Discovering process models of activities of daily living from sensors

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BP Meet IOT 2017, Barcelona, Spain, Sept. 10 – 15

Outline

Introduction about AAL and Activities of Daily Living

Case Study

Methodology
- pre-processing
- process discovery
- daily behavior model
- macro activity models

Conclusion and future work

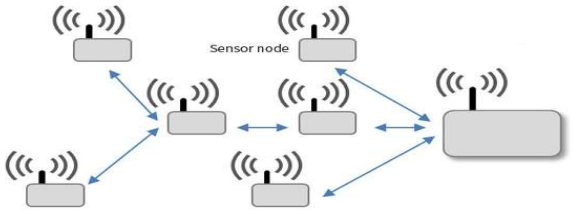
Introduction

Scenario: ambient assisted living (AAL)
ICT-based solutions improving the quality of life

Smart Enviroments: sensors and actuators
huge amount of data can be collected
from electronic devices

Introduction

Sensors generate a huge amount of data

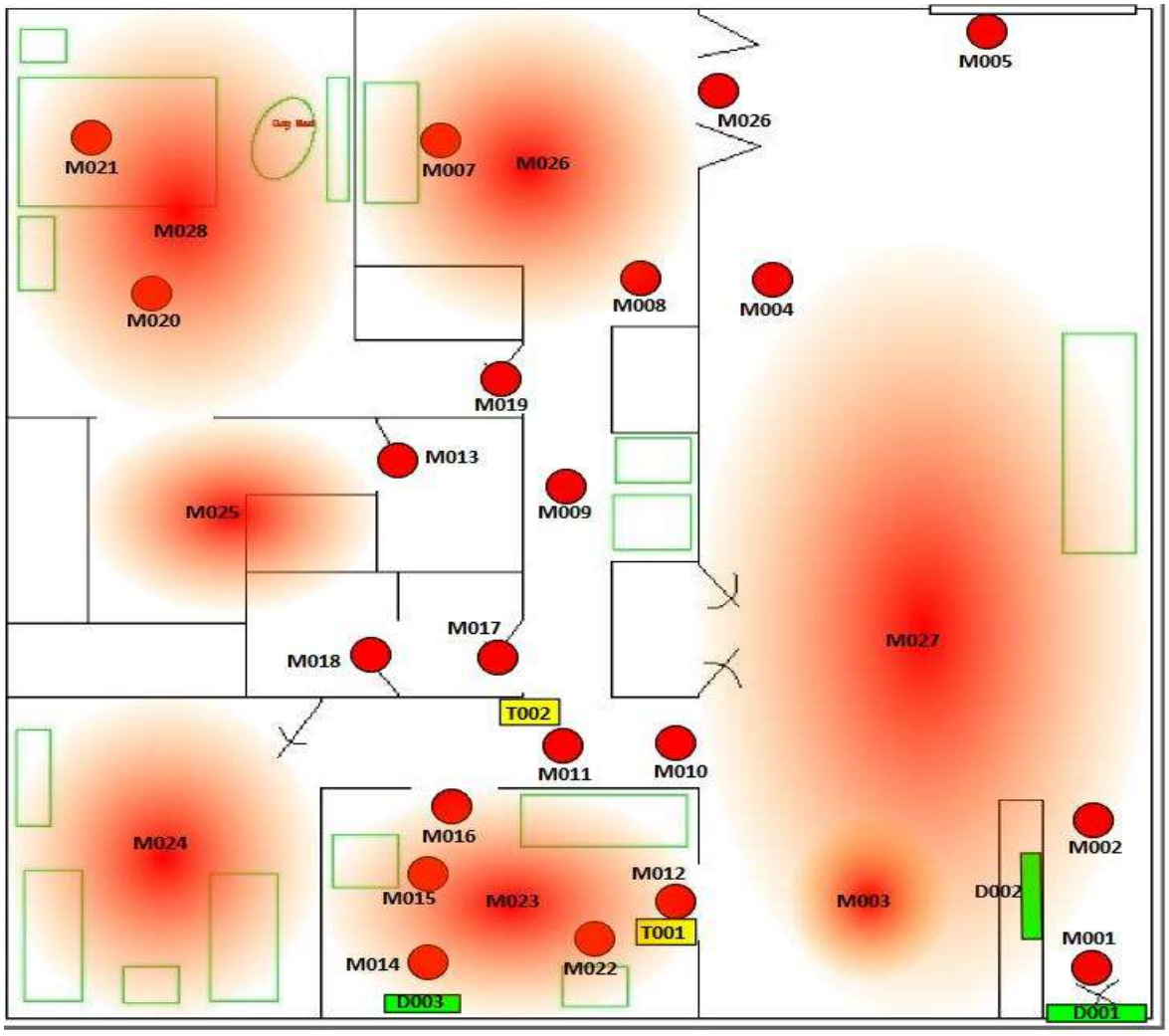


Collecting Data

User's behavior seen like a process

Exploiting Process Mining Techniques to extract models of the user's behavior

Case Study



CASAS Project
(Wathington State University)

58 days of recording

1 user + 1 pet + 1 guest

Home sensors:

Motion

External Doors

Temperature

Case Study: labeled dataset

During the dailylife the user is asked to manually annotate the performed activity

timestamp	sensor	value	macro activity
...	...	...	...
2009-10-16 08:45:38.000076	M016	ON	Kitchen_Activity begin
