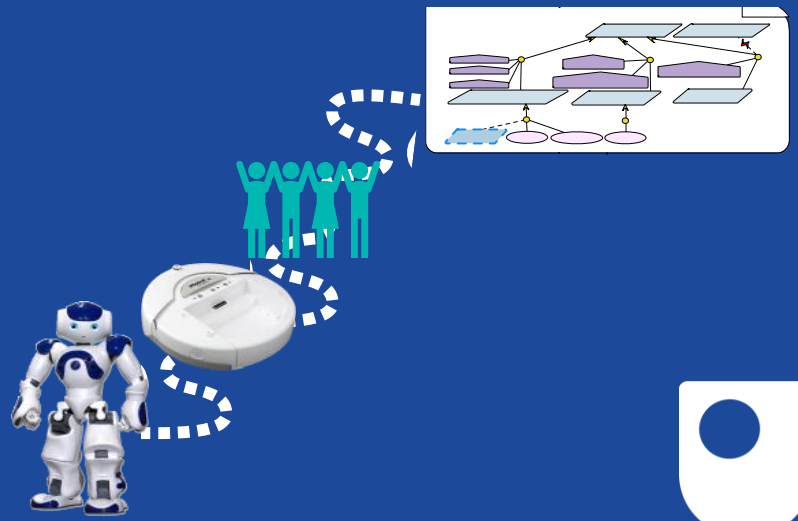
The Road to Collaboration is Paved with Goals

Dr Amel Bennaceur
amel.bennaceur@open.ac.uk

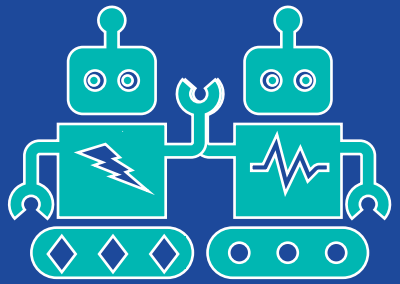


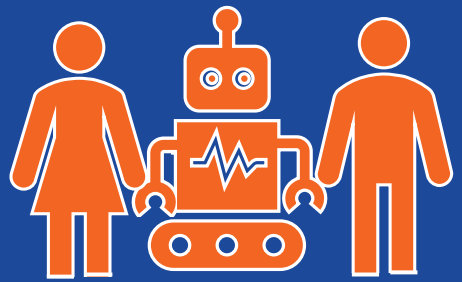
The Open University

Nothing worthwhile can be achieved in isolation

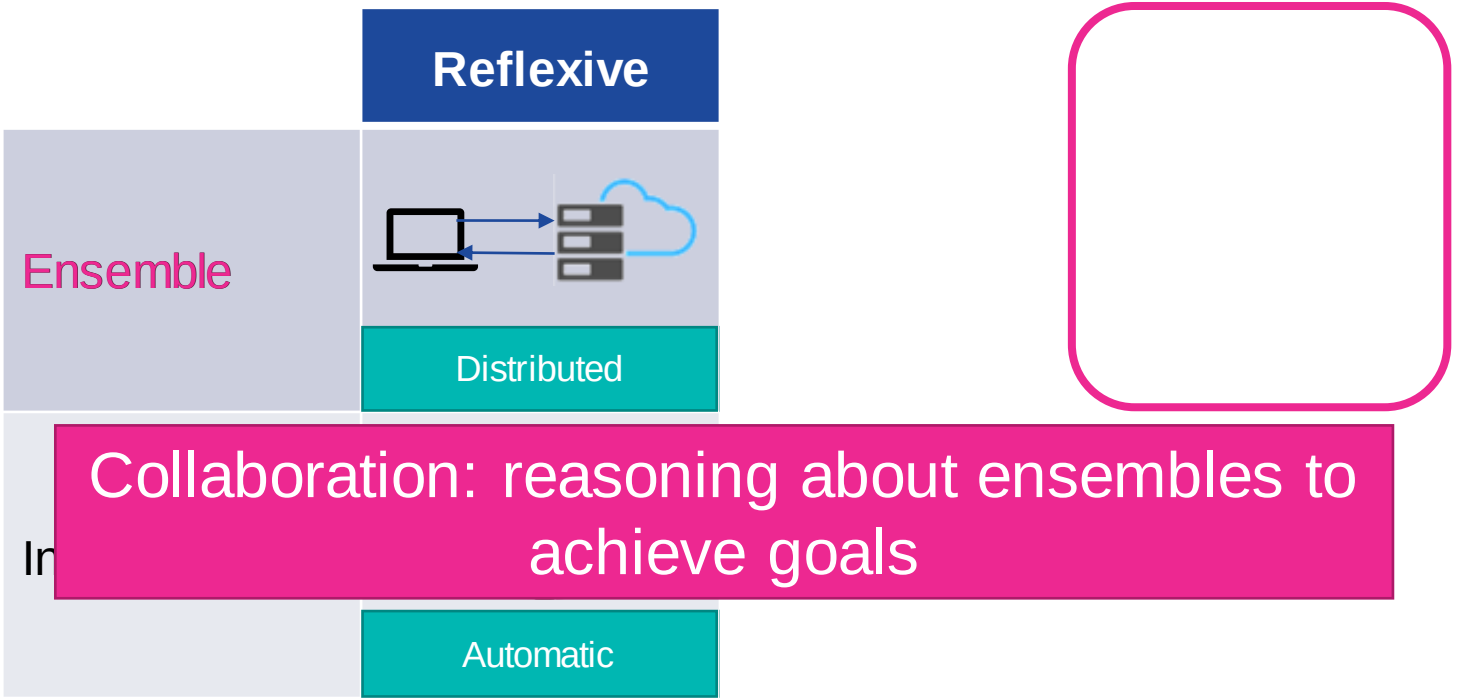
People and Agents can achieve more goals through collaboration

