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THE ROLE OF SENSING FOR HEALTH AND WELL-BEING

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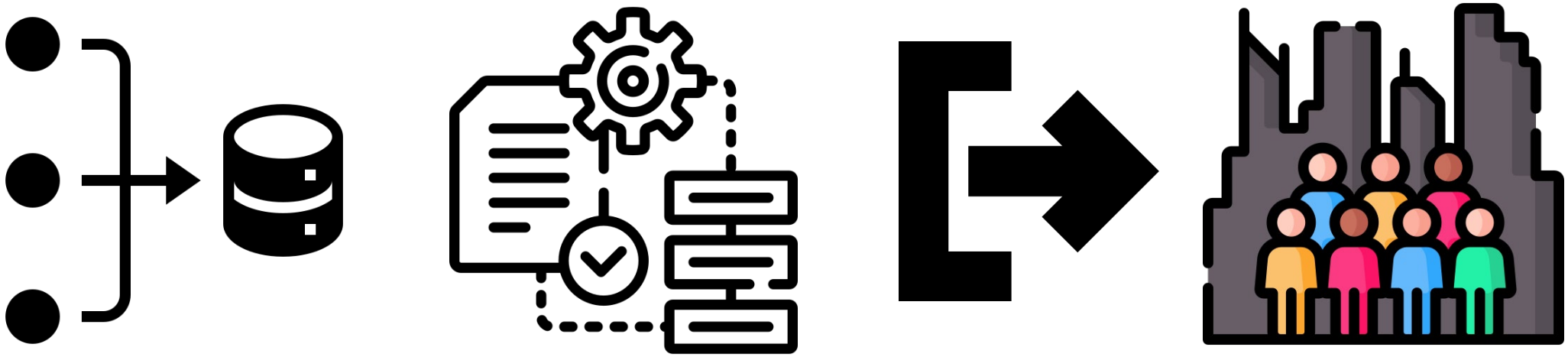
Rome
22.02.24

Current computing systems can process a sophisticated combination of sensing data at great speed and with high impact outputs

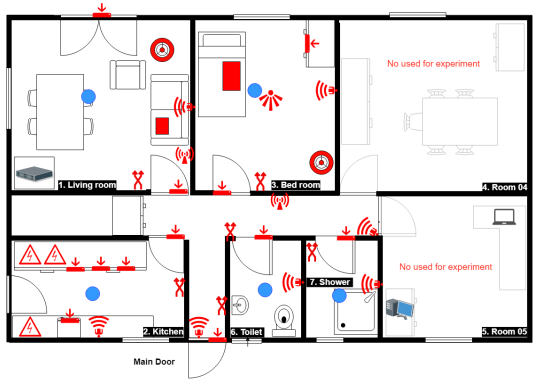


But… At what sort of quality level?

SENSOR DATA ACQUISITION

Technology is having a massive influence on how many different key services are deployed in society.

Sensing have become the back bone of the transformation or the creation of many of those services.



TYPE OF SENSORS

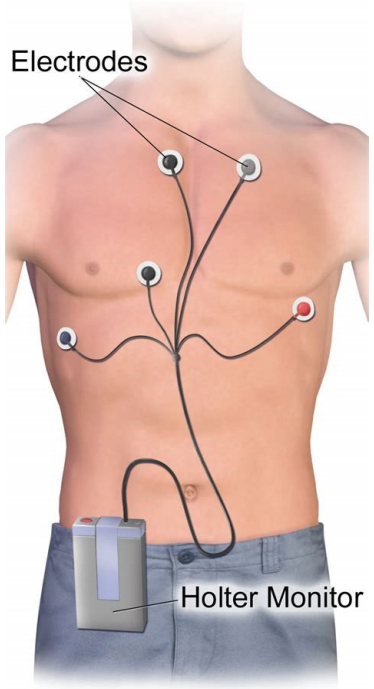
Smart watches and Smart Phones will typically have these and more!:

- Accelerometer
- Gyroscope
- Magnetometer or Compass
- Barometric Pressure Sensor
- Body Temperature Sensor
- Heart Rate Monitor
- Oximetry Sensor
- Ambient Light Sensor
- Altimeter Sensor
- Bioimpedance sensor
- Proximity Sensor
- ECG Sensor
- Gesture Sensor
- UV Sensor
- Skin Conductance Sensor
- GPS Sensor in Smartwatch

FOR EXAMPLE…

Let us consider a case that is sensitive: heart monitoring …

Holter monitor



Holter Monitor

Smartwatch

A COMPARISON

Holster monitor:

- Bulky
- (very) Expensive
- Uncomfortable
- Very precise
- Better info for physician
- Healthcare standard
  (UK-NHS approved)

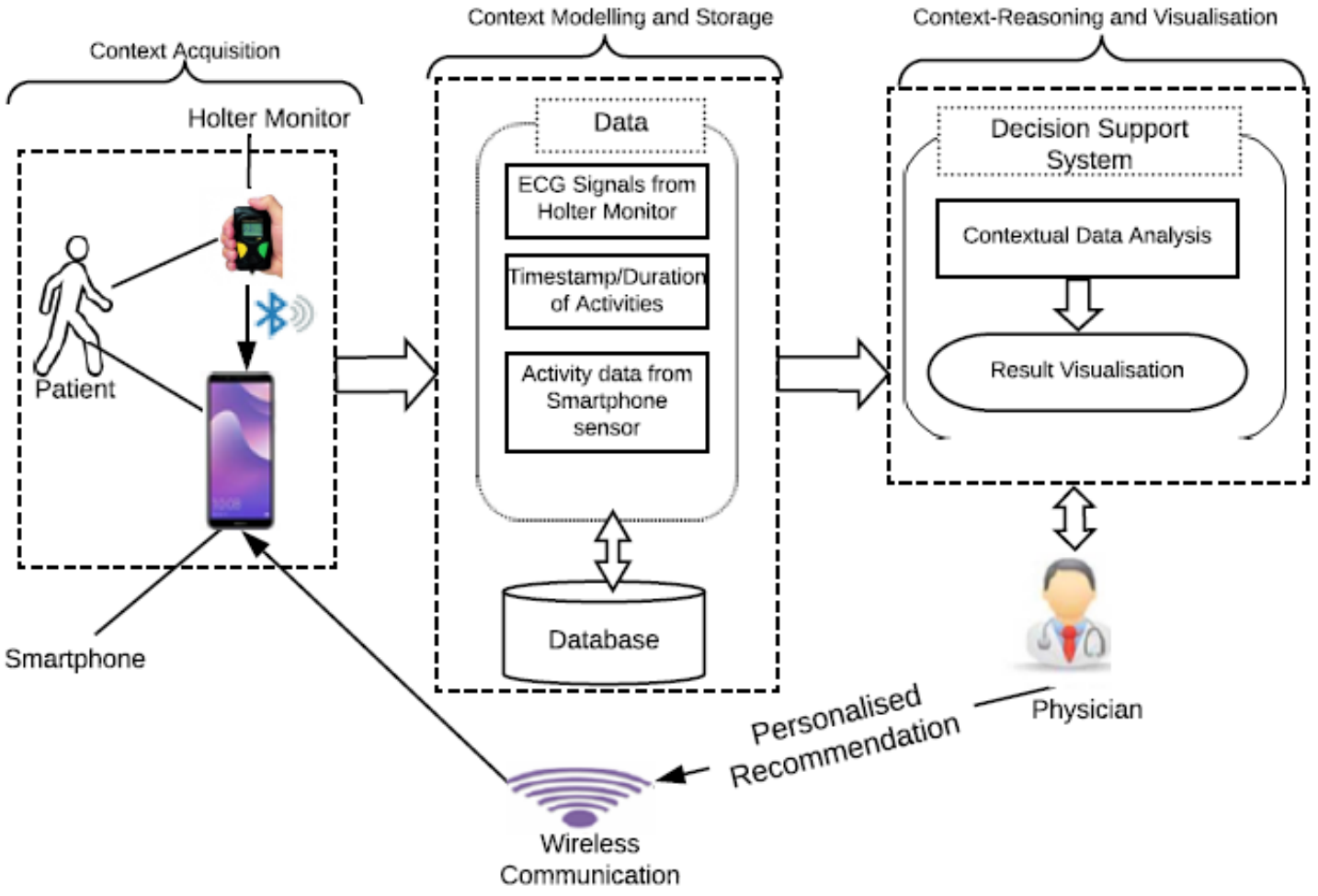
Smartwatch:

- Small
- (not so) Expensive
- Comfortable
- Not so precise
- Better info for user
- Not healthcare standard

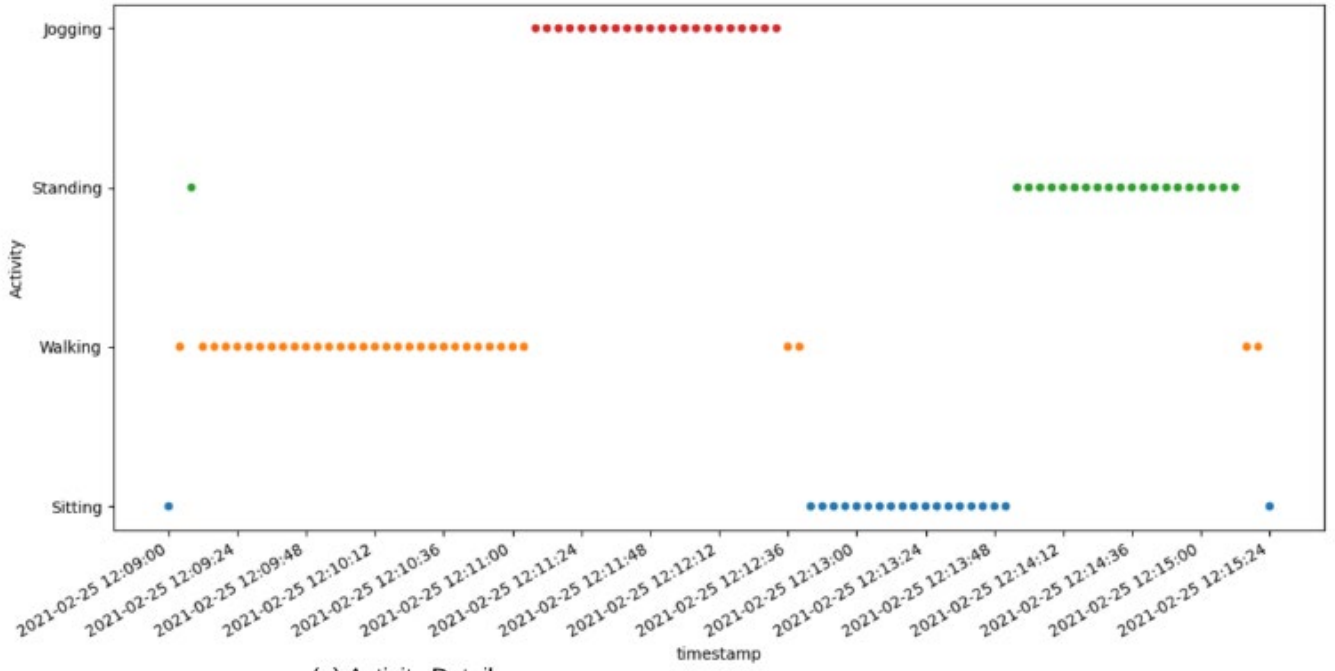
CONTEXT-AWARE SUPPORT FOR CARDIAC HEALTH MONITORING USING FEDERATED MACHINE LEARNING

Context-aware Support for Cardiac Health Monitoring using Federated Machine Learning.
Godwin Ogbuabor, J. C. Augusto, R. Moseley, and A. van Wyk.
Proc. of 41th SGAI Int. Conf. on Artificial Intelligence (AI-2021). Cambridge, December 2021. Springer Verlag.