2009-10-16 08:45:39.000094	M003	ON	NULL
2009-10-16 08:45:40.000041	M015	ON	NULL
2009-10-16 08:45:40.000090	M023	ON	NULL
...	...	...	...
2009-10-16 08:58:52.000004	M016	ON	Kitchen_Activity end
2009-10-16 08:58:52.000053	M023	OFF	NULL
...	...	...	...
2009-10-16 08:59:02.000054	M019	ON	Chores begin
...	...	...	...
2009-10-16 09:14:47.000090	M006	ON	Chores end
...	...	...	...

Goal

We consider two kind of models

1) daily behavior model
behavior of the user in the form of a process model where activities are daily tasks

2) macro activities models
a process model representing the flow of sensors activations when a given daily task is performed

Application of Process Discovery alghoritms to extract process models describing user behavior

Related Work

Researches proposed the use of Process Mining techniques to recognize user's ADLs
[Mecella 2016, Fernandez-Llatas 2015, Sztyler 2015, Smith 2011]

NOTE: the use of personal and wearable devices provide more accurate data to track user behavior minimizing noise

differing from our work, other researches do not deal with the discovery of macro activity models from sensor data

Methodology: pre-processing

DataSet errors

1) annotation errors due to user's mistakes

2) sensors' value errors (e.g. 0N instead ON)

