing ADL

Ability to evaluate deviation of behavior (between performed ADLs)

Activity of Daily Living study



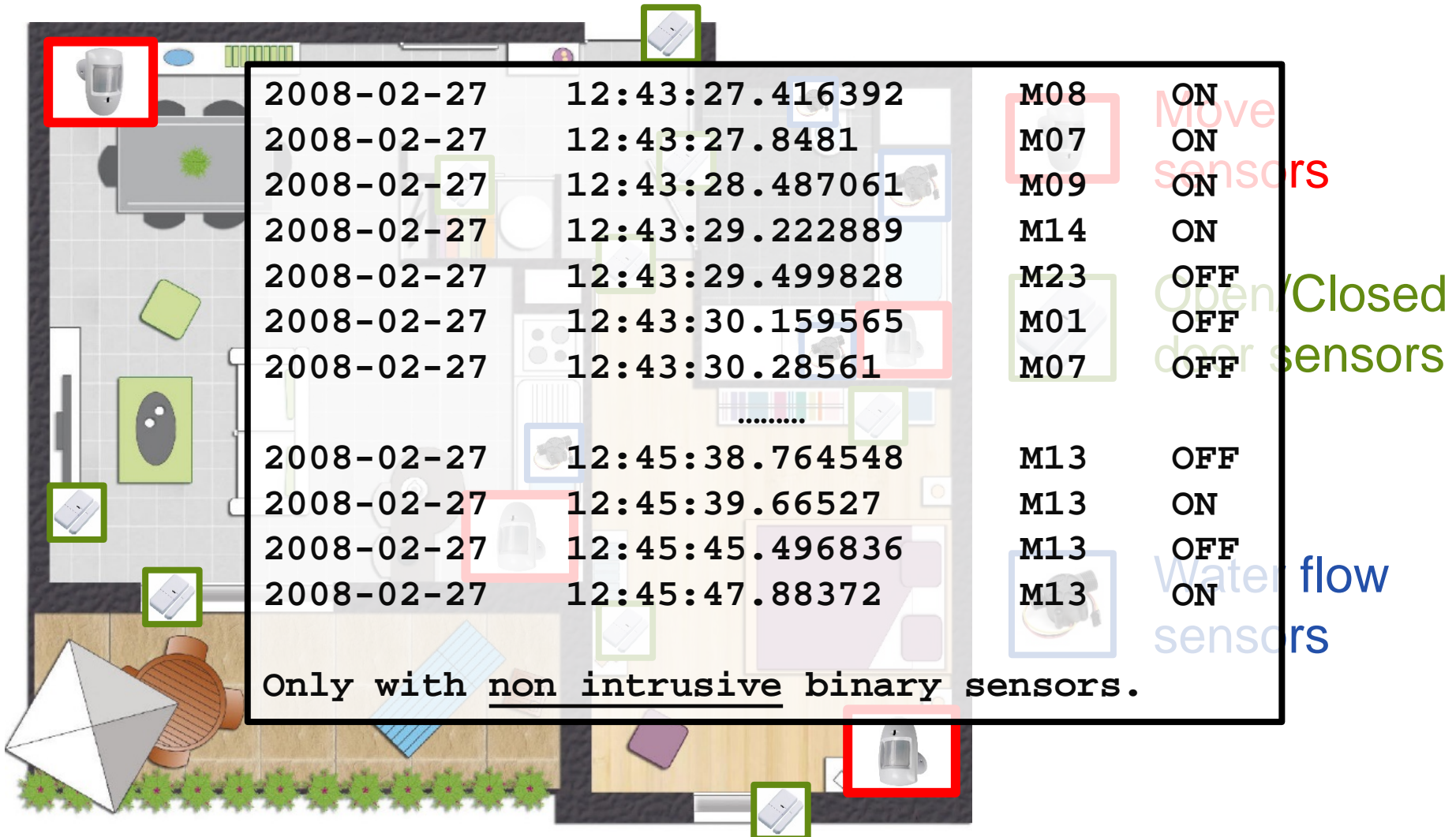
Hypothesis of the work (1)

- No intrusive sensors (cameras, ...)
- Does not depend of the person's willingness (no wearable sensors, ...)
- Only low-cost sensors

→ Use of binary sensors

→ Discrete Event Systems (DES)
Paradigms

Context of work: single-inhabitant home



Hypothesis of the work (2)

□ Human behaviour is non deterministic.

→ Activities can be modelled by probabilistic models.

→ Probabilistic Finite-State Automata (PFA)
[Vidal05],[Duong05],[VanKasteren08],[Cook15]

Activity of Daily Living study

[Cook15]

Discovery

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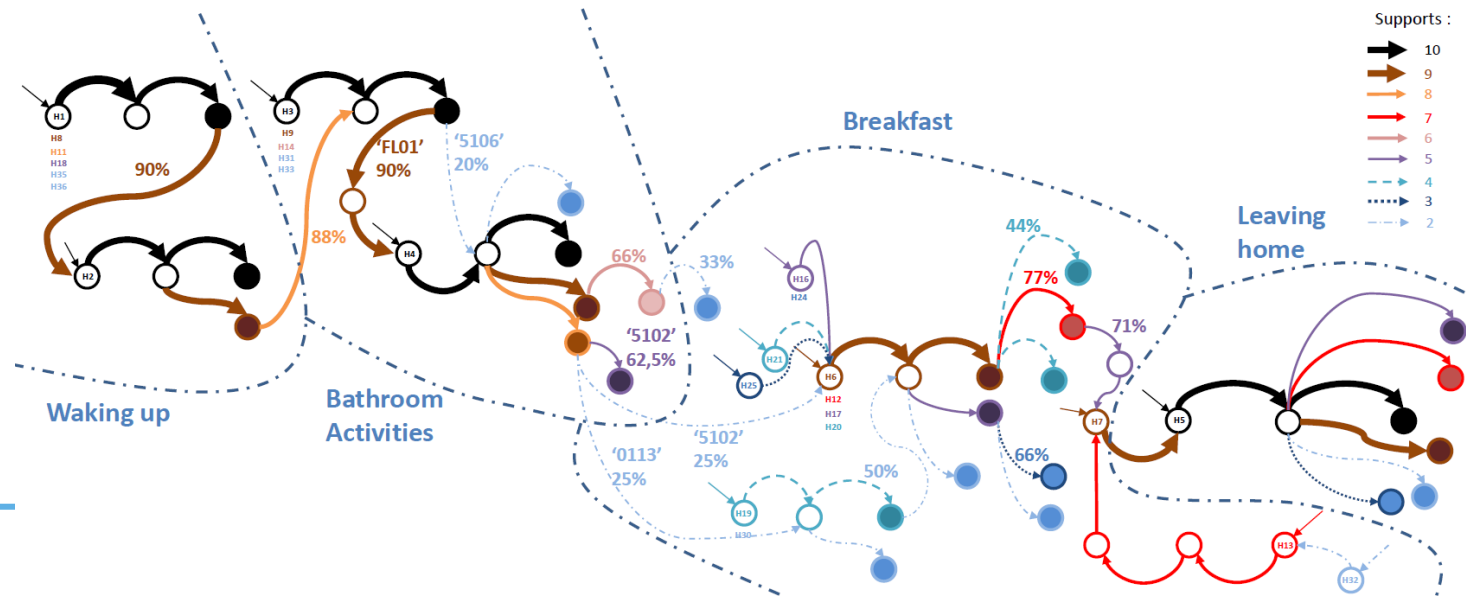
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Ability to detect, in real-time, a performing ADL

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➤ Biggest difficulty :

Labelling



Activity of Daily Living study

[Cook15]