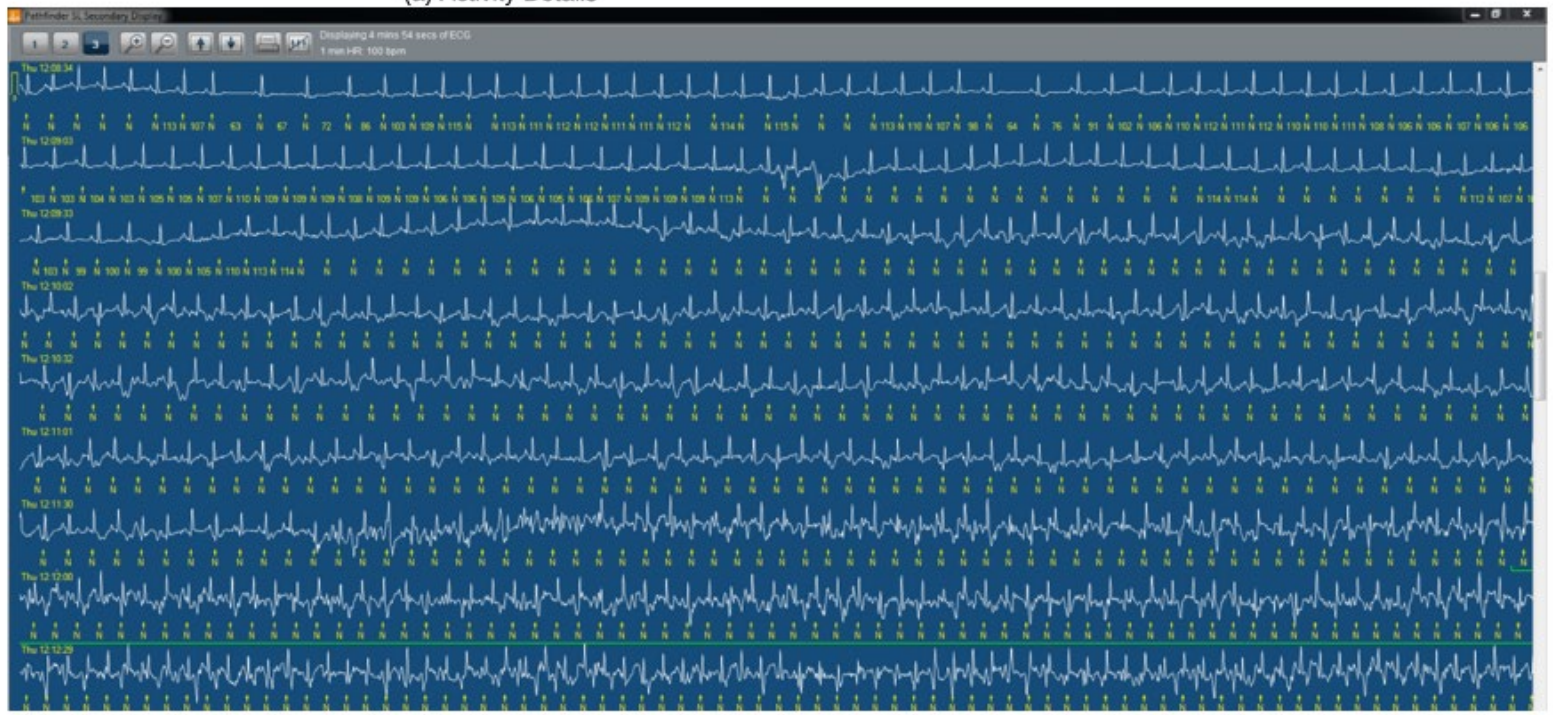
https://repository.mdx.ac.uk/item/89803



Combining/complementing the best of both technologies …



(a) Activity Details



(b) ECG Signals

Each data has a natural conceptual granularity…

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SOME POINTS ON PREVIOUS ANALYSIS

- As indicated initially there is a lot of different sensors at different standards (for example, NHS vs commercial).
- I am not suggesting research on wearables available to the public is not worth doing or that they are completely useless, it is what people make of it, e.g., the reasoning on extreme ways, especially unrealistically optimistic.
- The problem exceeds citizens believing their smartwatch is extremely accurate on delicate issues of health, also academics' believes on technical reports of experiments carried out with gadgets such as smartwatches for health with little evidence on the thoroughness of the reported (possibly inflated) positives (and possibly underplayed negatives).


Made in Middlesex
While you're at Middlesex, say 'Yes'. Get involved in anything and everything and you'll really enjoy your time there.
Fil Kamps
Footballer for Team GB at Deaflympics
BSc Sport and Exercise Science
Class of 2016
Share your story using
Lola Yyong

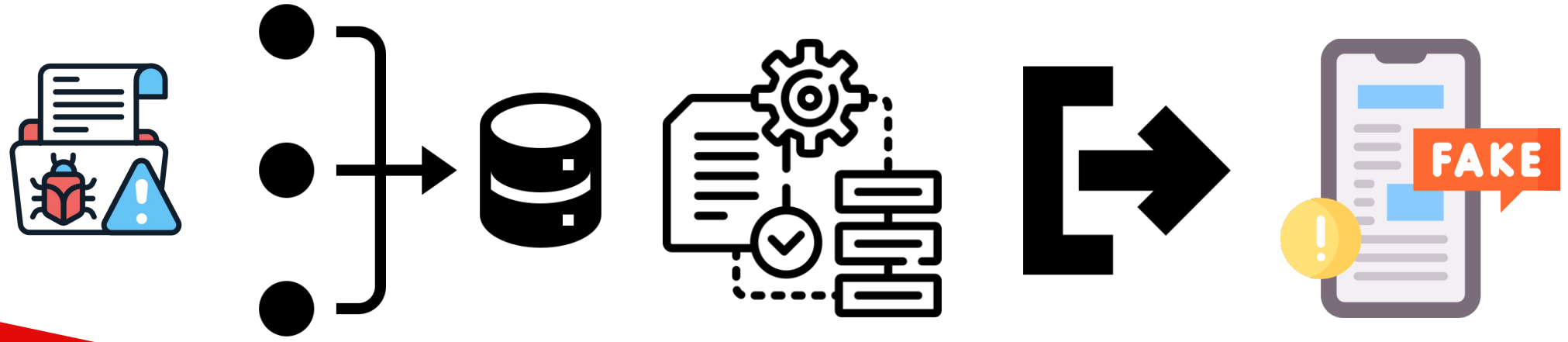
DATA PROCESSING

Spoilt for choice, many approaches…

- Logic (non-monotonic, temporal, fuzzy, description,…)
- Probabilistic methods (Bayesian Networks, HMMs, Kalman Filters,…)
- Classifiers (decision trees, k-NN, SVM, ANNs,…)
- ML/NLP (un-/semi-/supervised learning, Large Language Models and Generative Pre-trained Transformers)

Each one with pros and cons…!

- Latest developments grabbing the attention of the media come from the data intensive systems: GPT-4 it is estimated to have been trained concerning more than1 trillion parameters.
- That allows the system to create text and images resembling human production, still producing “hallucinations”.
- One problem being the quality of the input data



OTHER IMPORTANT AREAS ARE UNDERDEVELOPED

Despite the potential usefulness of LLMs based Generative AI, in health and well-being applications, other algorithmic and system qualities are also extremely important and are not so well explored, for example:

* explainability

* reliability

EXPLAINABILITY

```
ssr((CorridorMotion ^ prefLight) -> CorridorLight);
ssr((CorridorMotion ^ prefComfort) -> #CorridorLight);
ssr((BedroomMotion ^ BigPadIdle) -> BedRoomLight);
ssr((BedroomMotion) -> #BedRoomLight);
ssr((ToiletMotion) -> ToiletLight);
ssr((ShowerMotion) -> ShowerRoomLight);
ssr((CorridorMotion) -> #ShowerRoomLight);
```

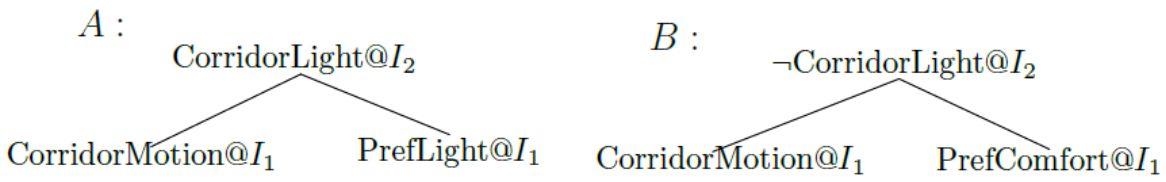


Figure 23.: Argument tree for Corridor-Light "on" or "off".

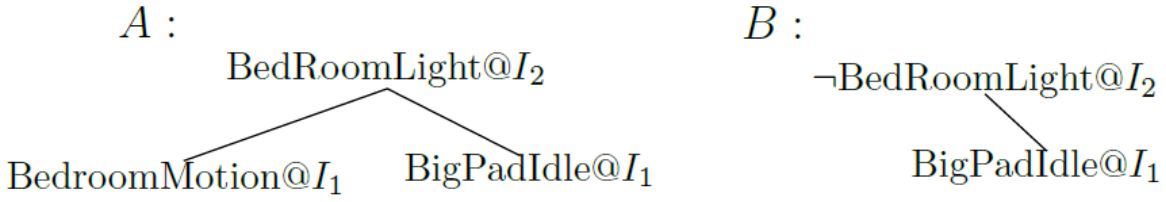


Figure 24.: Argument for BedRoom-Light.

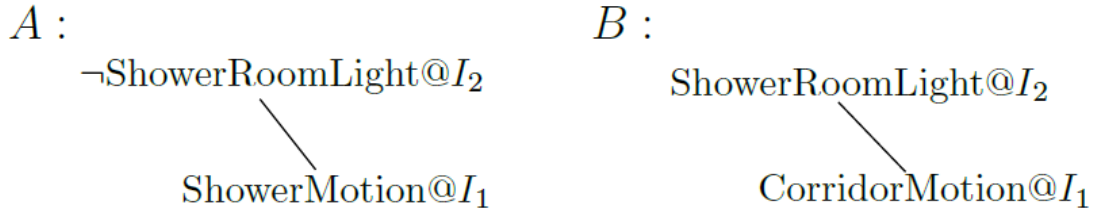


Figure 25.: Argument for ShowerRoom-Light.

Using Argumentation to Manage Users' Preferences.
C. L. Oguego, J. C. Augusto, A. Muñoz, M. Springett.
Future Generation Computer Systems, , 81 . pp. 235-243 (Elsevier). 2018.