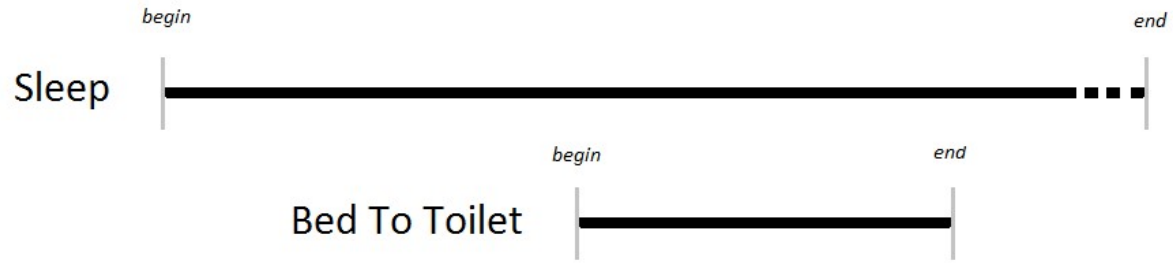
Inconsistent *begin* / *end:*

1) sequential activities stored as parallel activities

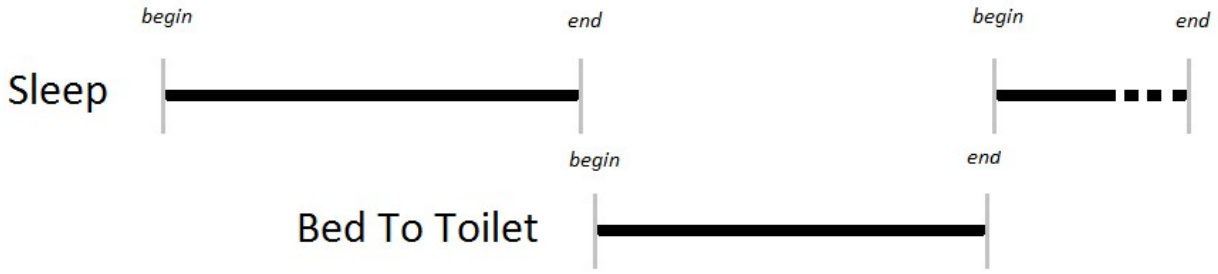
2) parallel activities

Sequential activities stored as parallel activities

The user cannot perform the BedToToilet activity while sleeping



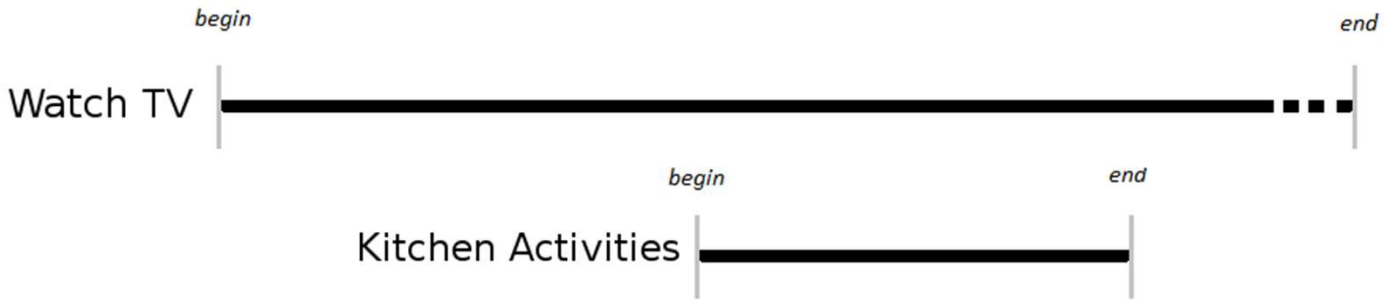
Solution: new dummy *begin / end* have been artificially added in order to make such activities sequential



Parallel activities

Some activities are actually performed in parallel

For instance, while watching the TV
the user can start cooking



Removed “end” timestamps to simplify the obtained models

Methodology: pre-processing

Splitting Days

Days have been splitted on the basis of the users' activities. We set the begin of the day dinamically when the user wakes up (*Sleep end*)

NOTE:

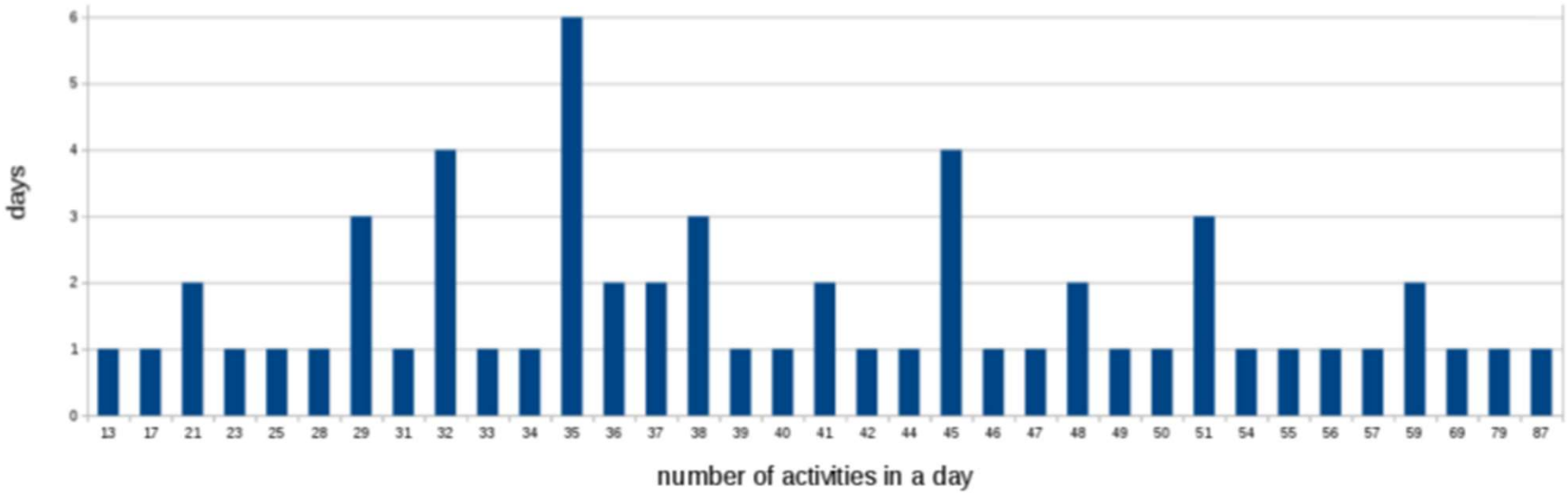
During some days the user didn't sleep at home so such days have been excluded from the analisys

Methodology: pre-processing

The resulting cleaned DataSet is put in the form of a Log

```
Day 1: [Sleep, 2009-10-16 21:03:28.034]
       [Bed_to_Toilet, 2009-10-16T21:29:11.043]
       ...
Day 2: [Sleep, 2009-10-16 03:58:44.068]
       [Morning_Meds, 2009-10-16 08:42:01.077]
       [Watch_TV, 2009-10-16 08:43:59.024]
       ...
```

Methodology: pre-processing



The obtained dataset is characterized by non-uniform daily distribution of macro activities

To extract models classical approaches cannot be adopted, so we refer to algorithms able to deal with spaghetti-like processes

Methodology: process discovery

Process mining algorithms:

1) Fuzzy Miner
2) Heuristic Miner
3) Infrequent Inductive Miner

The process is ***unstructured*** so we choose the ***infrequent Inductive Miner Algorithm*** because:

- it gives a Petri net as output
- it provides a more sound Petri net other algorithms