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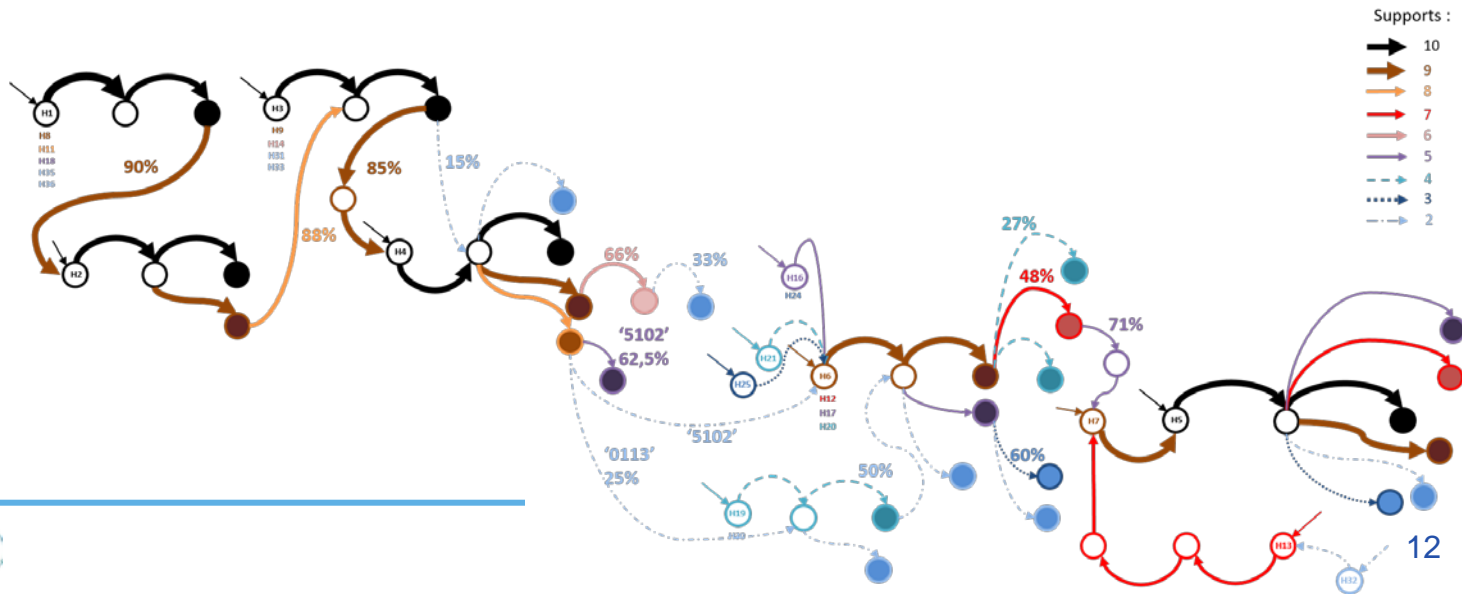
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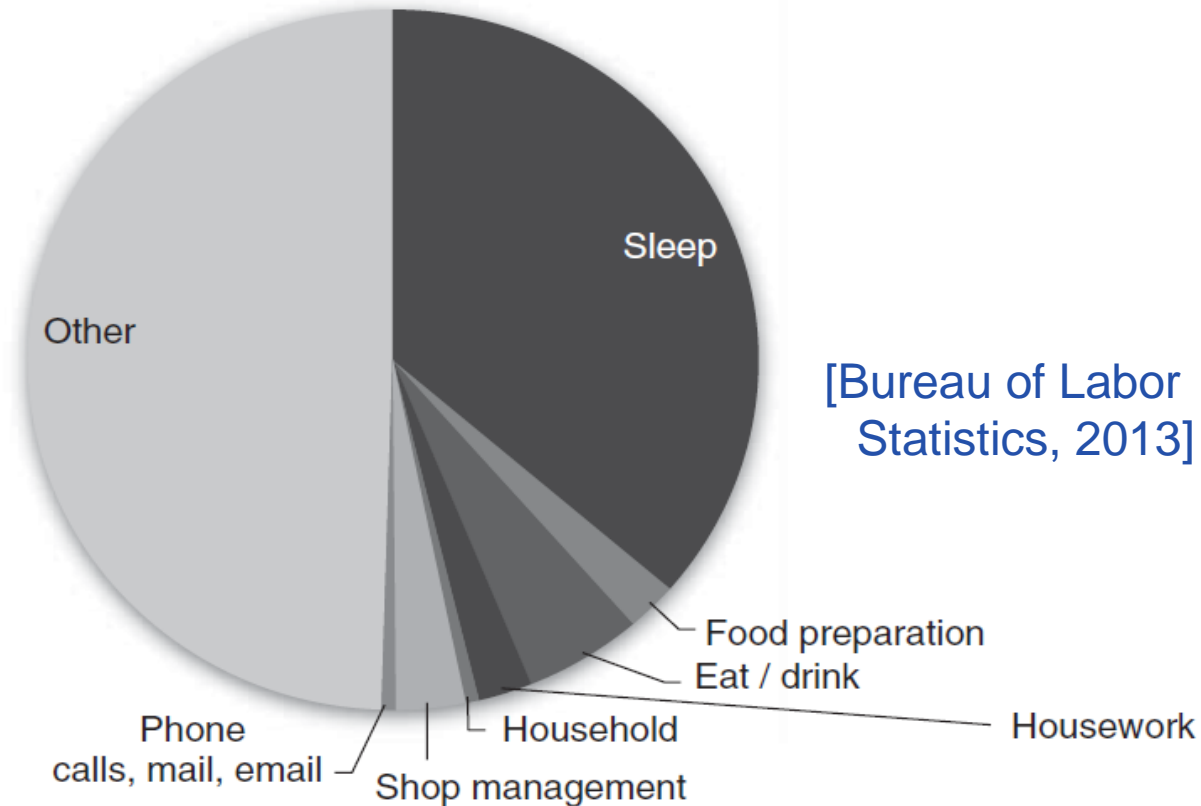
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Activity of Daily Living study

[Cook15]