Select Specification File

idPossibleConflict	detected_time	conflictName
1	2019-09-16 14:42:17.0	CorridorLight
2	2019-09-16 14:42:17.0	BedRoomLight
3	2019-09-16 14:42:17.0	ShowerRoomLight

MReasoner

This detected conflict was solved using Persistency

Argumentation Solver

Load Results/Solved Conflicts

iteration	syste...	BedRo...	BedRo...	Showe...	ShowerRoomLight	Toilet...	Toilet...	Corri...	Corri...	BigP...	pref...	prefL...
255	156864...	true	true	true	true	true	true	false	true	true	true	true
256	156864...	true	true	true	true	true	true	false	true	true	true	true
257	156864...	true	true	true	true	true	true	false	true	true	true	true
258	156864...	true	true	true	true	true	true	false	true	true	true	true
259	156864...	true	true	true	true	true	true	false	true	true	true	true
260	156864...	true	true	true	false	true	true	true	true	true	true	true
261	156864...	true	true	true	false	true	true	true	true	true	true	true
262	156864...	true	true	true	false	true	true	true	true	true	true	true
263	156864...	true	true	true	false	true	true	true	true	true	true	true
264	156864...	true	true	true	false	true	true	true	true	true	true	true
265	156864...	false	true	false	false	true	true	true	true	true	true	true
266	156864...	false	true	false	false	true	true	true	true	true	true	true
267	156864...	false	true	false	false	true	true	true	true	true	true	true
268	156864...	false	true	false	false	true	true	true	true	true	true	true
269	156864...	false	true	false	false	true	true	true	true	true	true	true

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sult Grid | Filter Rows: | Edit: | Export/Import: | Wrap Cell Content: | Fetch rows:

idResolve	iteration	resolved_time	BedRoomMotion	BedRoomLight	ShowerMotion	ShowerRoomLight	ToiletMotion	ToiletLight	CorridorMotion	CorridorLight	BigPadIdle	prefComfort	prefLight	solved_reason
85	255	2019-09-16 14:47:18	NULL	1	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	Specificity
86	256	2019-09-16 14:47:19	NULL	1	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	Specificity
87	257	2019-09-16 14:47:20	NULL	1	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	Specificity
88	258	2019-09-16 14:47:21	NULL	1	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	Specificity
89	259	2019-09-16 14:47:23	NULL	NULL	NULL	NULL	NULL	NULL	NULL	1	NULL	NULL	NULL	User Preferences
90	259	2019-09-16 14:47:23	NULL	1	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	Specificity
91	259	2019-09-16 14:47:23	NULL	NULL	NULL	0	NULL	NULL	NULL	NULL	NULL	NULL	NULL	Persistency
92	260	2019-09-16 14:47:24	NULL	NULL	NULL	NULL	NULL	NULL	NULL	1	NULL	NULL	NULL	User Preferences
93	260	2019-09-16 14:47:24	NULL	1	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	Specificity
94	260	2019-09-16 14:47:24	NULL	NULL	NULL	0	NULL	NULL	NULL	NULL	NULL	NULL	NULL	Persistency
95	261	2019-09-16 14:47:26	NULL	NULL	NULL	NULL	NULL	NULL	NULL	1	NULL	NULL	NULL	User Preferences
96	261	2019-09-16 14:47:26	NULL	1	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	Specificity
97	261	2019-09-16 14:47:26	NULL	NULL	NULL	0	NULL	NULL	NULL	NULL	NULL	NULL	NULL	Persistency
98	262	2019-09-16 14:47:28	NULL	NULL	NULL	NULL	NULL	NULL	NULL	1	NULL	NULL	NULL	User Preferences
99	262	2019-09-16 14:47:28	NULL	1	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	Specificity
100	262	2019-09-16 14:47:28	NULL	NULL	NULL	0	NULL	NULL	NULL	NULL	NULL	NULL	NULL	Persistency
101	263	2019-09-16 14:47:29	NULL	NULL	NULL	NULL	NULL	NULL	NULL	1	NULL	NULL	NULL	User Preferences
102	263	2019-09-16 14:47:29	NULL	1	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	Specificity
103	263	2019-09-16 14:47:29	NULL	NULL	NULL	0	NULL	NULL	NULL	NULL	NULL	NULL	NULL	Persistency
104	264	2019-09-16 14:47:30	NULL	NULL	NULL	NULL	NULL	NULL	NULL	1	NULL	NULL	NULL	User Preferences
105	265	2019-09-16 14:47:31	NULL	NULL	NULL	NULL	NULL	NULL	NULL	1	NULL	NULL	NULL	User Preferences
106	266	2019-09-16 14:47:32	NULL	NULL	NULL	NULL	NULL	NULL	NULL	1	NULL	NULL	NULL	User Preferences

Specificity

Using argumentation to solve conflicting situations in users' preferences in ambient assisted living. C. L. Oguego; J.C. Augusto; M. Springett; M. Quinde and C. James-Reynolds. Applied Artificial Intelligence, 35(15):2327-2369, Taylor and Francis. 2021.

RELIABILITY

A substantial part of the work in our Research Group as been focused on:

- Testing
- (formal) Verification

→ Are we building the system right?

- Validation

→ Are we building the right system?

RELIABILITY - TESTING

Context Testing Table

	Enablers	Assumptions Initial values	Preconditions	Context testing table ID (CTTID)			
				CL1-FR1			
Context Description				Sleeping pattern			
Expected Outcome (s)				Monitor sleeping pattern based on defined preconditions			
				Tests			
				PIR Sensor	*Pressure Pad*	*Light Actuator*	*Sleep*
				0	0	0	**Sleeping**
				0	0	1	**Not Sleeping**
				1	1	0	**Not sleeping**
				1	1	1	**Not sleeping**
			Other combinations not defined by developer	*	*	*	**Sleep/not sleeping**
				Range of values		*Values of interest*	
Sensors	PIR Sensor	Activated	No change triggered	0 and 1		0, 1	
	Pressure Pad	Activated	User still in bed	0 and 1		0, 1	
	Light Actuator		No change in light status	0 and 1		0, 1	
Network	Z-wave (vera hub)		Continuous connection with sensors				
Database	Preferences database						
Reasoner	Real-time Context Reasoner	MReasoner in use	MReasoner does not detect user activity				
HCI	Preference interface						
Preferences	P_1						
Users	Only user						
Clock			Time is within the prescribed normal sleep period	Time between 00:00:00 and 23:59:59			

Random timebased test cases

Please complete the form to auto generate test cases

TestID

CL1-FR1

Context

sleep

Sensor

BedroomBedPressure

-- Select Sensor --
BedroomBedPressure
BedroomMotion
BedRoomLight

09:30:00

End time

10 : 00

Number of tests

10

Submit

Test cases generation time interval

Please set up minimun and maximum time interval

TestID

CL1-FR1

Context

sleep

Min test case time (in seconds)

4

Maximum test case time (in seconds)

30

Export to excel

Test Output

Requirement	Requirement Priority	Context	CTT ID	Date	Time	Actual outcome	Predicated outcome	Test result	Re-run Test
sleep alert	HIGH	sleep	CL_FR1	2021-11-02	10:40:29	TRUE	TRUE	MATCH	☐

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RELIABILITY– (FORMAL) VERIFICATION

Requirements

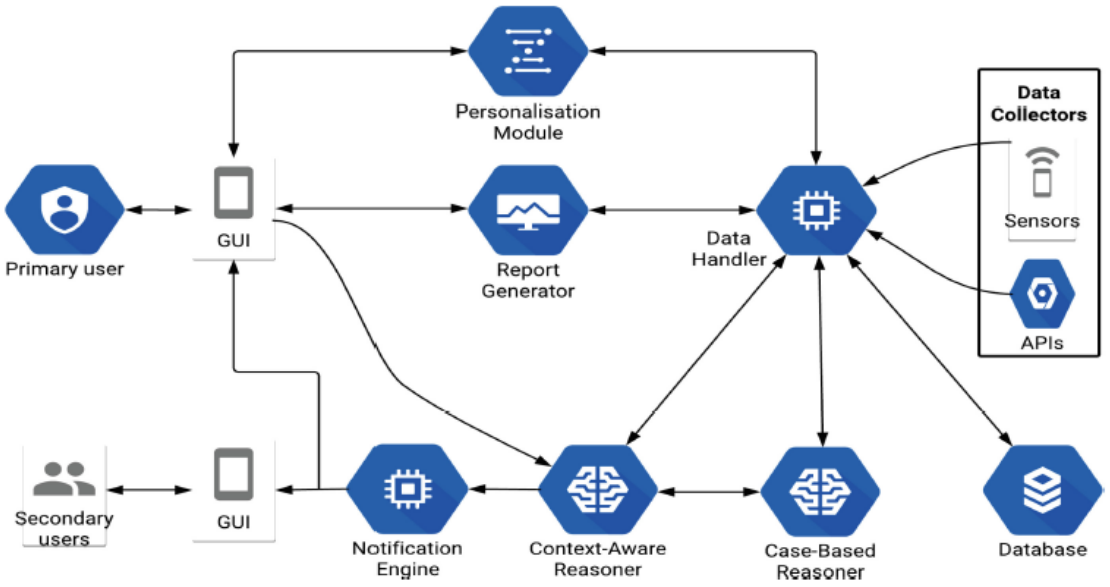
→ Model

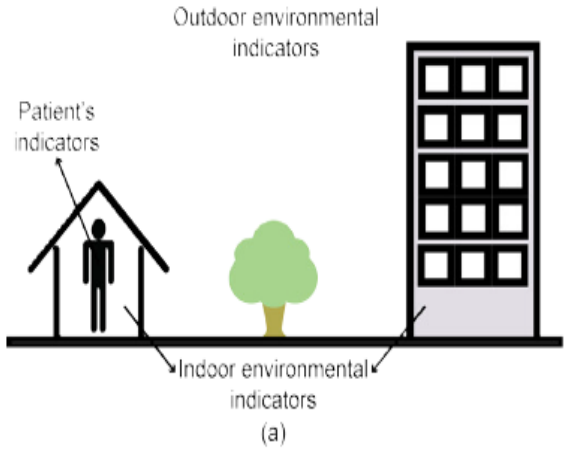
→ Simulations

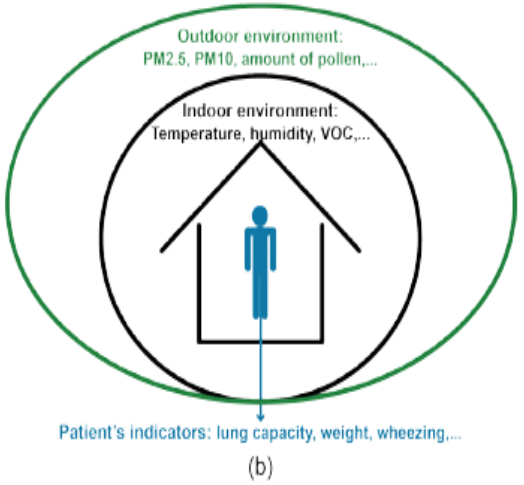
→ Properties (requirements) verification or counter-examples

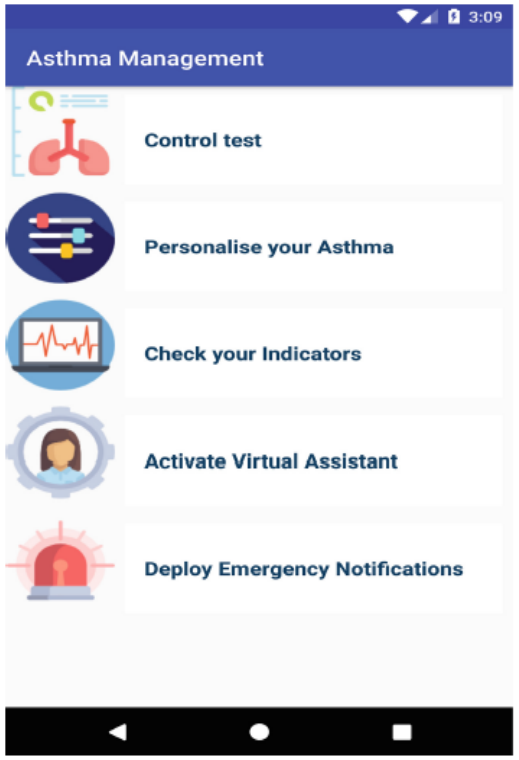
Example: Asthma Management System

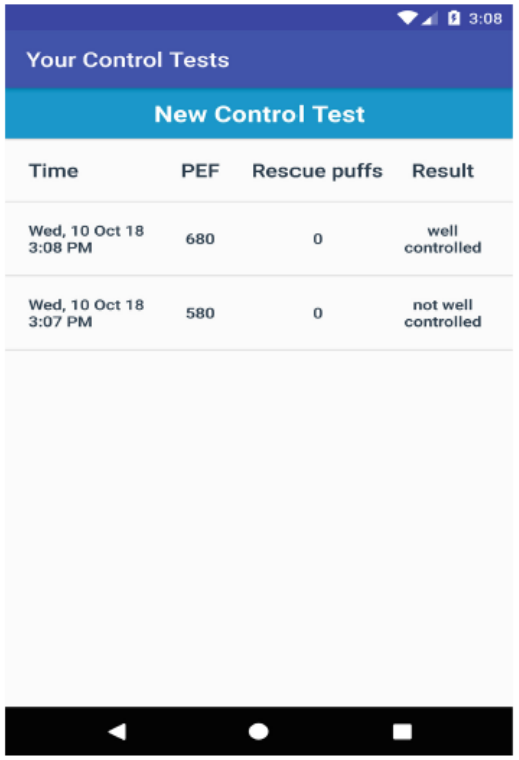
Using Formal Methods to Guide the Development of an Asthma Management System. Juan Carlos Augusto, Mario Jose Quinde, Nawaz Kahn. Proceedings of 10th Int. Conf. on Dependable Systems, Services and Technologies Leeds, UK, June 5-7, 2019