? How to enable collaboration between autonomous agents and between autonomous agents and humans?





Collaboration as Reasoning about Ensembles



Castro, Mosterman, Rajhans, Valenti, Challenges in the Operation and Design of Intelligent Cyber-Physical Systems (2019)

Different Types of Ensembles

How to achieve goals?

How to represent and reason about goals?

Services

Robots

Resources

Socio-Technical

Robot-Humans

People

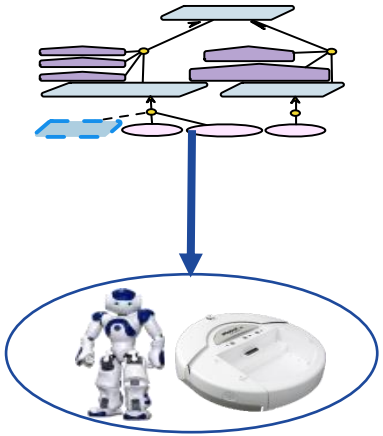
Cyber

Physical

Social

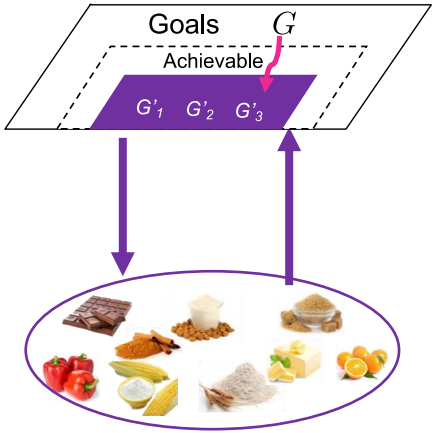