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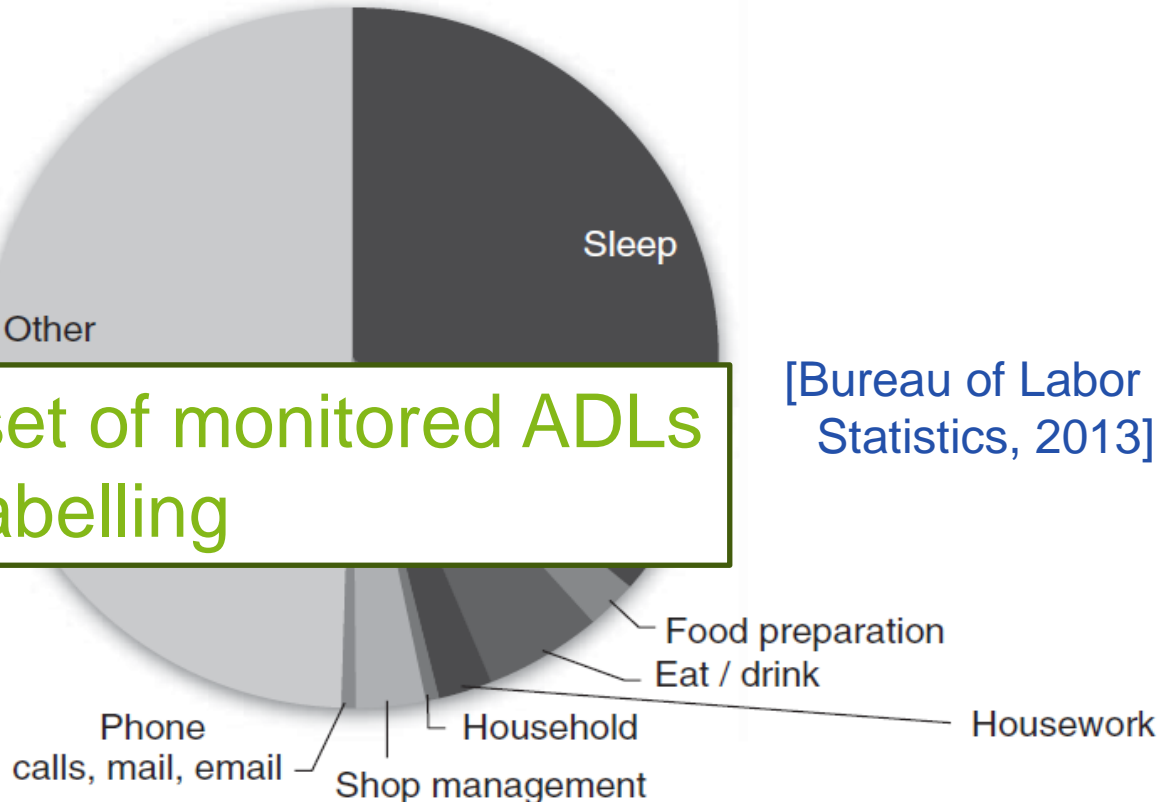
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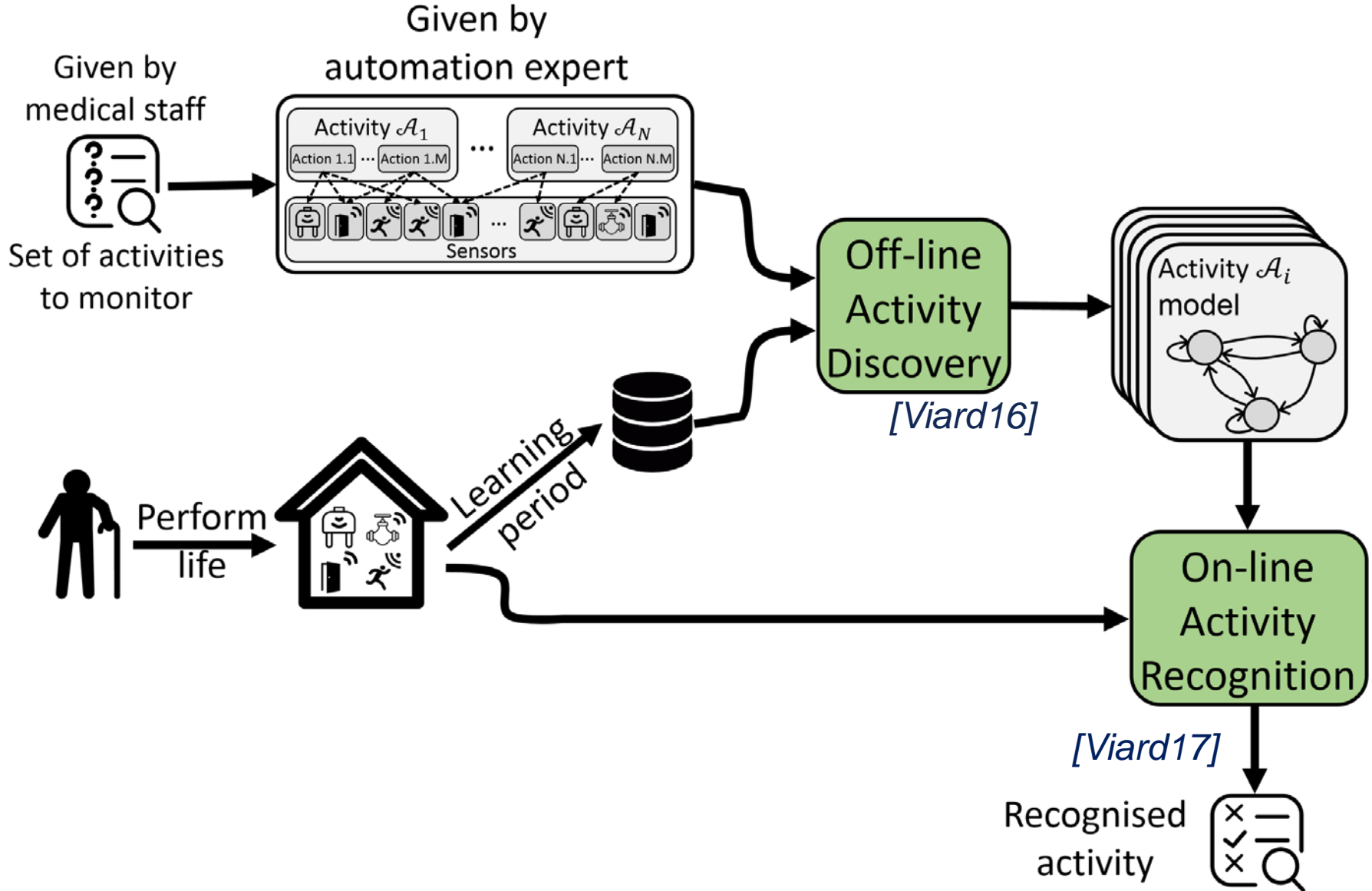
➤ Biggest difficulty :
Labelling