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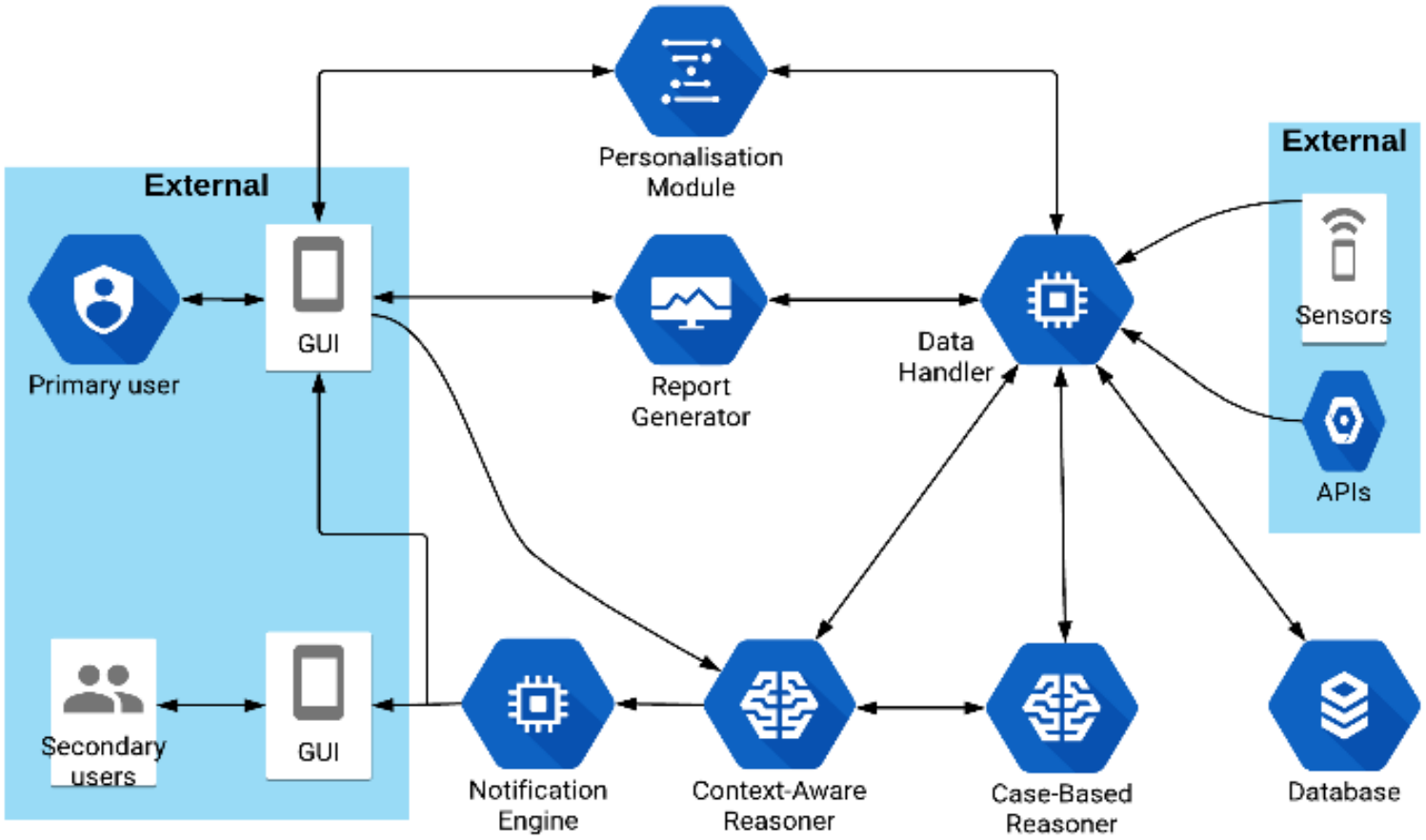
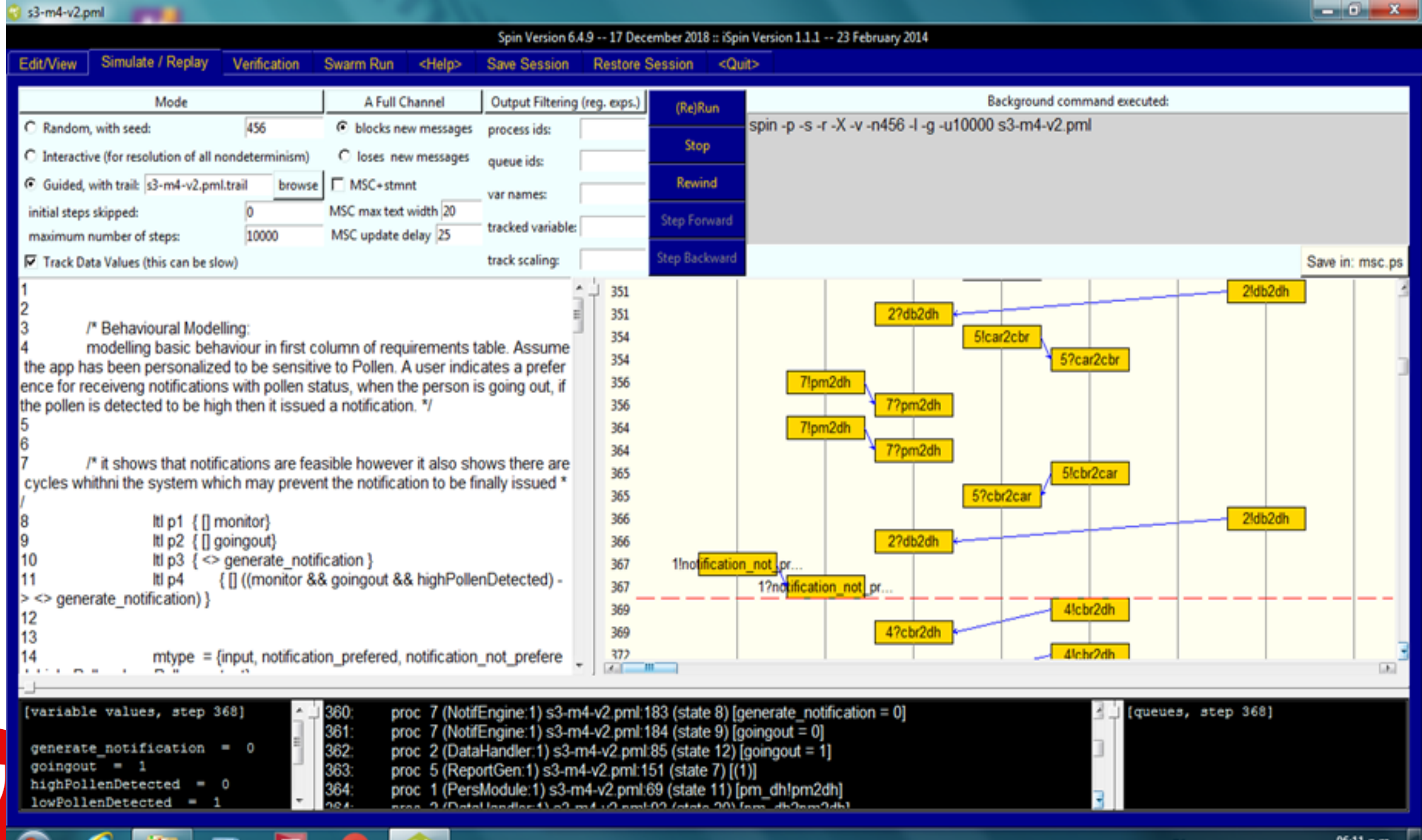
Requirements	
1. The Personalization Module (PM) should allow users to customise the following features of the prototype:	a. The indicators that the system should track. (In case the triggers of the person with asthma are still not known, the system should track all the indicators that it possibly can.)
	b. The places where the system should track those indicators in case they are outdoor or indoor environmental indicators.
	c. The users that will have access to the context-related information of the person with asthma.
	d. The users that will receive notifications when the system detects a potentially risky situation.
2. The system Notification Engine should notify users (pull approach) when the C-A/CBR Reasoner detects a potentially risky situation based on the indicators-tracking personalization done by the user (1.a).	a. In case the triggers of the person with asthma are still not known, the C-A/CBR Reasoner should analyze the context based on previous situations that led the person with asthma to a deterioration of their health status.
	b. In case the triggers of the person are partially known, the C-A/CBR Reasoner should notify users depending on the indicators-tracking personalization (2), and it should also analyze previous situations that led to a deterioration of their health status (2.a).
3. The C-A/CBR Reasoner can be activated by the user (push approach) in case they want to know the possibilities of a risky situation to occur.	
4. The user should be able to ask the Report Generator subsystem to show a report based on the indicators-tracking personalization (1.a).	a. In case the triggers of the user are not known, the Report Generator subsystem should show a report about all the indicators that it is tracking.
5. The Data Handler subsystem should obtain context-related data from the APIs considering the indicators-tracking	a. The Data Handler subsystem should query the APIs every certain time.
	b. Every time the system obtain context-related data from the APIs, it should activate the C-A/CBR