The algorithm is exploited to extract the process models for

Daily Behavior model
Macro activities models

Methodology: daily behavior model

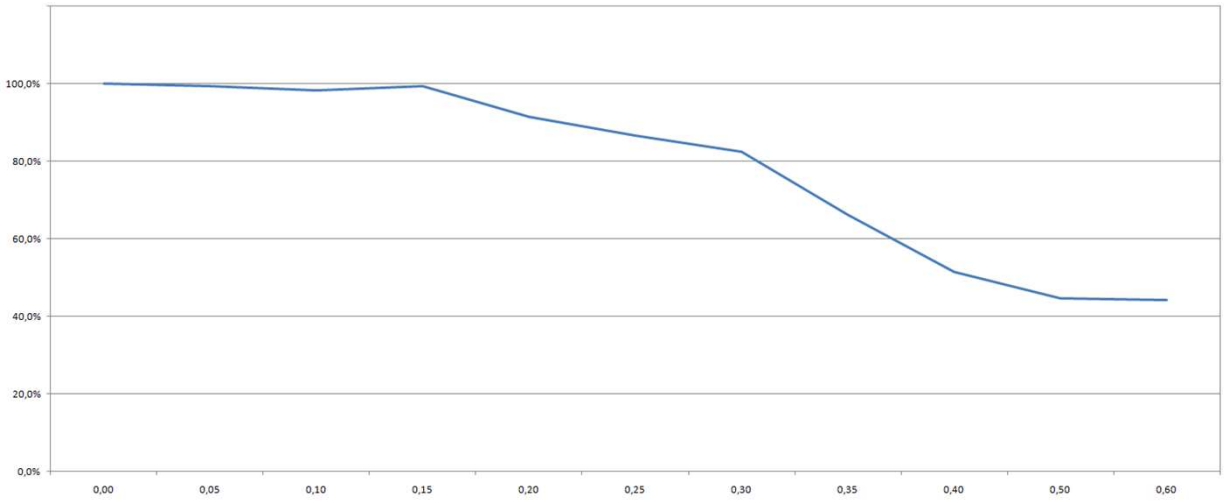
Day 1: [Sleep, 2009-10-16 21:03:28.034]
[Bed_to_Toilet, 2009-10-16T21:29:11.043]
...
Day 2: [Sleep, 2009-10-16 03:58:44.068]
[Morning_Meds, 2009-10-16 08:42:01.077]
[Watch_TV, 2009-10-16 08:43:59.024]
...

Threshold parameter [ranges from 0 to 1]