The Journey

Assured Goal-driven Mediation



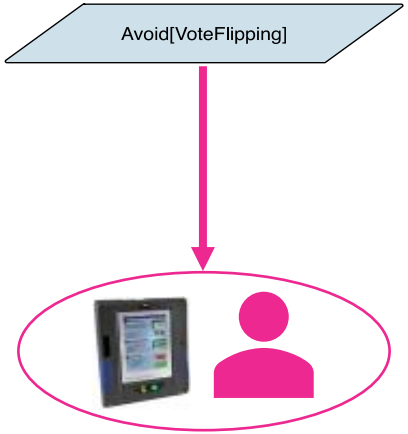
Collaborative Security

Resource-driven Goal Adaptation



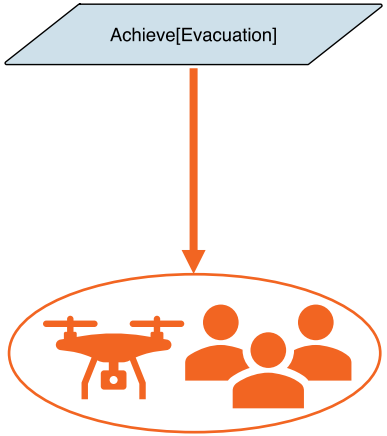
Adaptive Recipe Recommendations

Relaxing User Obligations



Revised eVoting System

Group Identity Awareness

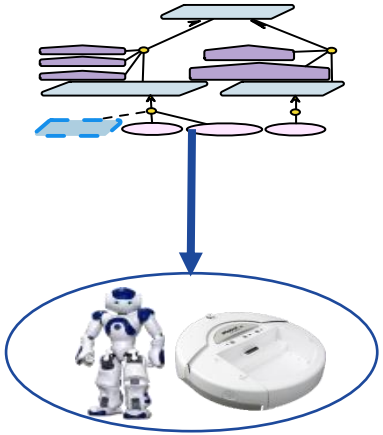


Adaptive Rescue Robot

Cyber — Physical — Social

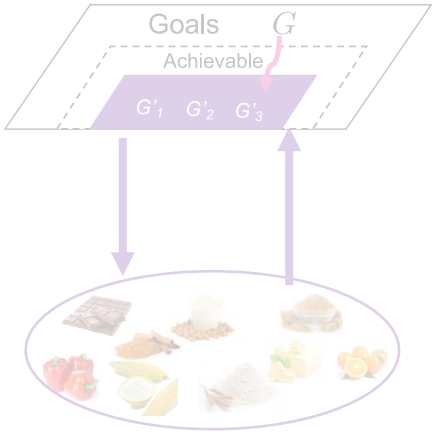
The Journey

Assured Goal-driven Mediation



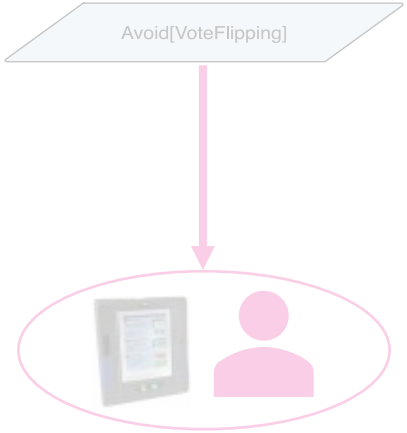