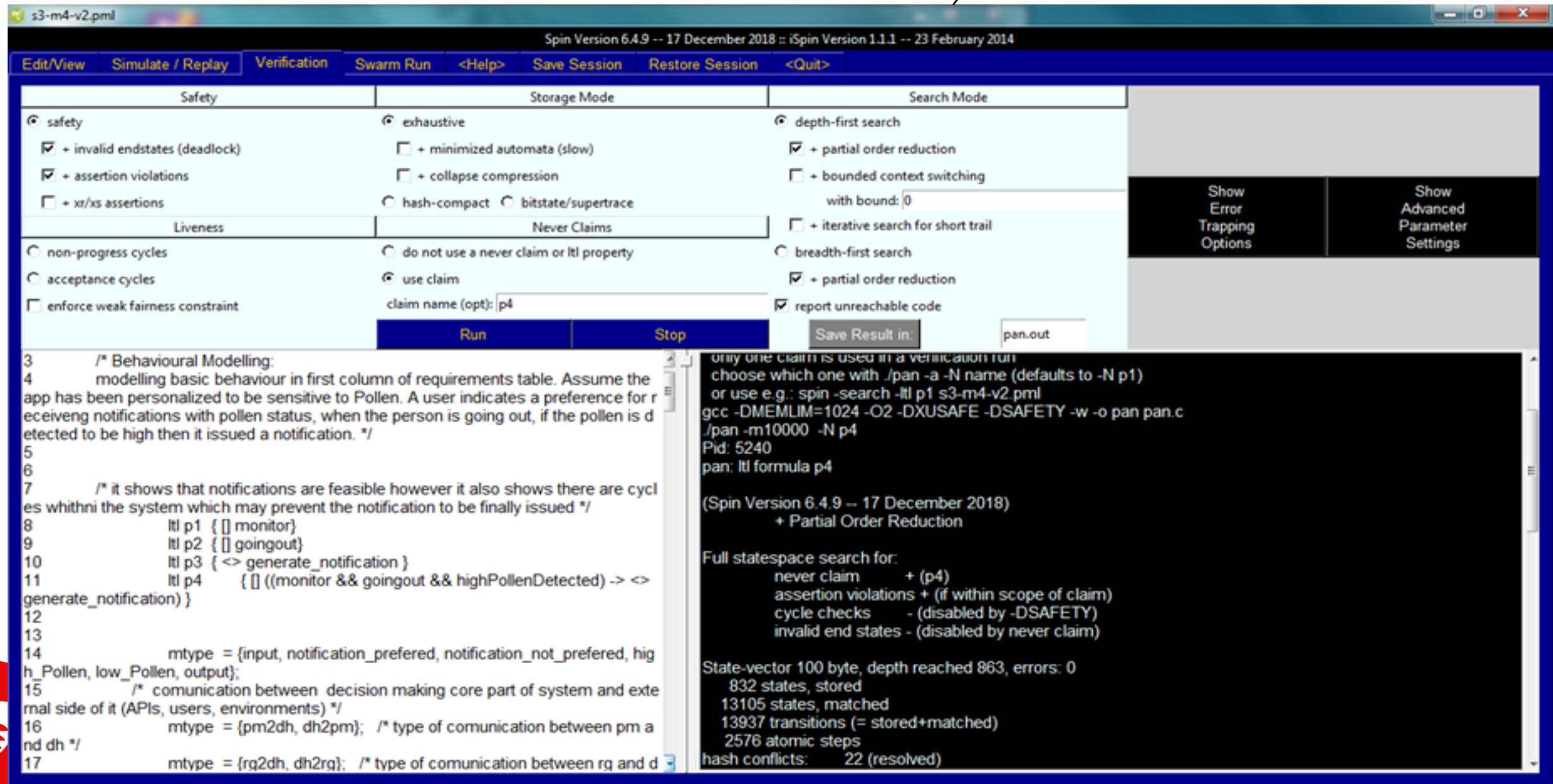



```
        chan cacbr_db = [0] of {mtype};
        chan dh_db = [0] of {mtype};
        chan dh_cacbr = [0] of {mtype};
        chan cacbr_ne = [0] of {mtype};

/* ---------------------------------------------------*/

active [1] proctype External ()
{

end:    do
        ::      if
                :: external!input
                :: external?output
                fi
        od
}

/* ---------------------------------------------------*/

active [1] proctype PersModule ()
{

end:    do
        ::      if
                :: atomic{external?input -> true}
                :: pm_db?db2pm
                :: pm_db!pm2db
                :: atomic{external!output -> true}
                fi
        od
}

/* ---------------------------------------------------*/

active [1] proctype ReportGen ()
```


s3-m4-v2.pml
Spin Version 6.4.9 -- 17 December 2018 :: iSpin Version 1.1.1 -- 23 February 2014
Edit/View
Simulate / Replay
Verification
Swarm Run
<Help>
Save Session
Restore Session
<Quit>
Mode
Random, with seed: 456
Interactive (for resolution of all nondeterminism)
Guided, with trail: s3-m4-v2.pml.trail
browse
initial steps skipped: 0
maximum number of steps: 10000
Track Data Values (this can be slow)
A Full Channel
blocks new messages
loses new messages
MSC+stmnt
MSC max text width 20
MSC update delay 25
Output Filtering (reg. exps.)
process ids:
queue ids:
var names:
tracked variable:
track scaling:
(Re)Run
Stop
Rewind
Step Forward
Step Backward
Background command executed:
spin -p -s -r -X -v -n456 -l -g -u10000 s3-m4-v2.pml
Save in: msc.ps
1
2
3 /* Behavioural Modelling:
4 modelling basic behaviour in first column of requirements table. Assume the app has been personalized to be sensitive to Pollen. A user indicates a preference for receiveng notifications with pollen status, when the person is going out, if the pollen is detected to be high then it issued a notification. */
5
6
7 /* it shows that notifications are feasible however it also shows there are cycles whithni the system which may prevent the notification to be finally issued */
8 ltl p1 { [] monitor}
9 ltl p2 { [] goingout}
10 ltl p3 { <> generate_notification }
11 ltl p4 { [] ((monitor && goingout && highPollenDetected) -> <> generate_notification) }
12
13
14 mtype = {input, notification_prefered, notification_not_prefere
2!db2dh
2?db2dh
5!car2cbr
5?car2cbr
7!pm2dh
7?pm2dh
7!pm2dh
7?pm2dh
5!cbr2car
5?cbr2car
2!db2dh
2?db2dh
1!notification_not_pr...
1?notification_not_pr...
4!cbr2dh
4?cbr2dh
[variable values, step 368]
generate_notification = 0
goingout = 1
highPollenDetected = 0
lowPollenDetected = 1
360: proc 7 (NotifEngine:1) s3-m4-v2.pml:183 (state 8) [generate_notification = 0]
361: proc 7 (NotifEngine:1) s3-m4-v2.pml:184 (state 9) [goingout = 0]
362: proc 2 (DataHandler:1) s3-m4-v2.pml:85 (state 12) [goingout = 1]
363: proc 5 (ReportGen:1) s3-m4-v2.pml:151 (state 7) [(1)]
364: proc 1 (PersModule:1) s3-m4-v2.pml:69 (state 11) [pm_dh!pm2dh]
[queues, step 368]

p4: [] ((monitor && goingout && highPollenDetected) -> <> generate_notification)

(i.e., whenever the system is monitoring and user goes out of the house and high pollen has been detected then an notification is issued)



RELIABILITY - VALIDATION

There are no recipes out there that innovating teams can apply, each one reinventing the wheel and not sharing so there is no “good practice” arising developing… we have been exploring simple repeatable processes:

Pre-validation Steps

- Smart home infrastructure set up
- Ensure the DMMS is running (e.g., reasoning software, sensors hub, and Server)
- Determine Validation scenarios
- Carried out a physical check of all the equipment (including sensors)
- Access/Print Context Testing Tables
- Print validation scenario tables
- Print performance indicator tables
- Print validation error log

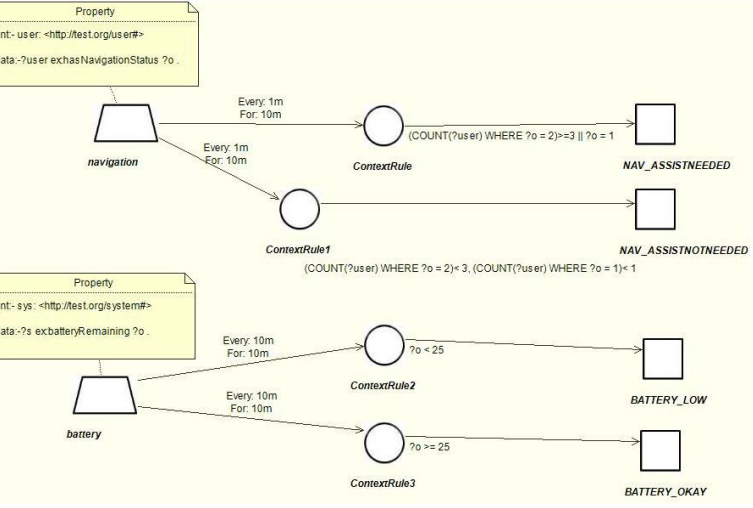
Active Validation Steps

- Familiarise participant with the smart home
- Explain the validation scenarios (Eat, Sleep, Indoor activity)
- Explain performance indicator tables for each scenario
- Go through the documents to be completed
- Perform a trial run of scenarios
- Carry out individual validation scenarios
- Carry out combined validation scenarios
- Participant completes validation scenario tables
- Participant completes performance indicator tables
- Document results
- End validation process

Validation ID	CTT ID	Source Document(s)	Scenario	Participant	Observer	Assumptions made
V100	CL1-FR1	• Requirements Table • Context Table • Context Testing Tables (CTT)	Sleep	User	Developer	• Clock between 8:30pm and 07:30 am • User naps between 02:00 pm to 04:00 pm • User sleeps between 08:30 pm and 07:00 am • User sleeps with the light off
			Expected Outcomes • Depending on specified time of day, i.e., 8:30 pm to 06:30 am, when the user gets out of bed, the light should come on • When the user is in bed, the light should go off			
Steps to execute the scenario			Observable Effects			Time dimension
1. Walk into the bedroom and get into the bed **2. Lay on the bed for 5 minutes** **3. Get out of bed** **4. Walk and out of the bedroom to the bathroom** **5. Stay in the bathroom for a minute or two** **6. Walk back into the bedroom** **7. Lay on bed**			1. The light turns on when participant walks into the room 2. The light turns off when participant is in bed and no motion is detected in the bedroom 3. The light turns on when user gets out of bed between 8:30 pm and 07:30 am			• Light should turn on within 4 seconds of walking into the bedroom • Light should turn off within 5 seconds of the participant being in bed • Light should turn on/off within 3 seconds of getting out of bed and turn off when the user gets back into bed respectively

Participant No.	Scenario	Validation No.	Affected service	Error Description	Error Effect	Error Source	CTT ID
1	Sleep	1	Bedroom lighting	Bedroom light did not turn off as expected	• System Quality	• Inadequate requirement capture	CL1-FR1
				Bedroom light remained on	• Logical error	• System specification	

Quality Traceability for User-centric Context-aware Systems in Intelligent Environments. Nawa Sakanga, Juan Carlos Augusto, Lindsey Brodie, and Liza Marzano. Proceedings of Internet of Healthcare Things Workshop, co-located with IEEE 8th World Forum on Internet of Things 26th of October − 11th of November 2022, Yokohama, Japan



MONITORING | EATING | SLEEPING | ELOPEMENT | WANDERING

Save Cancel

Schedules

From 07:00 to 09:00

From 13:00 to 14:30

From 19:00 to 21:00

Add period

Alerts

Alert to caregiver after 3600 seconds

Alert to user after 1800 seconds

Message

Message to user

Have you eaten already?