It filters the less frequent causal relations

low threshold values >> very complex models

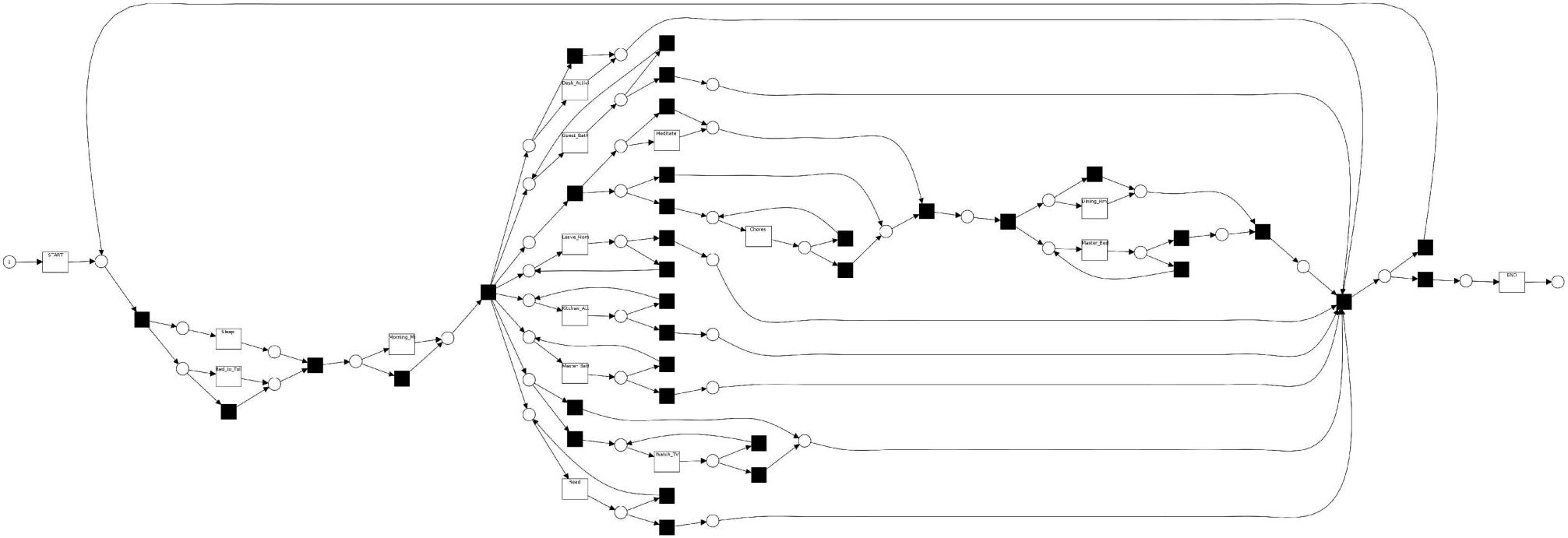
Fitness results



We choosed the **0.20 threshold value** since this way the algorithm can extract an understandable model with a very good fitness value

Methodology: daily behavior model

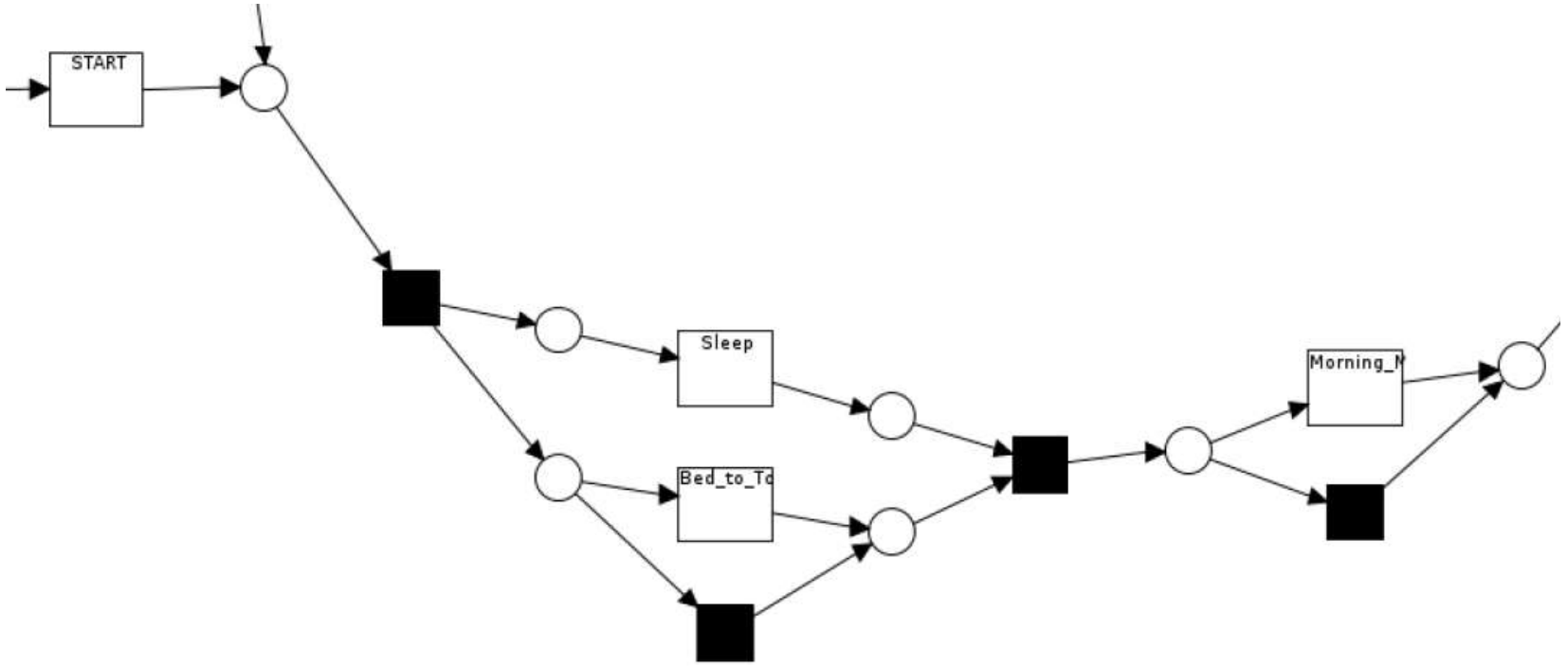
Petri net of Daily Behavior process model
(threshold 0.20)