Collaborative Security

Resource-driven Goal Adaptation



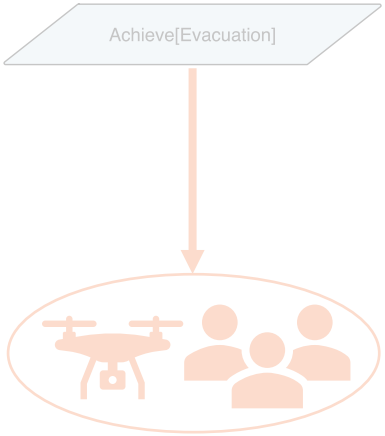
Adaptive Recipe Recommendations

Relaxing User Obligations



Revised eVoting System

Group Identity Awareness

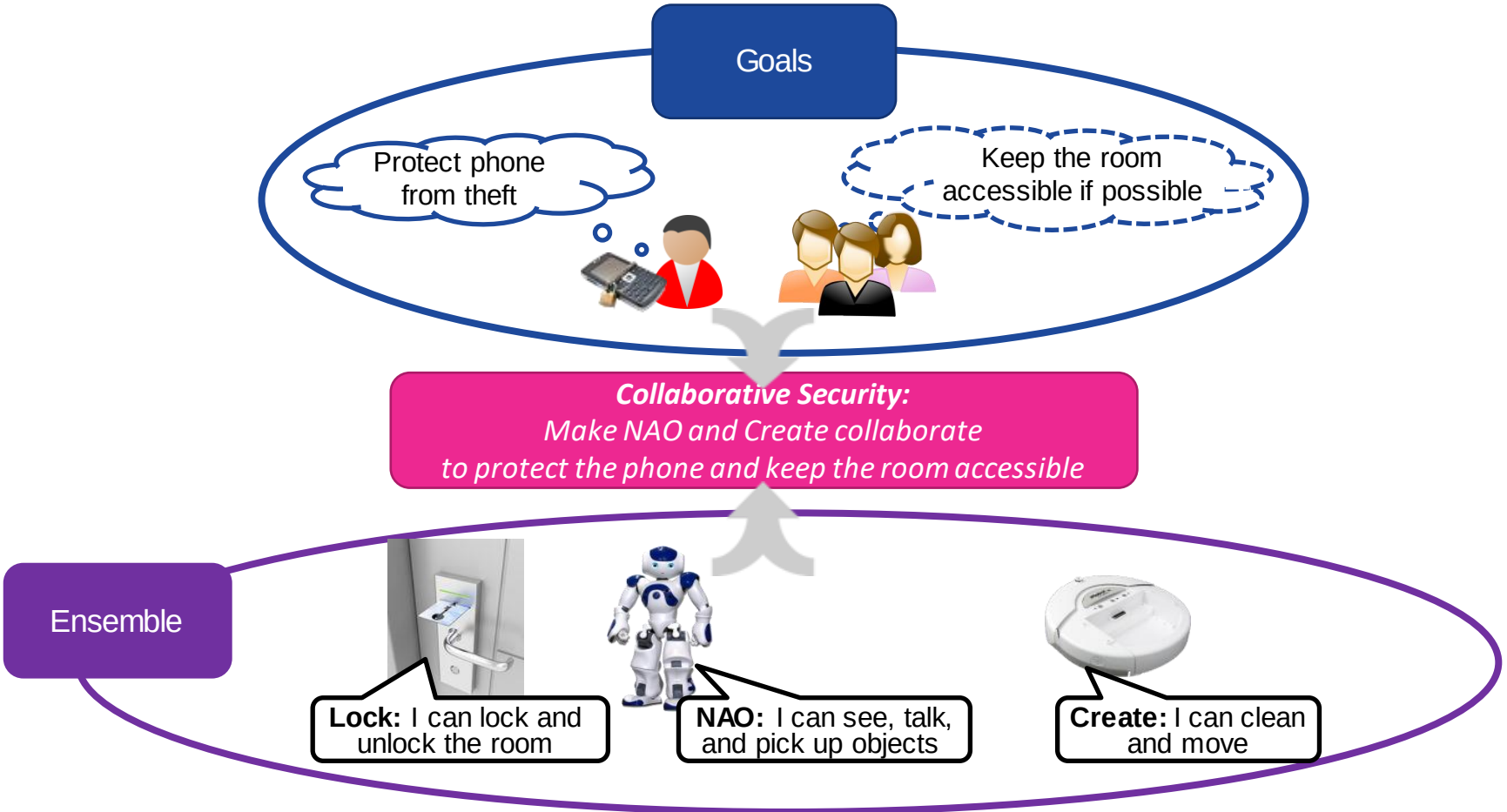


Adaptive Rescue Robot

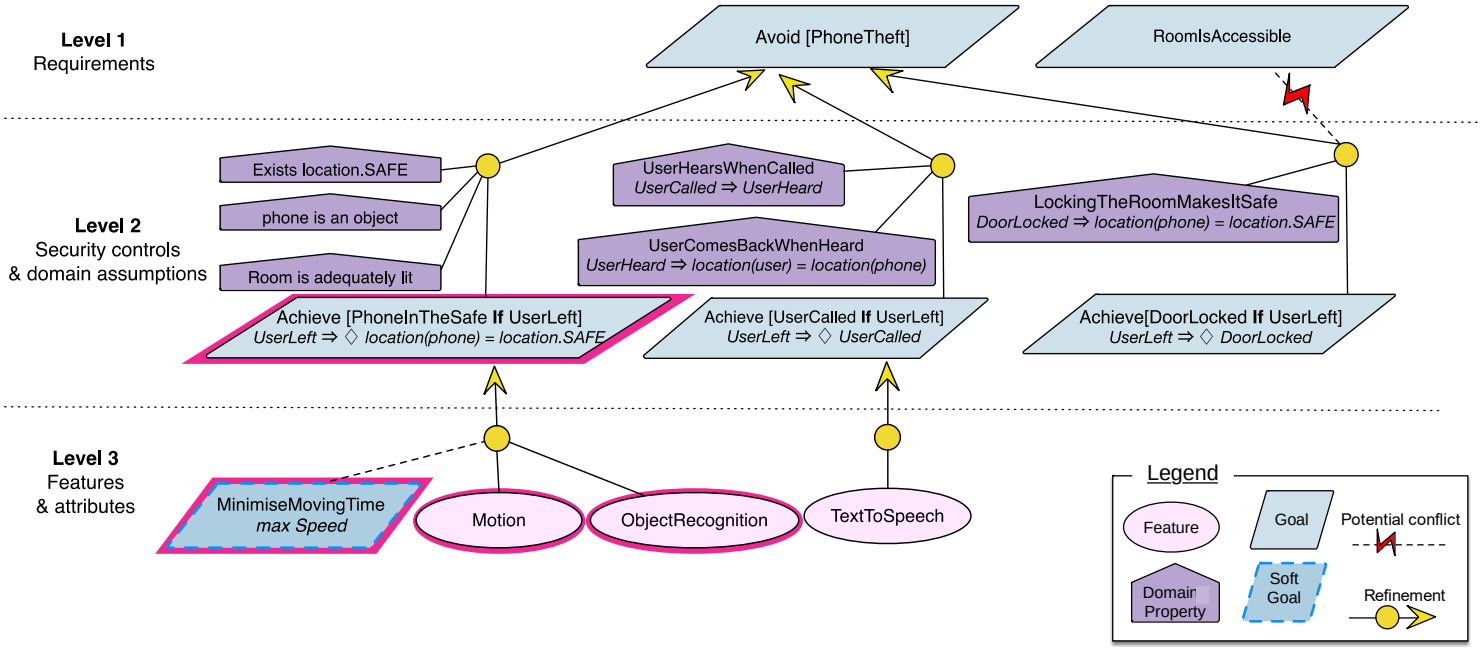
Cyber — Physical — Social

Collaborative Security

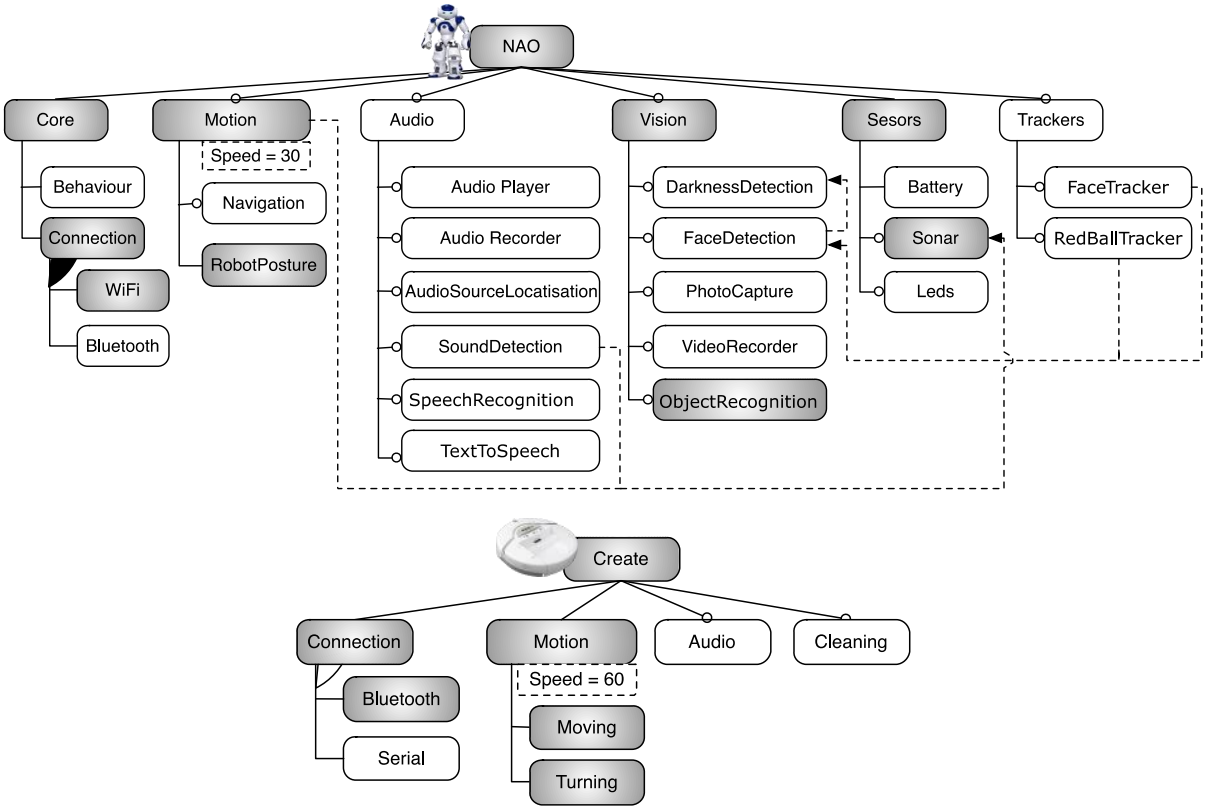
Collaborative Security - Example

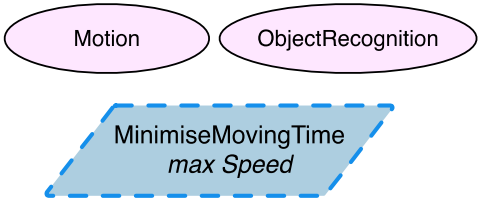


Specifying (and Refining) the Requirements