Reponses availabe to the user

- Yes
- No, I am going to eat now
- Peter cooked for me
- I am not hungry

Add response

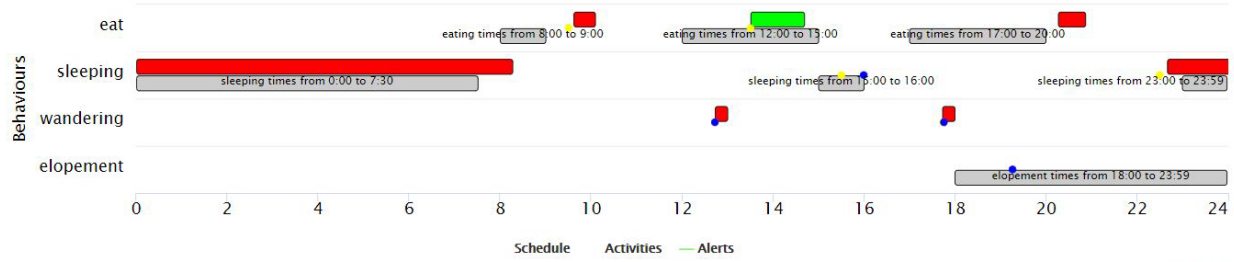
AnAbEL - User's Interface

MONITORING | EATING | SLEEPING | ELOPEMENT | WANDERING

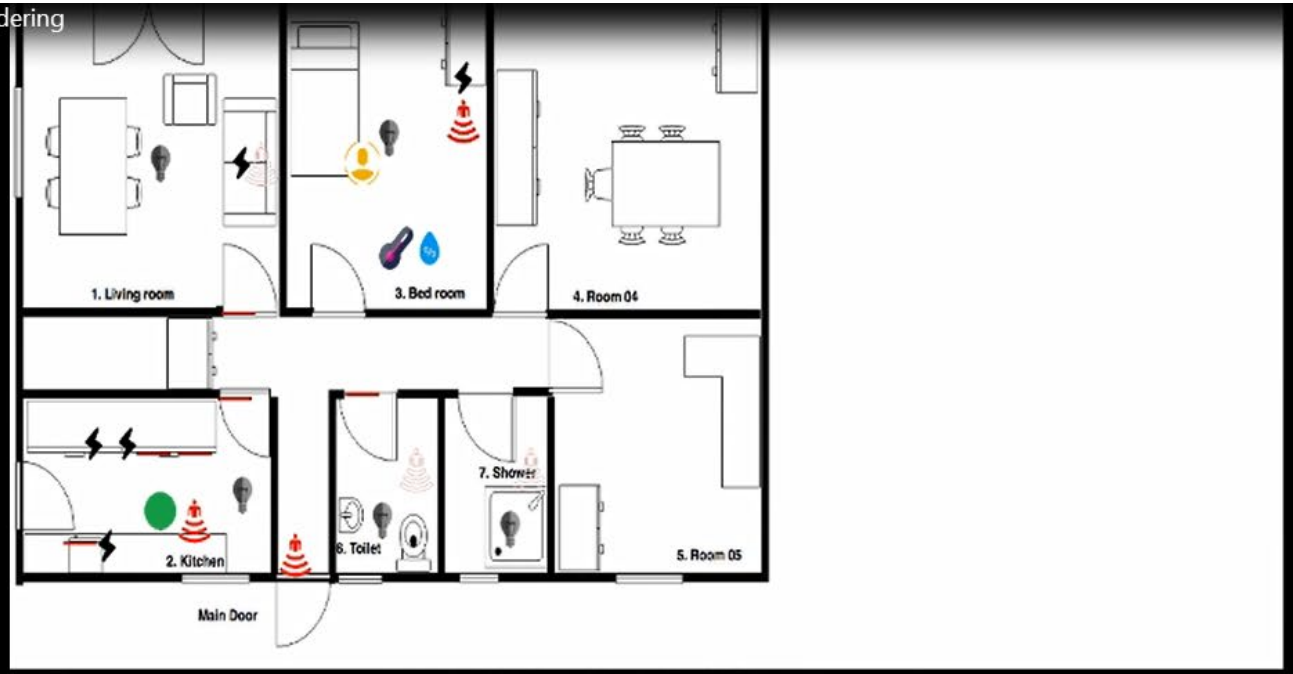
Save Cancel

Load Day 07/05/2019 Go

Daily Activities



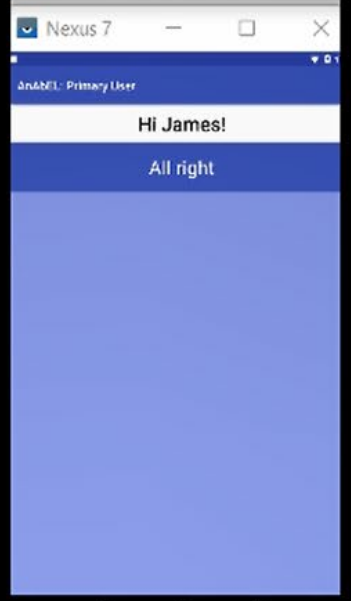
eat-wandering



INDOOR LOCALISATION

USER'S VIEW

PRIMARY USER



SECONDARY USER

MREASONER

M Specification File Editor | Database Results | LFPUBS Rule Translations

```
//ALERTS
ssr{([-][1800s.]eatSchedule ^ #healthyEating) -> eatAlertUser);
ssr{([-][3600s.]eatSchedule ^ #healthyEating) -> eatAlertCarer);
ssr{(skipMeal) -> eatAlertCarer);
//ssr{([-][1s.]#eatingOutTime ^ eatingOutTime)-> eatAlertCarer);

//reset for next meal
ssr{(<->[2s.]eatSchedule ^ #eatSchedule) -> #healthyEating);
ssr{(skipMeal ^ eatAlertCarer) -> #skipMeal);
ssr{([-][60s.]eatingOutTimeAlert ^ #eat)-> #eatingOutTimeAlert);
//ssr{([-][60s.]eatingOutTime ^ #eat)-> #eatingOutTime);

//RESET ALERTS
ssr{([-][60s.]#eatAlertUser ^ eatAlertUser)  -> #eatAlertUser);
ssr{([-][60s.]#eatAlertCarer ^ eatAlertCarer) -> #eatAlertCarer);



ssr{(clockBetween(00:00:00-07:59:59)) -> #eatSchedule);
ssr{(clockBetween(08:00:00-09:00:00)) -> eatSchedule);
```

Line: 85 Column: 102

```
ITERATION: 270 - 2019-10-03 17:19:03.236


*********  Change on State: 0 ******* INFO: 1-4: Gineslivingroom change 1 to 0
*********  Change on State: 1 ******* INFO: 1-5: Gineskitchen change 0 to 1

ITERATION: 271 - 2019-10-03 17:19:04.236


ITERATION: 272 - 2019-10-03 17:19:05.236


ITERATION: 273 - 2019-10-03 17:19:06.236

*********  Change on State: 1 ******* INFO: 505: KitchenMotion change 0 to 1
 ********** Warning! Polling process span 6537 ms


ITERATION: 274 - 2019-10-03 17:19:07.236

        Occurs( ingr( KitchenMotion ) ),274)

        Occurs( isKitchen ),274)
        isKitchen TRIGGERED BY ( KitchenMotion , Gineskitchen )

        isKitchen TRIGGERED BY ( KitchenMotion , Gineskitchen )
```

05:00


Made in Middlesex
While you're at Middlesex, say 'Yes'. Get involved in anything and everything and you'll really enjoy your time there.
Fil Kamps
Footballer for Team GB at Deaflympics
BSc Sport and Exercise Science
Class of 2016
Lola Young

DATA AND CONTEXT

- Sensor data helps to define contexts of users. On the other hand the quality of the interpretation of sensor data is proportional to its wider context.

- So data and context are powerfully related, and we need to consider these inter-relation more carefully.
- However, for two decades colleague have been using a definition of context-awareness which is mostly technology-oriented.

CONTEXT-AWARENESS

A more human/stakeholder-centric view is needed:

- Context: *the information which is directly relevant to characterize a situation of interest to the stakeholders of a system.*
- Context-awareness: *the ability of a system to use contextual information in order to tailor its services so that they are more useful to the stakeholders because they directly relate to their preferences and needs.*

Systems should be conceived more explicitly to serve humans!

A Smart Environments Architecture (SEArch), J. C. Augusto et al. Applied Artificial Intelligence. Taylor and Francis. 2020.

Context-aware Systems Architecture (CaSA). J. C. Augusto et al. Cybernetics and Systems, Taylor and Francis. 2021.

This then more naturally capture what humans expect from an Intelligent Environment…

- Beneficiary Context Perception (BCP): is the context as perceived by the beneficiary, where Perception here is understood as measured with the available infrastructure.
- Beneficiary Context Expectations (BCE): are the services the beneficiary expects in a given context.

Hence an Intelligent Environment can be seen as one that should work to optimize the alignment of BCE and BCP in favour of the main beneficiaries.

They can be calculated in real-time:

- ***BCE(p_i, s_j, c_k, b; t)*** measures how a beneficiary (*b*) prefers (p_i) a contextualized (c_k) service (s_j) at a certain time (t),
- ***BCP(p_i, s_j, c_k, b; t)*** measures how that beneficiary perceives the actual delivery of that service, then we can define the level of *Service*

Achievement Satisfaction of an IE system for beneficiary b at time t is:

SAS (IE, b, t)= $\sum_{i=1..p;\ j=1..s;\ k=1..c} |BCE(p_i, s_j, c_k, b; t) - BCP(p_i, s_j, c_k, b; t)| = 0$

That is the IE system should aim to achieve the best possible alignment of the user expectation with the user perception of system services at all times.

(A generalization *SASm(IE, B, t)* for multiple users also available)

Contexts and Context-awareness Revisited from an Intelligent Environments Perspective.
J.C. Augusto. Applied Artificial Intelligence, Taylor & Francis (2022)

Contexts for **I**ntelligent **En**vironments (CIEn) Theory:

CIEn=<B, S, C, Ops, A, OW> where:

B={B_1, B_2, . . . , B_b} is a finite set of beneficiaries,

S={S_1, S_2, . . . , S_s} is a finite set of services,

C={C_1, C_2, . . . , C_c} is a finite number of contexts,

with C_i=*[Name*, *Beneficiary*, *Activation*, *Effect],*

Ops={Op_1,Op_2, . . . ,Op_o} is a finite set of context operations,

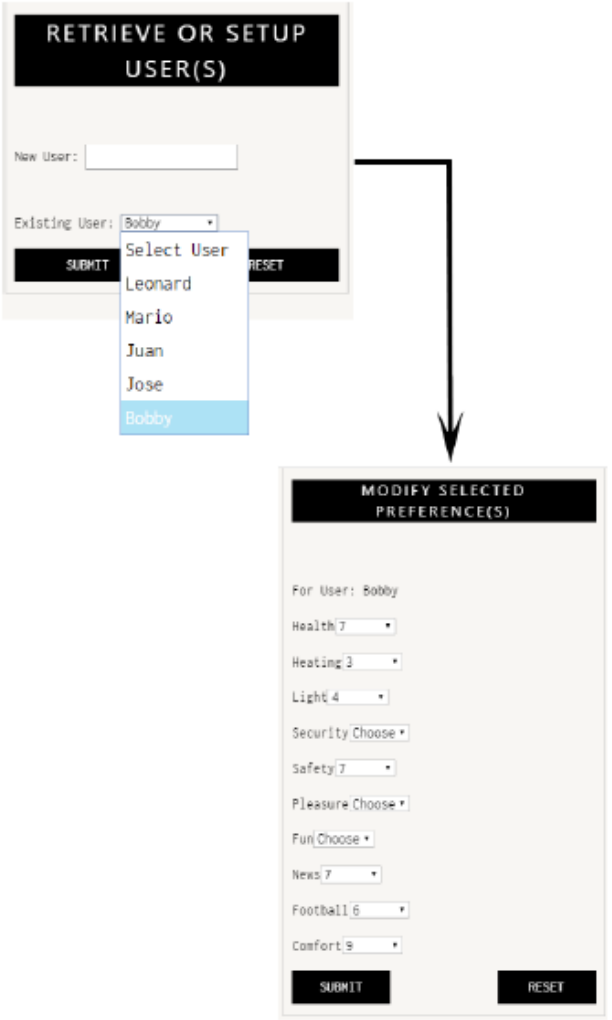
A={AI_1, AI_2,…,AI_a} a finite set of algorithms to process context information,

OW={… OW_i …} is a finite set of instances OW_i of observations of the real world.