Methodology: daily behavior model

Detail of the obtained Petri net

the Sleep / Bed To Toilet sequence is shown below



Methodology: macro activity model

trace	datetime	sensor	value
1	16/10/09 08:43	M008	ON
1	16/10/09 08:44	M026	ON
1	16/10/09 08:44	M026	OFF
1	16/10/09 08:44	M008	OFF
1	16/10/09 08:44	M026	ON
1	16/10/09 08:44	M026	OFF
1	16/10/09 08:44	M026	ON
1	16/10/09 08:44	M008	ON
1	16/10/09 08:44	M026	OFF
1	16/10/09 08:44	M008	OFF
2	16/10/09 15:52	M026	ON
2	16/10/09 15:52	M019	OFF
2	16/10/09 15:52	M008	OFF
2	16/10/09 15:52	M026	OFF
2	16/10/09 15:52	M008	ON
2	16/10/09 15:52	M008	OFF
2	16/10/09 15:52	M026	ON
2	16/10/09 15:53	M026	OFF

The most innovative part of the work concerns the **discovery of macro activities**

they represent the flow of sensors triggered when the macro activity is performed

To explain the methodolody by now on we take into account the **Watch TV Macro activity**

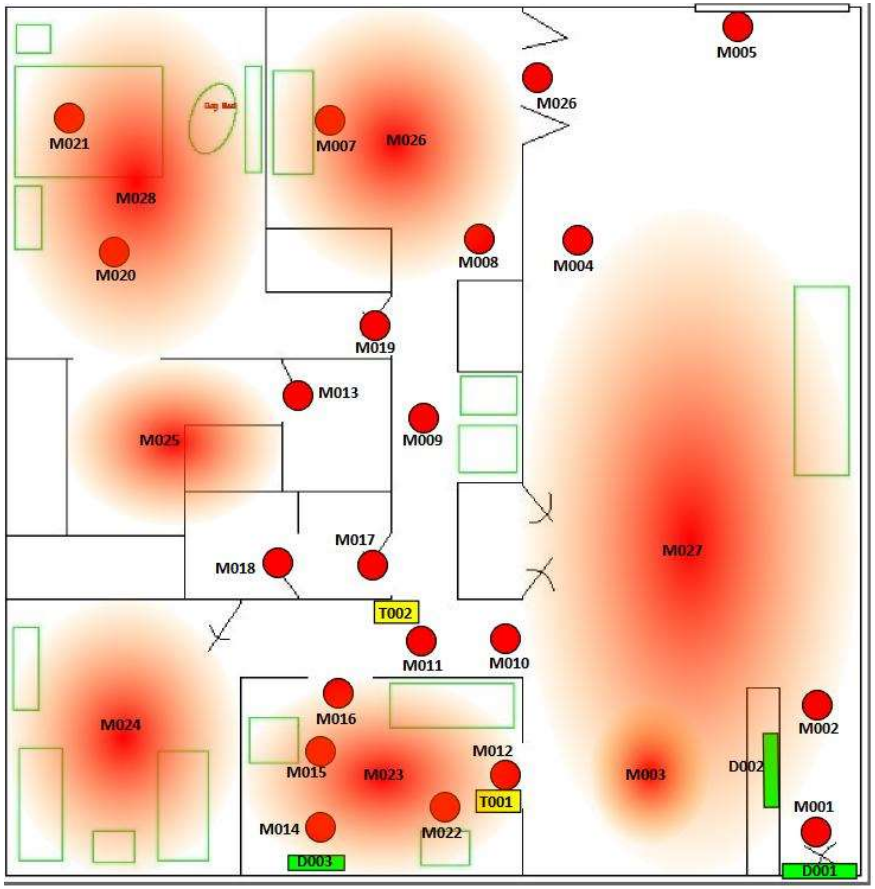
114 traces describing Watch TV, they are composed of 207.8 micro activities on average