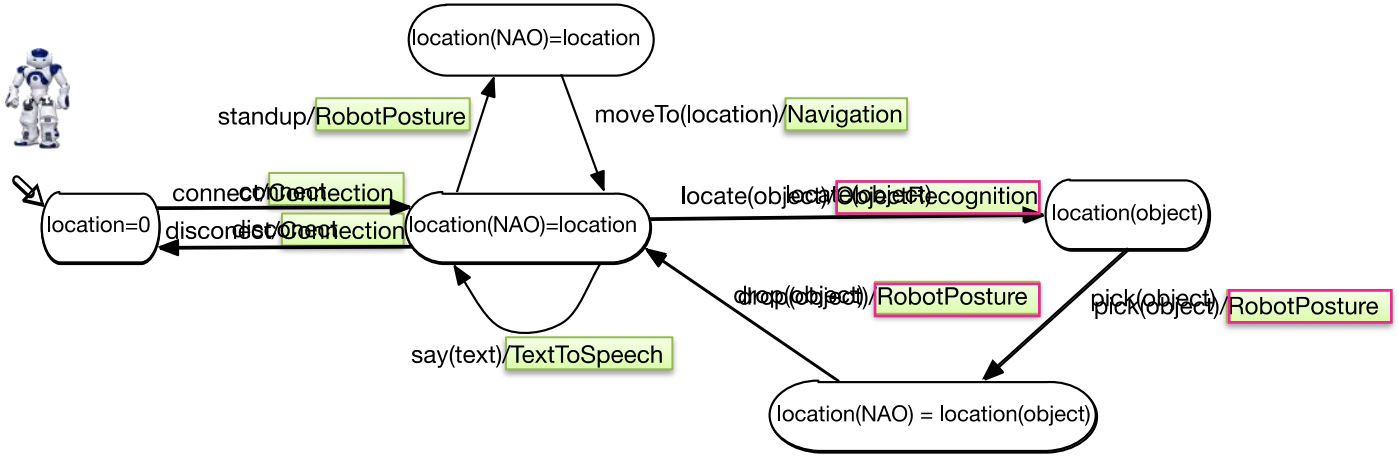


Selecting Features

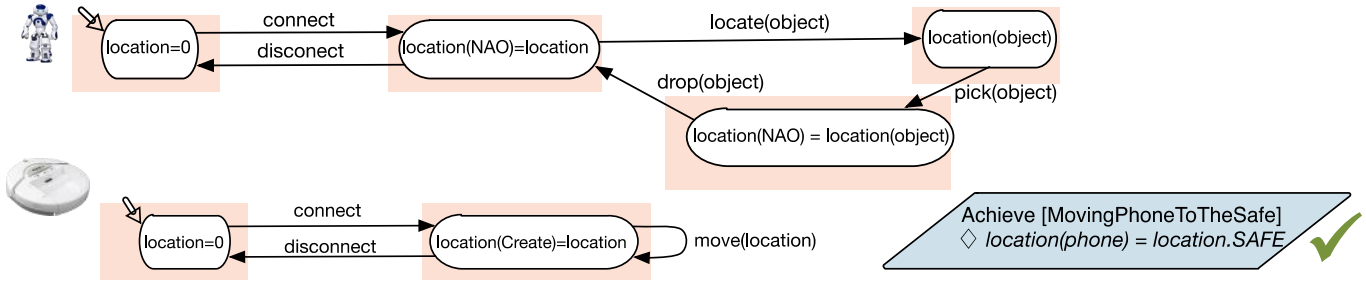




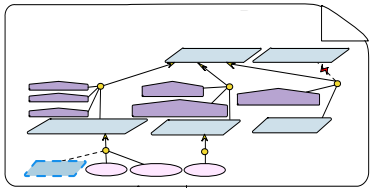
Projecting the Behaviour



Coordinating the Behaviour

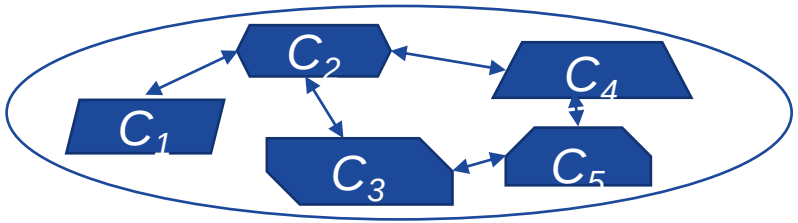


Putting it Together – Collaborative Security



$G = \{G_n, G_1, ..., Gm\}$ partially ordered set of goals

$\forall C \in \mathcal{P}(S)\ E, C \not\models E \models G$

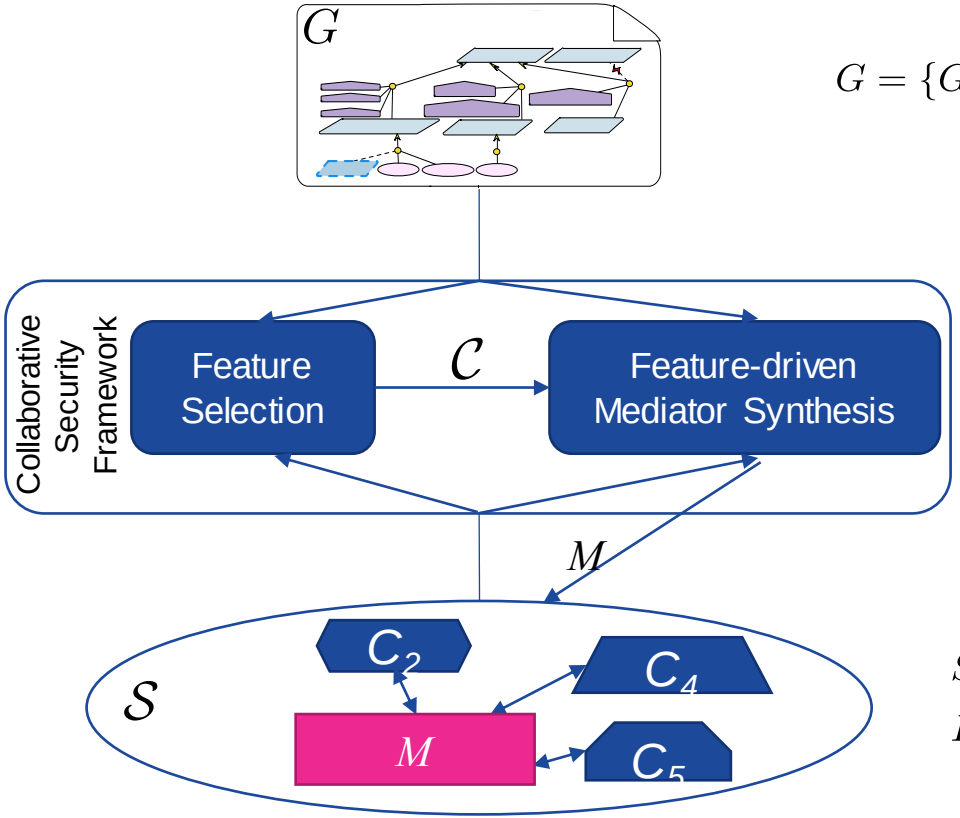


$S = \{C_1, ..., Cm\}$ set of Components' capabilities

E environment properties

Bennaceur, Tun, Bandara, Yu, Nuseibeh: Feature-Driven Mediator Synthesis: Supporting Collaborative Security in the Internet of Things. ACM Trans. Cyber Phys. Syst. (2018)

Putting it Together – Collaborative Security



$G = \{G_n, G_1, ..., Gm\}$ partially ordered set of goals

Find $\mathcal{C} \subseteq \mathcal{P}(\mathcal{S})$ and synthesise M such that $\mathcal{C}, M, E \vdash G$

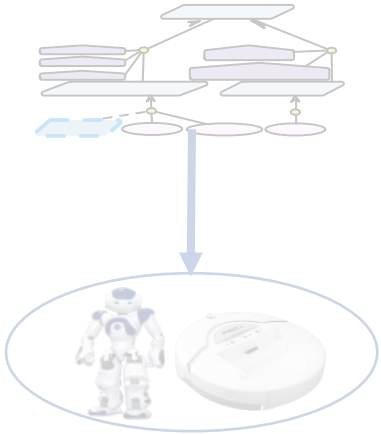
$S = \{C_1, ..., Cm\}$ set of Components' capabilities