More details in:

Contexts and Context-awareness Revisited from an Intelligent Environments Perspective.
J.C. Augusto. Applied Artificial Intelligence, Taylor & Francis (2022)

PERSONALIZATION, USER PREFERENCES ALIGNMENT



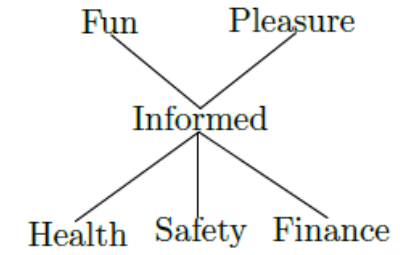


Figure 6: Ranking of Joe's Preferences

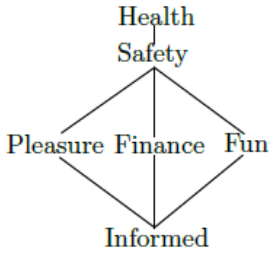
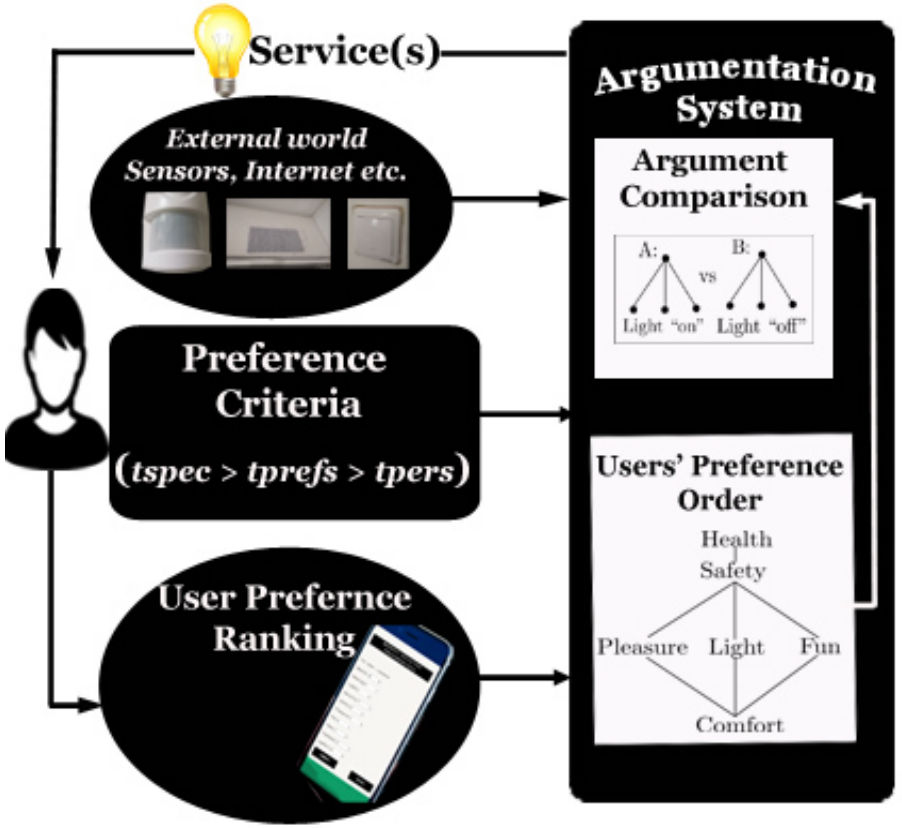
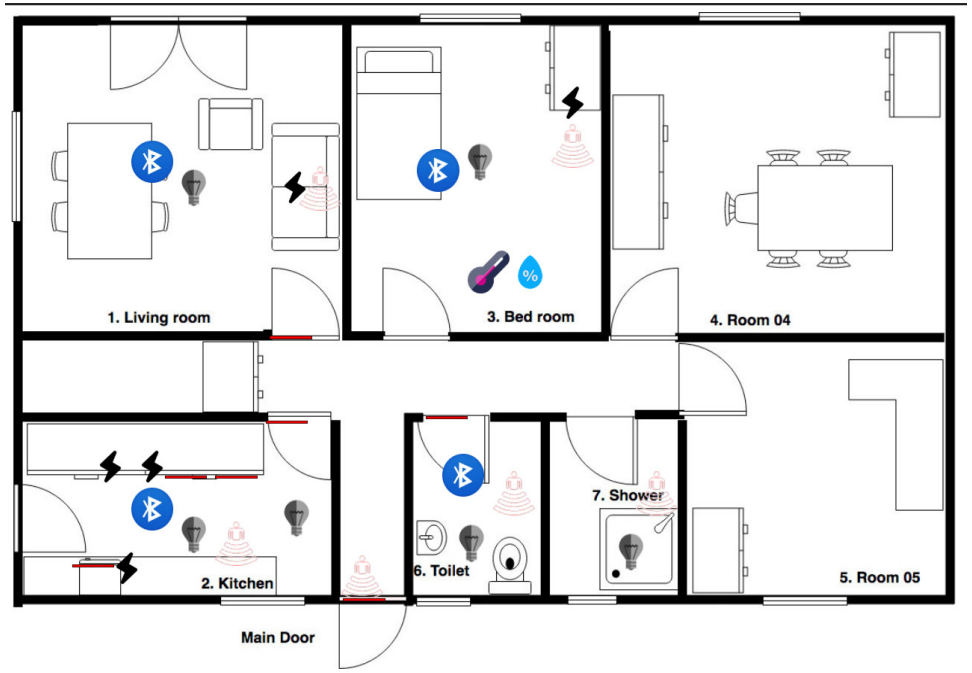


Figure 2: Ranking of Sara's Preferences



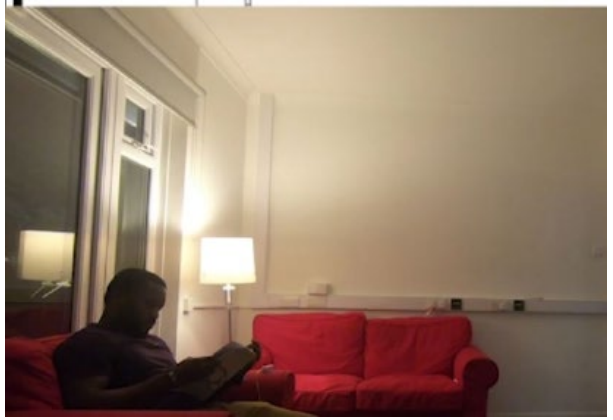
Using argumentation to solve conflicting situations in users' preferences in ambient assisted living. C. L. Oguego; J.C. Augusto; M. Springett; M. Quinde and C. James-Reynolds. Applied Artificial Intelligence, 35(15):2327-2369, Taylor and Francis. 2021.

DEALING WITH MULTIPLE USERS



Based on BLE beacons

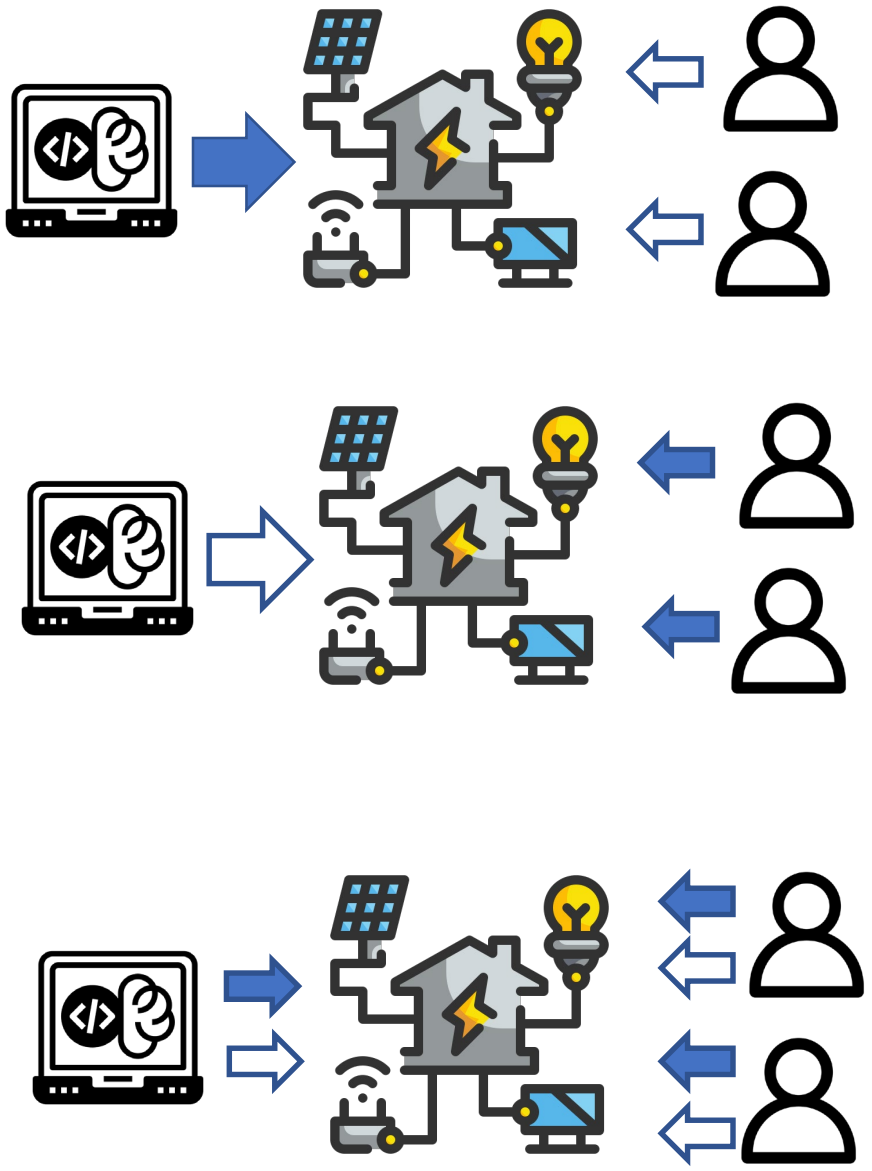
iBeacon
(Avvel International)



"Achieving Multi-User Capabilities through an Indoor Positioning System based on BLE Beacons". M. Quinde, J. Giménez-Manuel, C. Oguego and J. C. Augusto. Proceedings of 16th Int. Conf. on Intelligent Environments. Madrid, Spain, 20-24 of July 2020.

PREFERENCES SHARING

"Managing Preference Profiles in Multi-user Intelligent Environments". Juan Carlos Augusto and Andrés Muñoz. Proceedings of Citizen-Centric Smart Cities Services (CCSCS'2020) Workshop 20-21 July, Madrid, Spain.



SOME CHALLENGES AHEAD…

- How much information we will be willing to share with different smart environments (from which we do not know exactly their “real” policies): house, work, health, educational, entertainment, etc.
- How conflicting preferences will be solved?

- More on this towards the end…

- On the “Engineering Contexts” side of things we are behind what Industry needs.

- Many publications mention contexts and report on systems which use some sort of context related notion…

… however, they are mostly ad-hoc, it is rarely explained how contexts are defined, designed, related, maintained, modified, etc.

For more on this see:

Engineering Context Updates. Juan Carlos Augusto. Proceedings of Citizen-Centric Smart Cities Services Workshop (CCSCS’2022). Biarritz, France. 20-21 of June, 2022.


Made in Middlesex
While you're at Middlesex, say 'Yes'. Get involved in anything and everything and you'll really enjoy your time there.
Fil Kamps
Footballer for Team GB at Deaflympics
BSc Sport and Exercise Science
Class of 2016
Share your story using
Lola Yyong

TECHNOLOGY AND SOCIETY

Tesla's Privacy notice states:

"*Your privacy is and will always be enormously important to us*." … "*Tesla vehicles are equipped with a camera suite designed from the ground up to protect your privacy*" www.tesla.com/legal/privacy

However, in 2023 it emerged during 2019-2022 Tesla workers have been sharing images of:

- car owners walking naked in the garden
- Road accidents where a child in a bike was hit by a Tesla car
- Some pictures captured by the cameras were turned into memes and circulated internally

Tesla says after this was discovered Tesla cars terminated the feature which allowed cars to send recorded videos to Tesla if the user consented in the initial agreement.