Methodology: macro activity model

filtering the log in order to keep the closest WatchTV room sensors

(M004, M007, M008, M09, M019, M026)

threshold	fitness (room sensors)
0.1	97.68%
0.2	99.36%
0.3	91.88%
0.4	88.15%
0.5	24.67%



Methodology: macro activity model

Model Quality evaluation

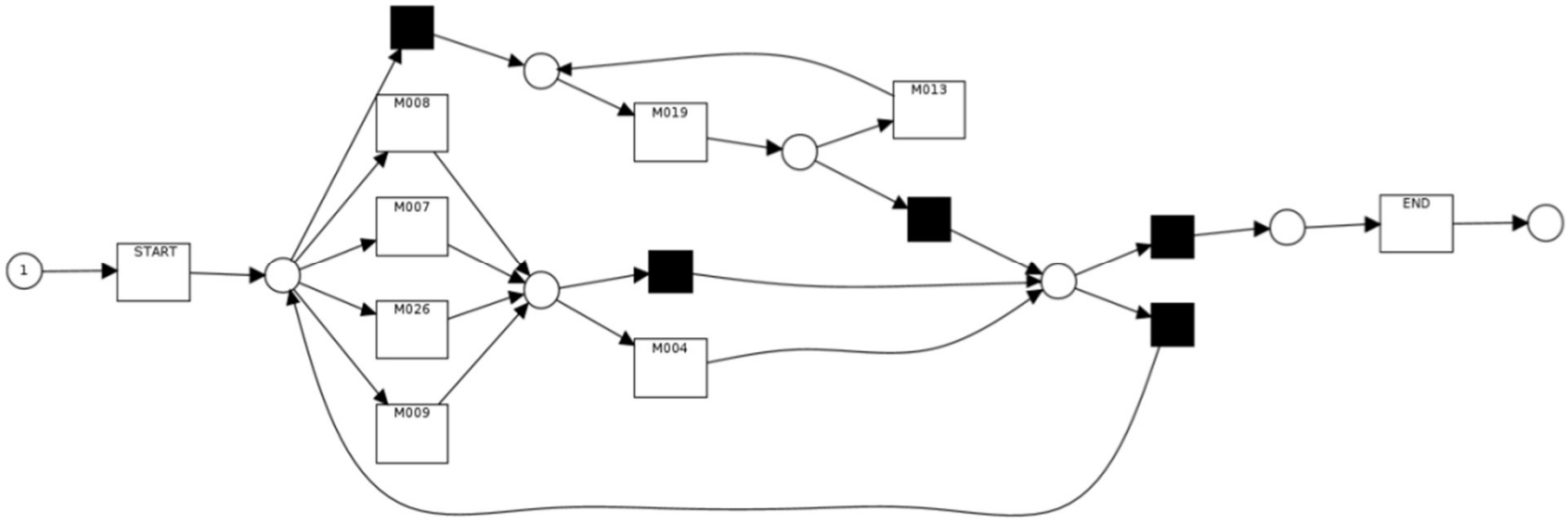
computed fitness of the model with respect to event logs of other macro activities

Macro Activity	Watch TV	Read	Kitchen Activity	Meditate
Fitness	73.16%	7.07%	7.89%	9.84%

As expected the model represents in a good way ONLY the Watch TV activity. The model shows a good fitness on Watch TV event log and very low values on other macro activities event

Methodology: macro activity model

Here the obtained Petri net



Conclusions and future work

we presented a methodology exploiting Process Mining techniques aimed at discover :

- daily behavior model of a user
- macro activities models

We experimentally show the efficacy of the methodology with a real case study

Future Work

- further testing with other datasets
- adopting sub-graph mining techniques to highlight the most frequent substructures

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