E environment properties

Bennaceur, Tun, Bandara, Yu, Nuseibeh: Feature-Driven Mediator Synthesis: Supporting Collaborative Security in the Internet of Things. ACM Trans. Cyber Phys. Syst. (2018)

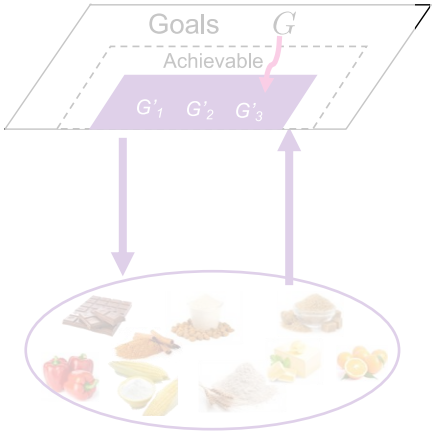
The Journey

Goal-driven mediation



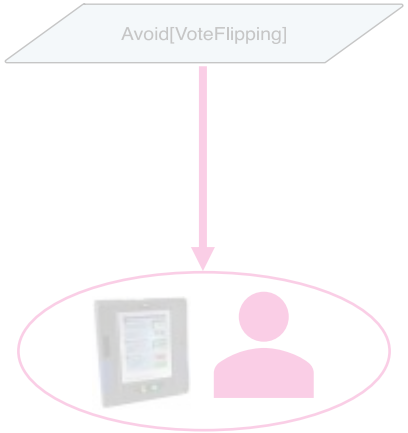
Collaborative Security