→ Limited set of monitored ADLs
→ *a priori* labelling

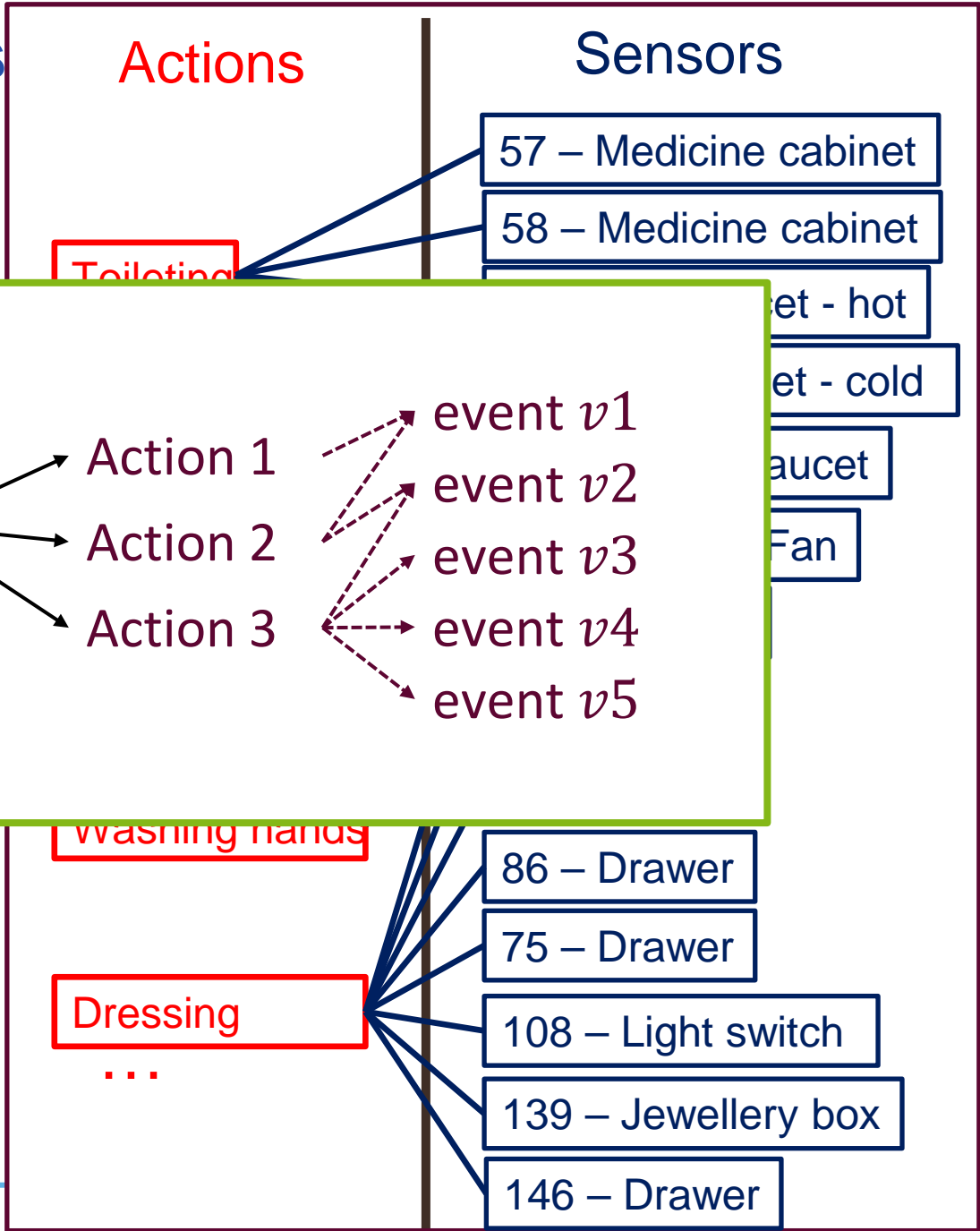
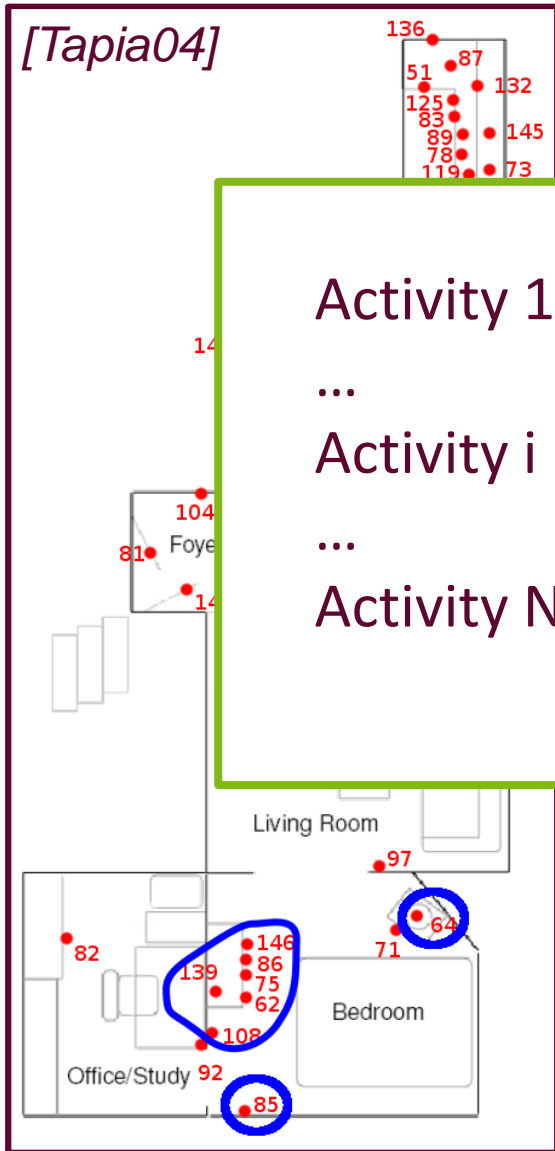
[Bureau of Labor Statistics, 2013]



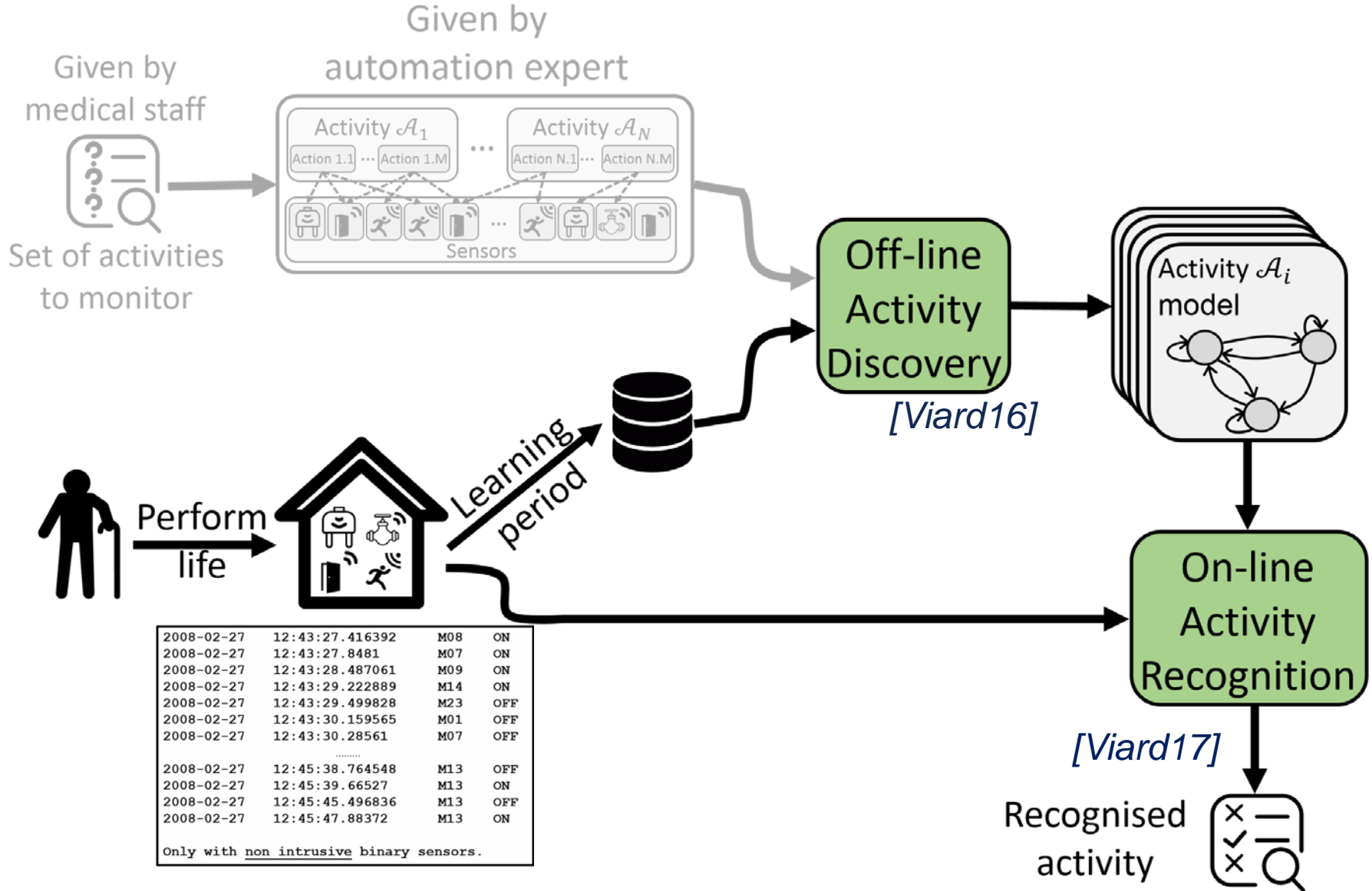
ADL Discovery and Recognition



Step 1: Association s



ADL Discovery and Recognition





Probabilistic Finite-State Automaton (PFA) definition

Given by [Vidal05]:

$\mathcal{A}_k = \langle Q_{\mathcal{A}_k}, \Sigma_{\mathcal{A}_k}, \delta_{\mathcal{A}_k}, I_{\mathcal{A}_k}, F_{\mathcal{A}_k}, P_{\mathcal{A}_k} \rangle$, where:

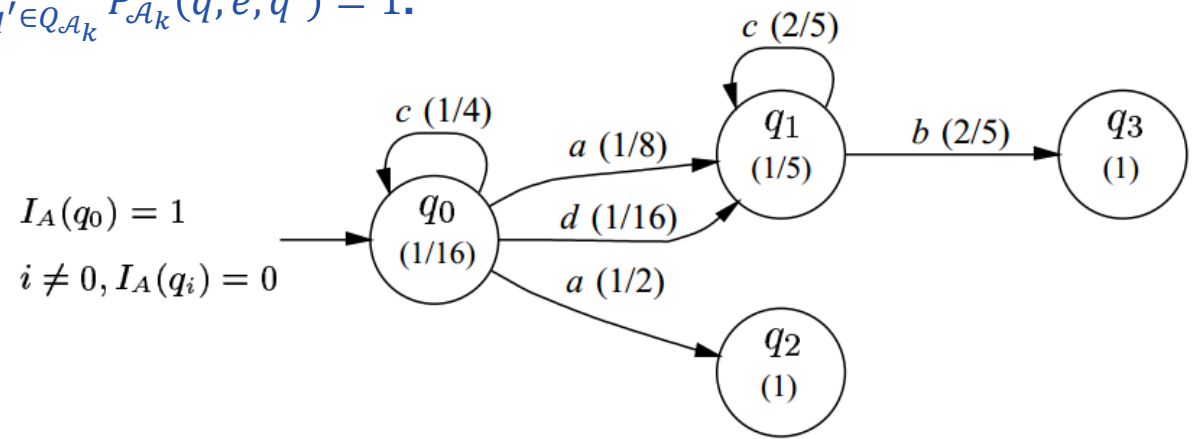
- $Q_{\mathcal{A}_k}$ is a finite non-empty set of states q ;
- $\Sigma_{\mathcal{A}_k}$ is a non-empty alphabet of events e ;
- $\delta_{\mathcal{A}_k} \subseteq Q_{\mathcal{A}_k} \times \Sigma_{\mathcal{A}_k} \times Q_{\mathcal{A}_k}$ is a set of transitions;
- $I_{\mathcal{A}_k} : Q_{\mathcal{A}_k} \rightarrow [0,1]$ (initial-state probabilities);
- $P_{\mathcal{A}_k} : \delta_{\mathcal{A}_k} \rightarrow [0,1]$ (transition probabilities);
- $F_{\mathcal{A}_k} : Q_{\mathcal{A}_k} \rightarrow [0,1]$ (final-state probabilities);

$I_{\mathcal{A}_k}, P_{\mathcal{A}_k}$ and $F_{\mathcal{A}_k}$ are functions such that:

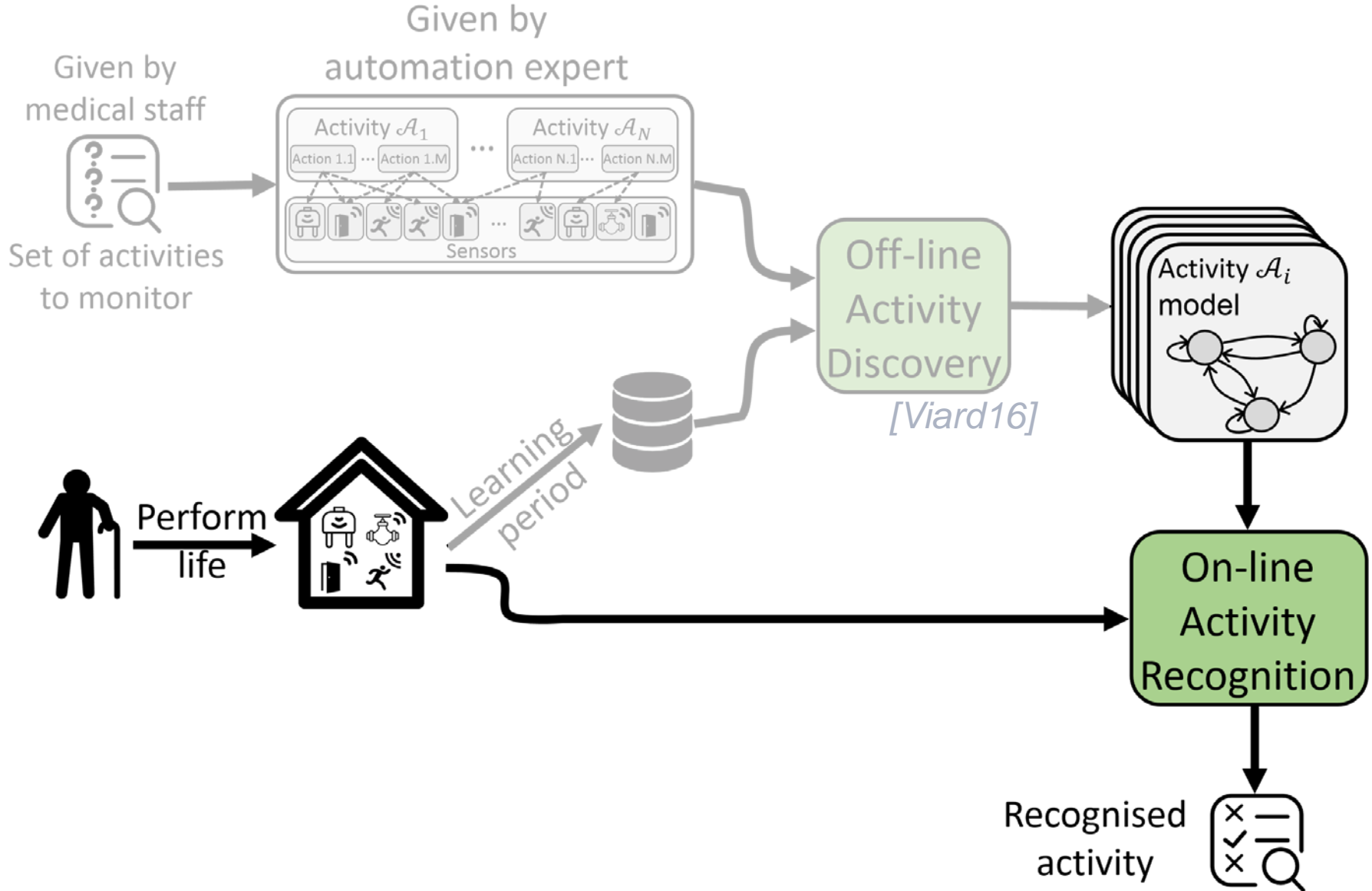
$$\sum_{q \in Q_{\mathcal{A}_k}} I_{\mathcal{A}_k}(q) = 1,$$

and

$$\forall q \in Q_{\mathcal{A}_k}, F_{\mathcal{A}_k}(q) + \sum_{e \in \Sigma_{\mathcal{A}_k}, q' \in Q_{\mathcal{A}_k}} P_{\mathcal{A}_k}(q, e, q') = 1.$$