If a company with the resources of Tesla and the commitment to privacy stated above does this, what can we expect from the rest… (most of which have generic privacy statements just to cover themselves legally but says nothing specific nor reassuring).

And… did they not know this could happen?

The introduction of technology has to be sensitive to the user and abide to the principle that the human is the master and the computer the slave and no the other way round (Dertouzos, 2001)

Michael Dertouzos (2001) Human-centered Systems.

Chapter in: The Invisible Future. P. Denning (editor) ACM Press, USA, pp 181–192.

THE 9 PRINCIPLES FOR I.E.

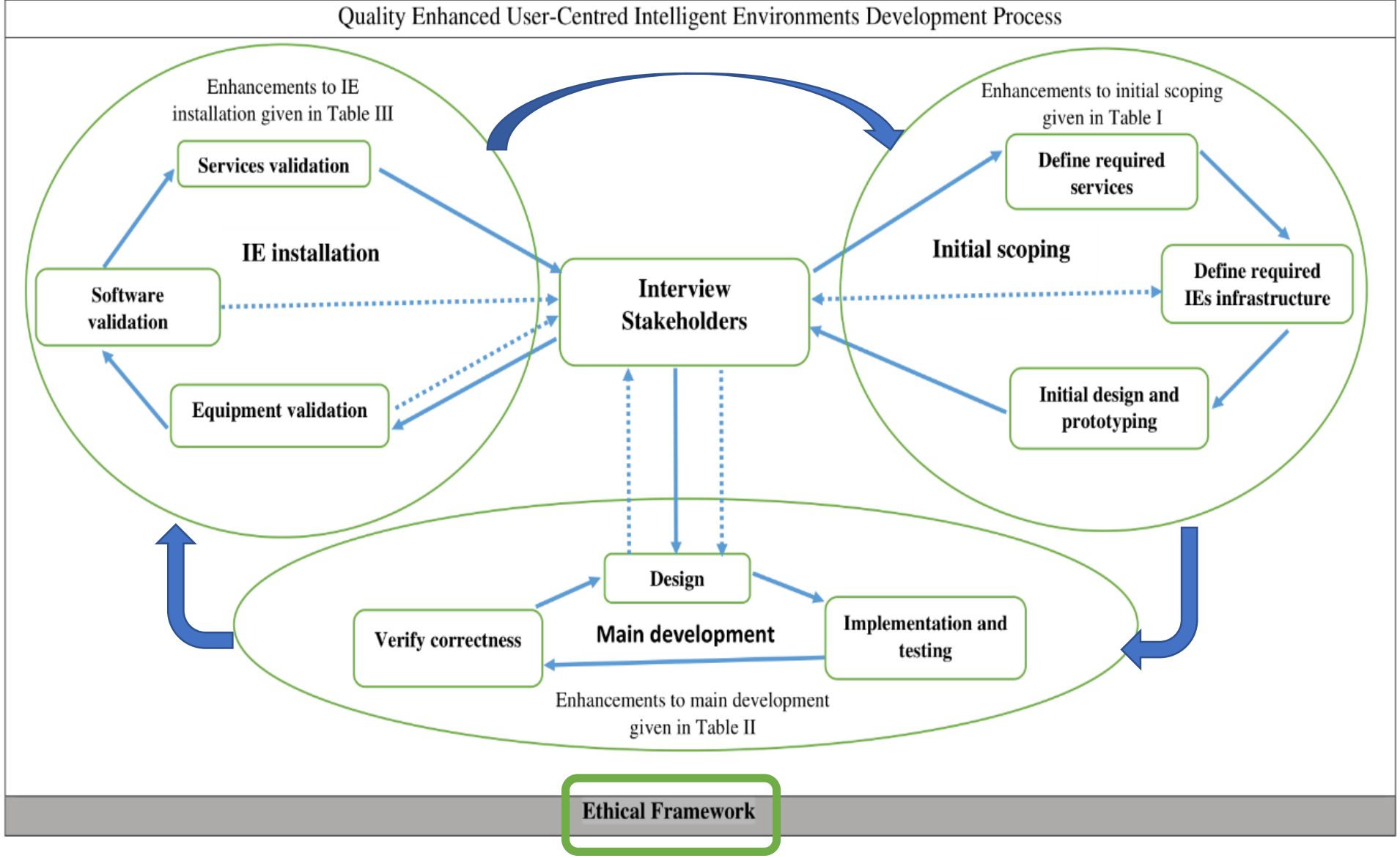
P1) *to be intelligent to recognize a situation where it can help.*
P2) *to be sensible to recognize when it is allowed to offer help.*
P3) *to deliver help according to the needs and preferences of those which is helping.*
P4) *to achieve its goals without demanding from the user/s' technical knowledge to benefit from its help.*
P5) *to preserve privacy of the user/s.*
P6) *to prioritize safety of the user/s at all times.*
P7) *to have autonomous behaviour.*
P8) *to be able to operate without forcing changes on the look and feel of the environment or on the normal routines of the inhabitants' environment.*
P9) *to adhere to the principle that the user is in command and the computer obeys, and not viceversa.*

Intelligent Environments: a manifesto. Juan C. Augusto, Vic Callaghan, Achilles Kameas, Diane Cook, Ichiro Satoh. Human-centric Computing and Information Sciences, 3:12, 2013. 2013. Springer. DOI: 10.1186/2192-1962-3-12 URL: http://www.hcis-journal.com/content/3/1/12

"**A User-Centred Software Development Process**". Juan Carlos Augusto. Proc. of the 10th Int. Conf. on Intelligent Environments,Shanghai, 2014. IEEE Press.

"**Quality Traceability for User-centric Context-aware Systems in Intelligent Environments**". N. Sakanga et al. Proc. of Internet of Healthcare Things Workshop, Yokohama, 2022.

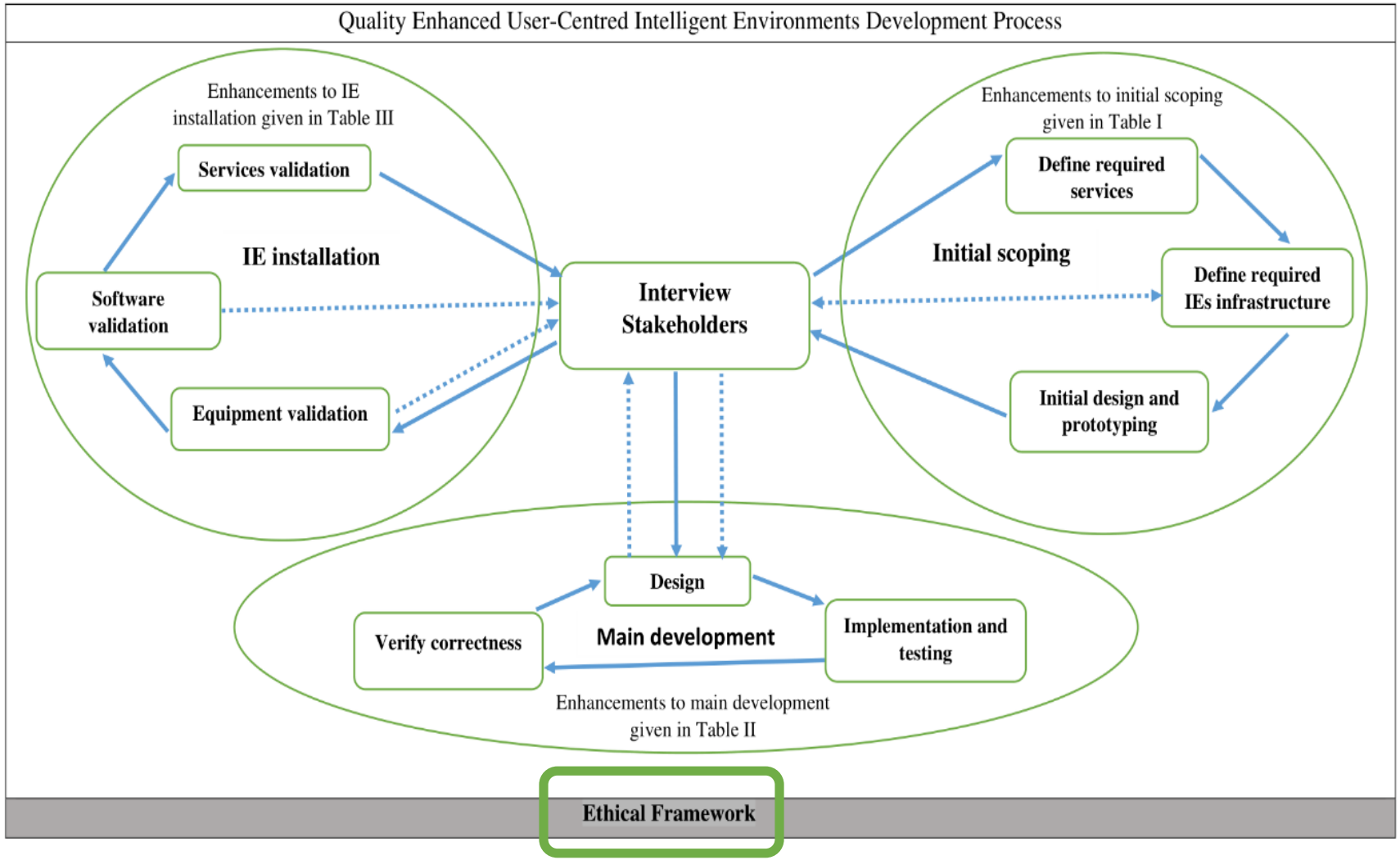
"**Towards Engineering Higher Quality Intelligent Environments: A Multi Case Study Approach**". A. Santokhee et al. Submitted to an International Journal.



eFRIEND: A PRACTICAL GUIDE FOR DEVELOPERS

Generic Principles	Examples
Non-Maleficence and Beneficence	System should proactively help and assist users
User-Centred	Systems should be customisable to individual needs, preferences and requirements
Multiple Users	System should be aware of different needs and preferences of all individuals in a multi-user environment
Privacy	Users decide on, and can change, the level of acceptable recording, monitoring and tracking of activities
Data Protection	Users can determine level of information disclosure
Security	Provide adequate security measures and standards, appropriate to different environments
Autonomy	Freedom to customise, adjust, override, switch off
Transparency	To inform users of the pros and cons of the services
Equality, Dignity and Inclusiveness	Help, regardless of age, technical background and ability

eFRIEND: an Ethical Framework for Intelligent Environment Development. Simon Jones, Sukhvinder Hara, Juan Carlos Augusto. Ethics and Information Technology (17)12. March 2015, Springer.



EU Project POSEIDON had 60+ ethical requirements

Ah! Requirements have to be tracked into final product!

eFRIEND IN PRACTICE...

CONCLUSIONS

- **As usual the problem is not in the tools but on what humans make of them**
- So we have seen there are shortcomings at all stages:
  - Sensors data acquisition
  - Sensor data processing
  - Interface between system and society
- Of course there has been progress and benefits: early diagnosis, fitness apps encouraging healthier lifestyles, etc.
- Despite the lack of engineering tools some systems have been built, however we need to improve their quality. At all stages, from regulations onwards, more interaction with AI/SE/HCI.
- Currently data being processed is mostly physiological. What will happen when machines (and companies) know more about individuals' stressors and fears?
- In the fourth helix of innovation: companies and politicians are not best placed to look after the common good, citizens and academics are, and we have an important historical role here on making innovation safer.

ONE WAY YOU CAN IMPROVE THINGS IS BY CONTRIBUTING TO THE:

SMART HEALTH HANDBOOK

Write to me if you are interested: j.augusto@mdx.ac.uk

(link to access publications mentioned in these slides)