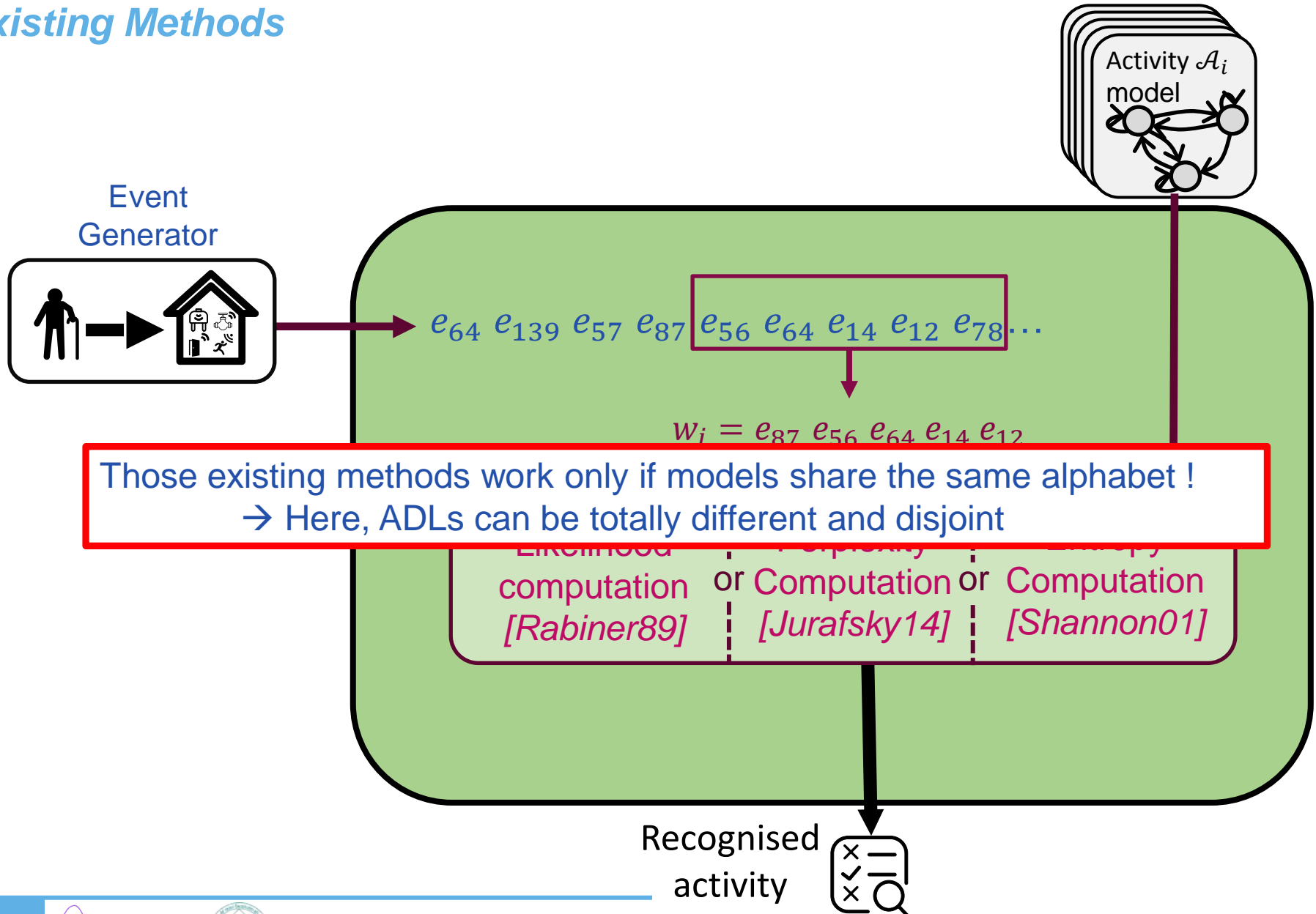


ADL Discovery and Recognition



Activity Recognition

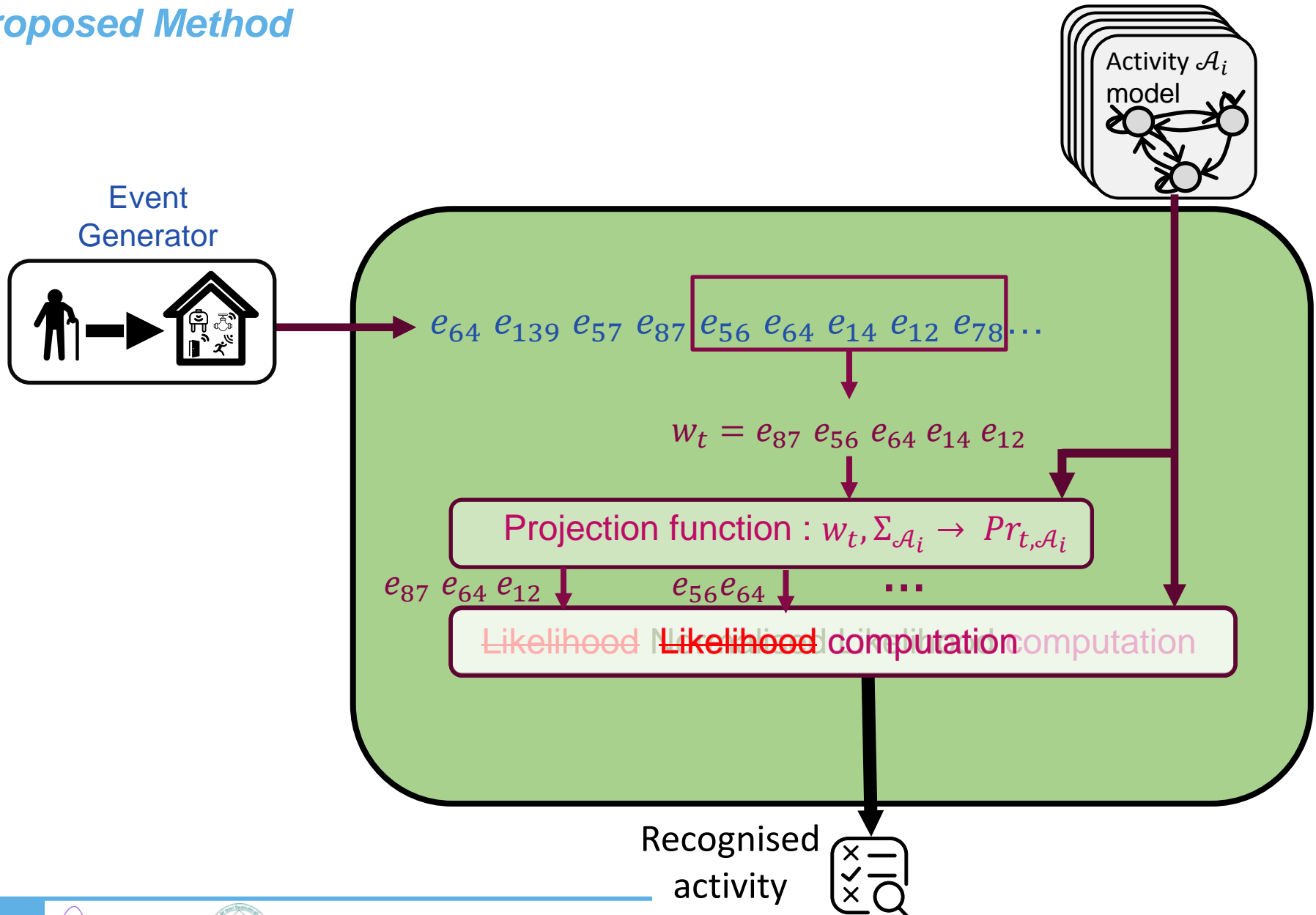
Existing Methods



Those existing methods work only if models share the same alphabet !
→ Here, ADLs can be totally different and disjoint

Activity Recognition

Proposed Method



Likelihood and Normalised Likelihood

Likelihood [Vidal05]

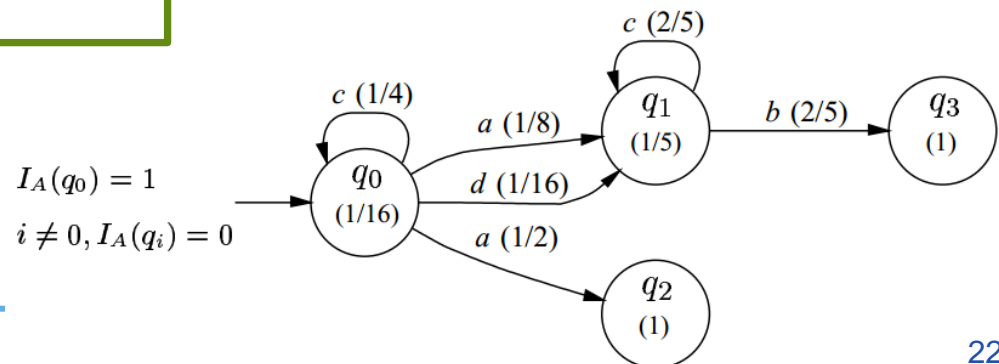
Let $\Theta_{\mathcal{A}_k}(w)$ be the set of paths for w in \mathcal{A}_k , the probability of generating w with \mathcal{A}_k , also called *likelihood* of w considering \mathcal{A}_k , is:

$$P_{\mathcal{A}_k}(w) = \sum_{\theta \in \Theta_{\mathcal{A}_k}(w)} P_{\mathcal{A}_k}(\theta)$$

Normalised Likelihood

Let us consider the PFA \mathcal{A}_k , the sequence $w \in \Sigma_{\mathcal{A}_k}^*$ composed with event included in the PFA alphabet $\Sigma_{\mathcal{A}_k}$ and each possible sequence $v \in \Sigma_{\mathcal{A}_k}^{|w|}$ having the same length than w and using only the alphabet $\Sigma_{\mathcal{A}_k}$ events. We define the *normalized likelihood* of sequence w in \mathcal{A}_k , as follows

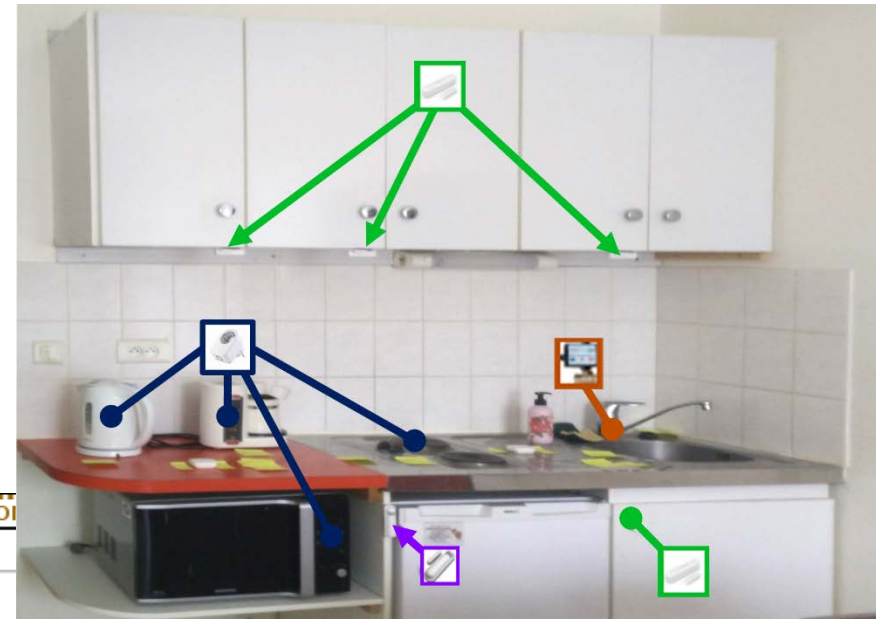
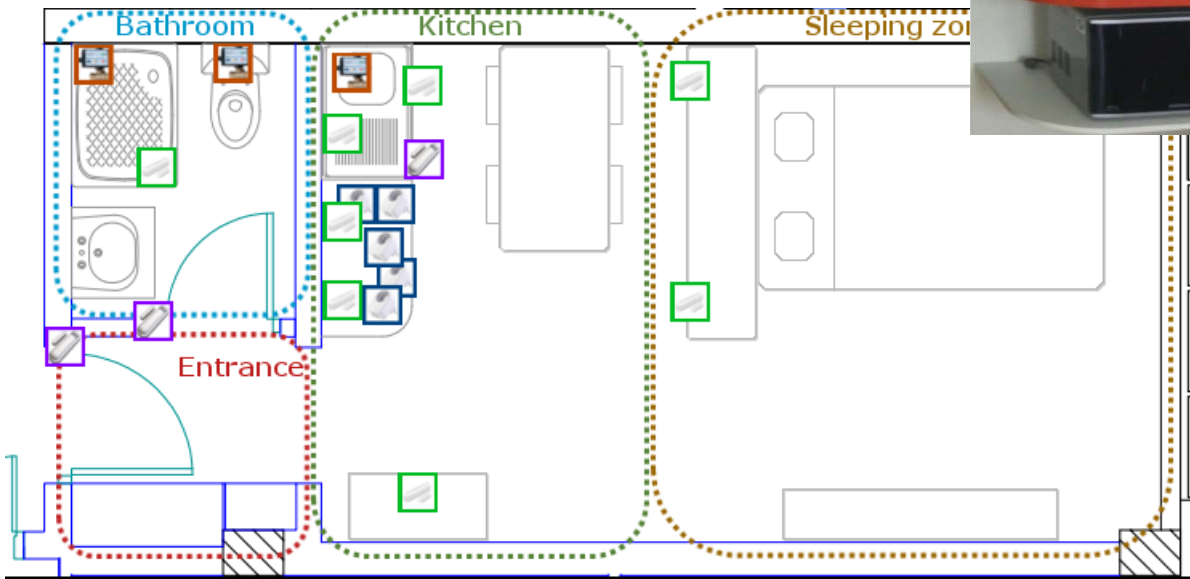
$$\|P_{\mathcal{A}_k}(w)\| = \frac{P_{\mathcal{A}_k}(w)}{\max_{v \in \Sigma_{\mathcal{A}_k}^{|w|}} [P_{\mathcal{A}_k}(v)]} ; 0 \leq \|P_{\mathcal{A}_k}(w)\| \leq 1$$



Application case

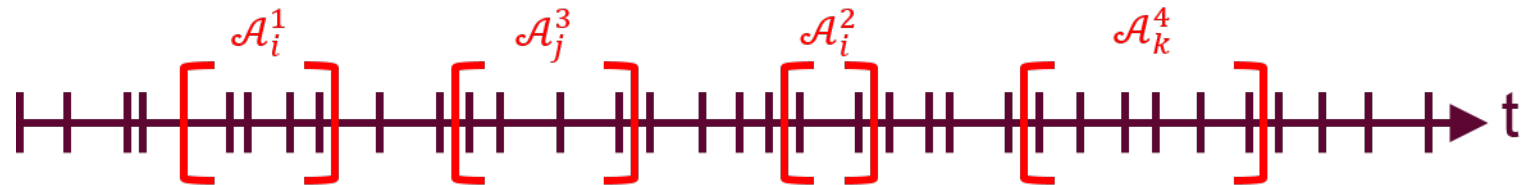
Monitored activities:

- Take care of Personal Hygiene
- Cooking
- Prepare Hot Beverage

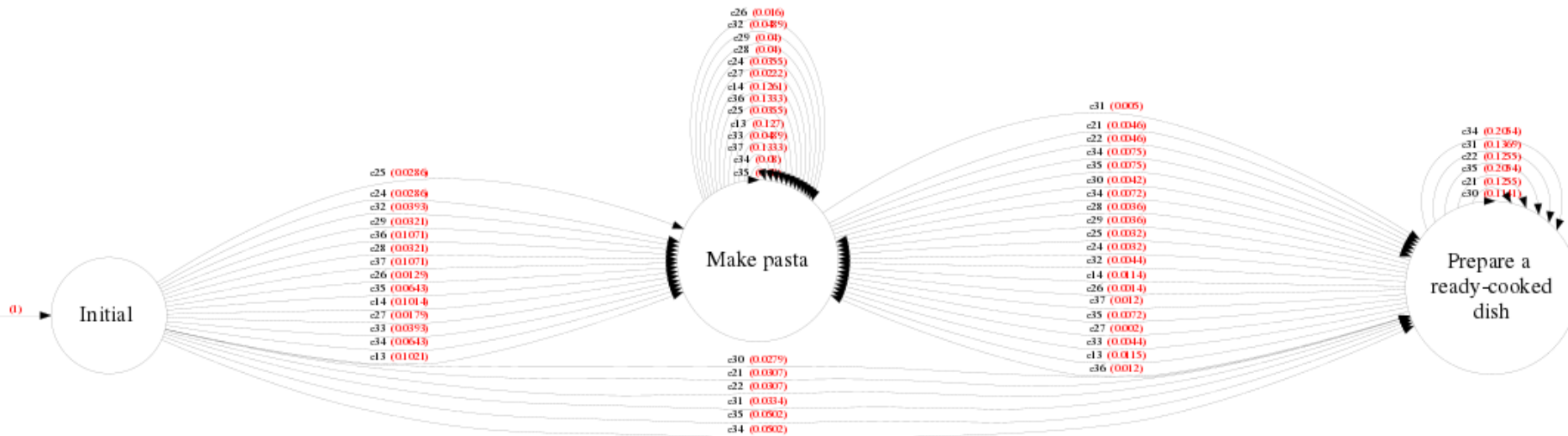


 Door Sensor Motion Detector  Door Sensor  Water Flow Sensor  Smart Outlet

Application and validation procedure

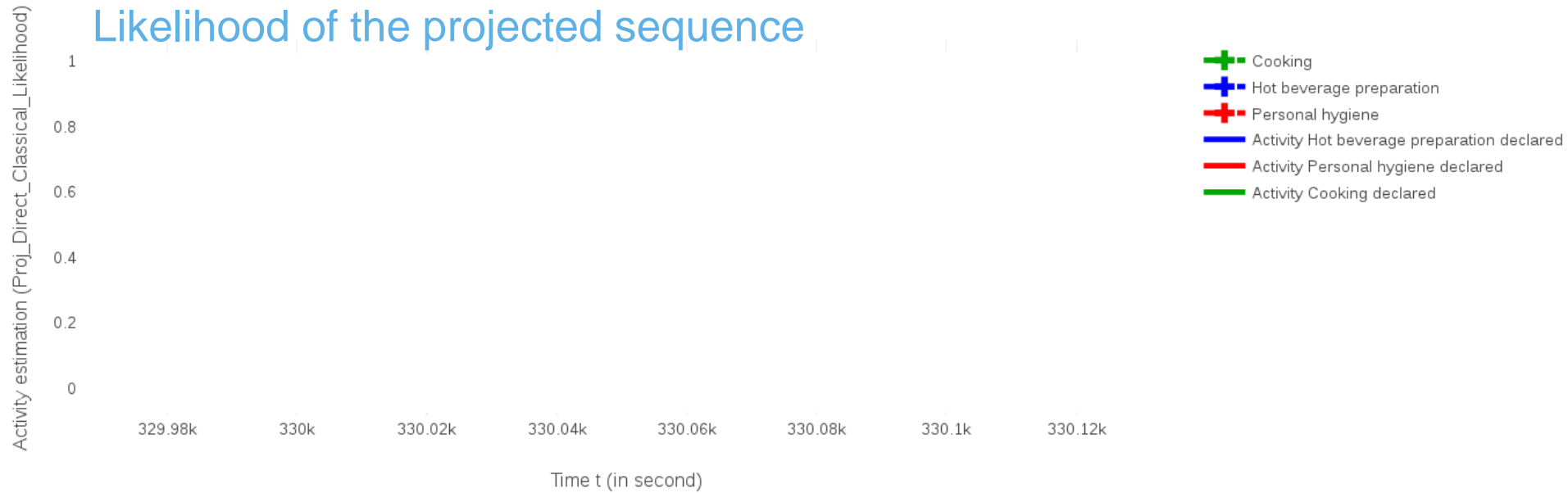


A_i^n : n^{th} realisation of the activity A_i

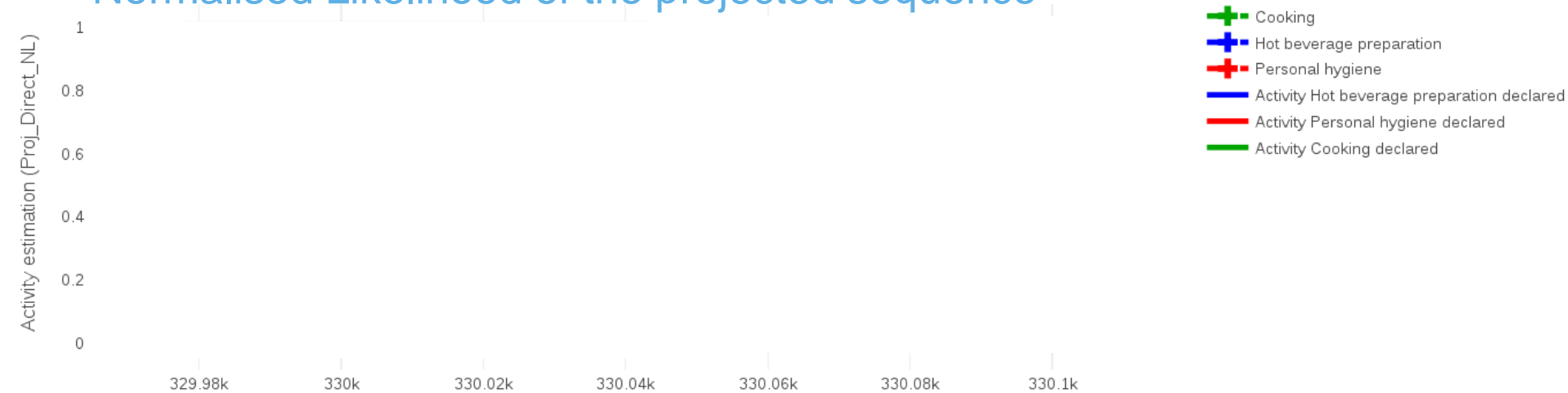


Results and validation

Likelihood of the projected sequence



Normalised Likelihood of the projected sequence



Conclusion and future works

Conclusion

The presented framework is adapted to model and recognize activities. The activity discovery is based on ***a priori labelling*** and **PFA models**, the activity recognition is based on ***a sequence projection*** and the ***normalised likelihood***.

Future works

Extend the computation of the distance

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