Resource-driven Goal Adaptation



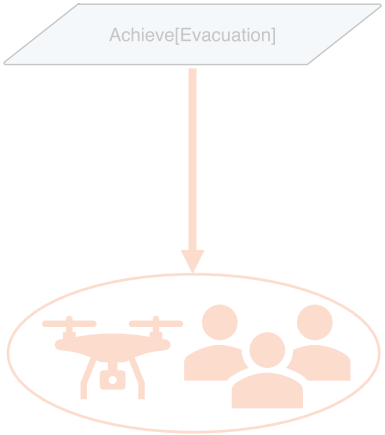
Adaptive Recipe Recommendations

Relaxing User Obligations



Revised eVoting System

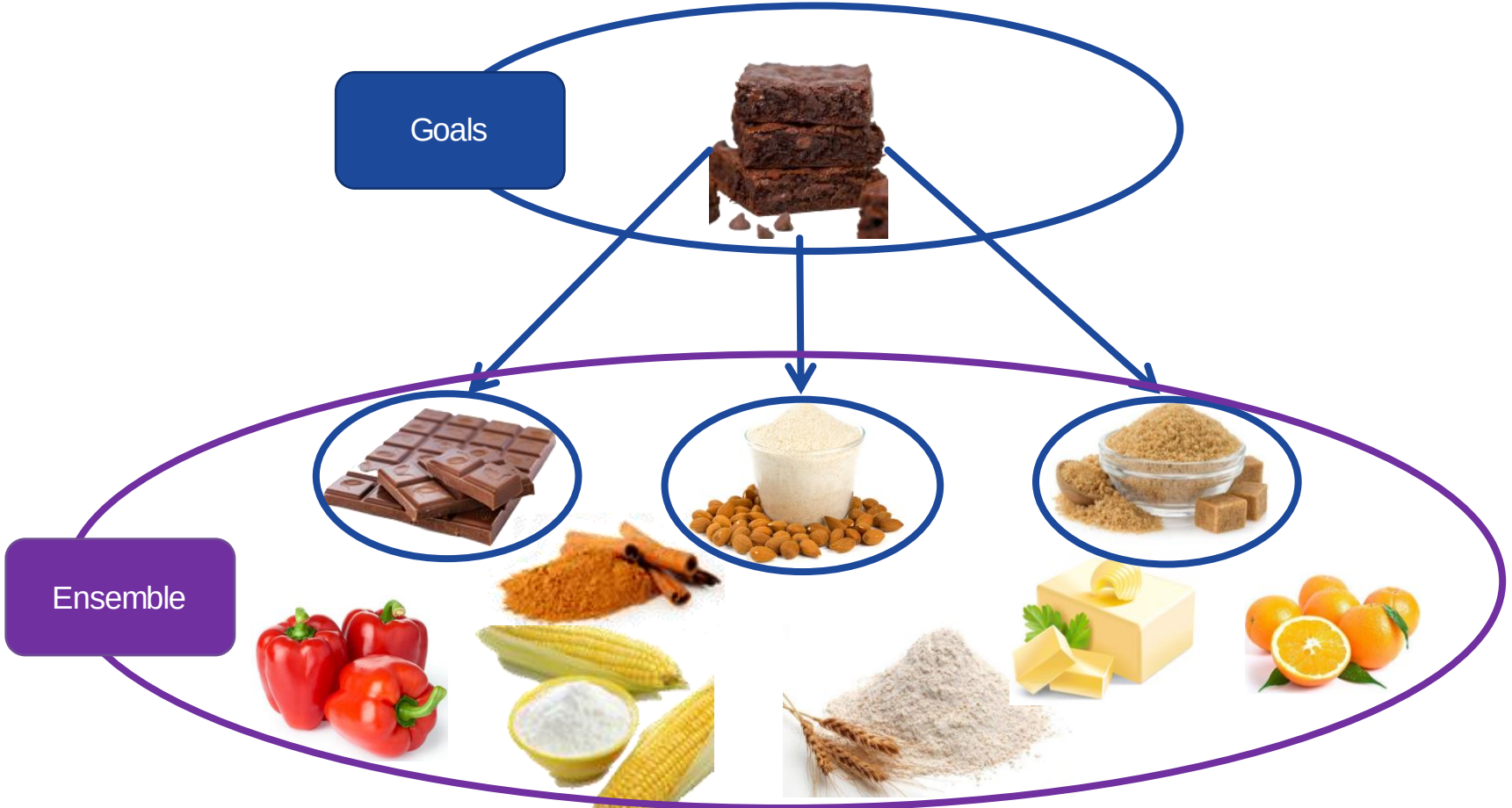
Group Identity Awareness



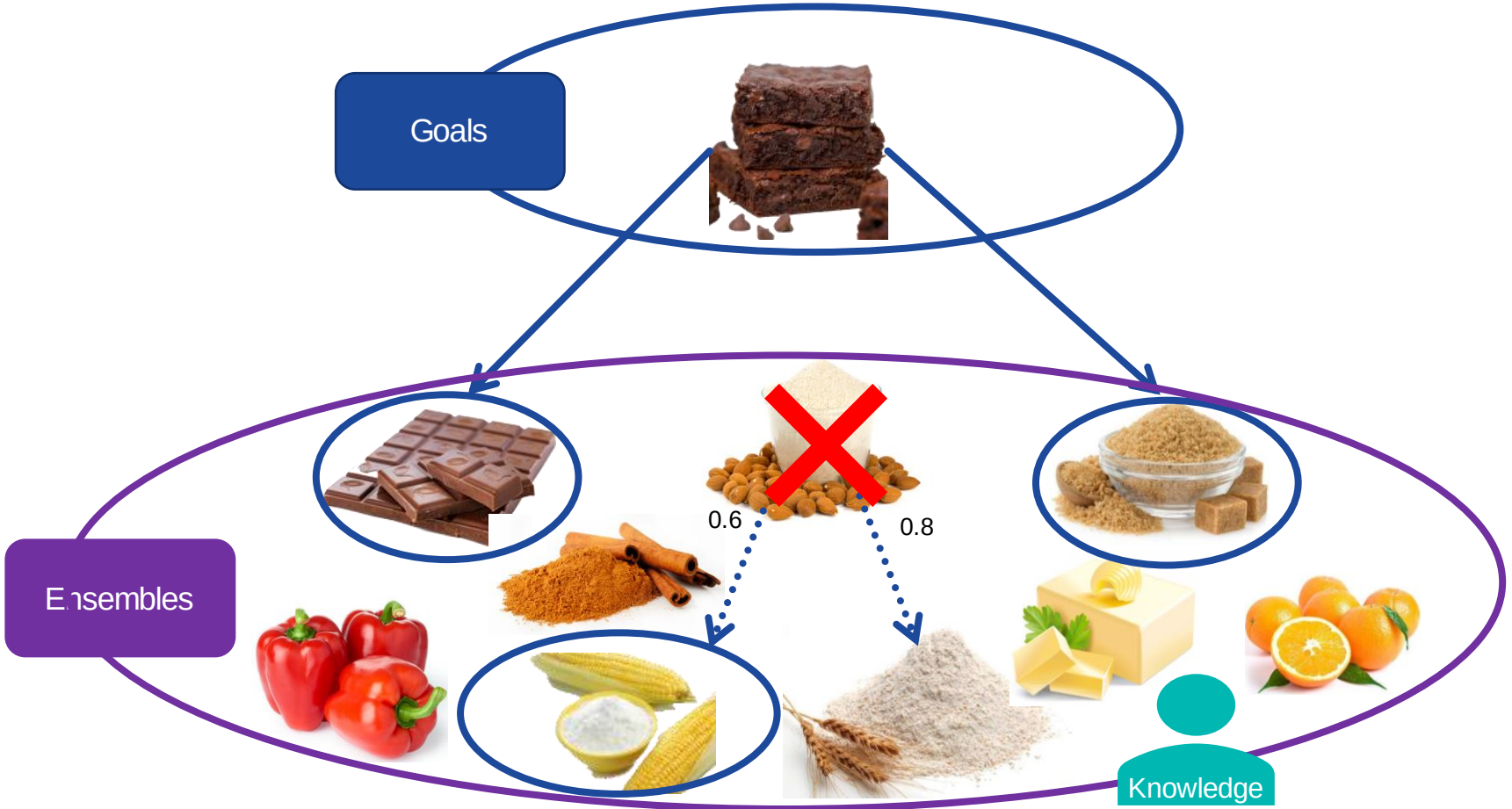
Adaptive Rescue Robot

Cyber — Physical — Social

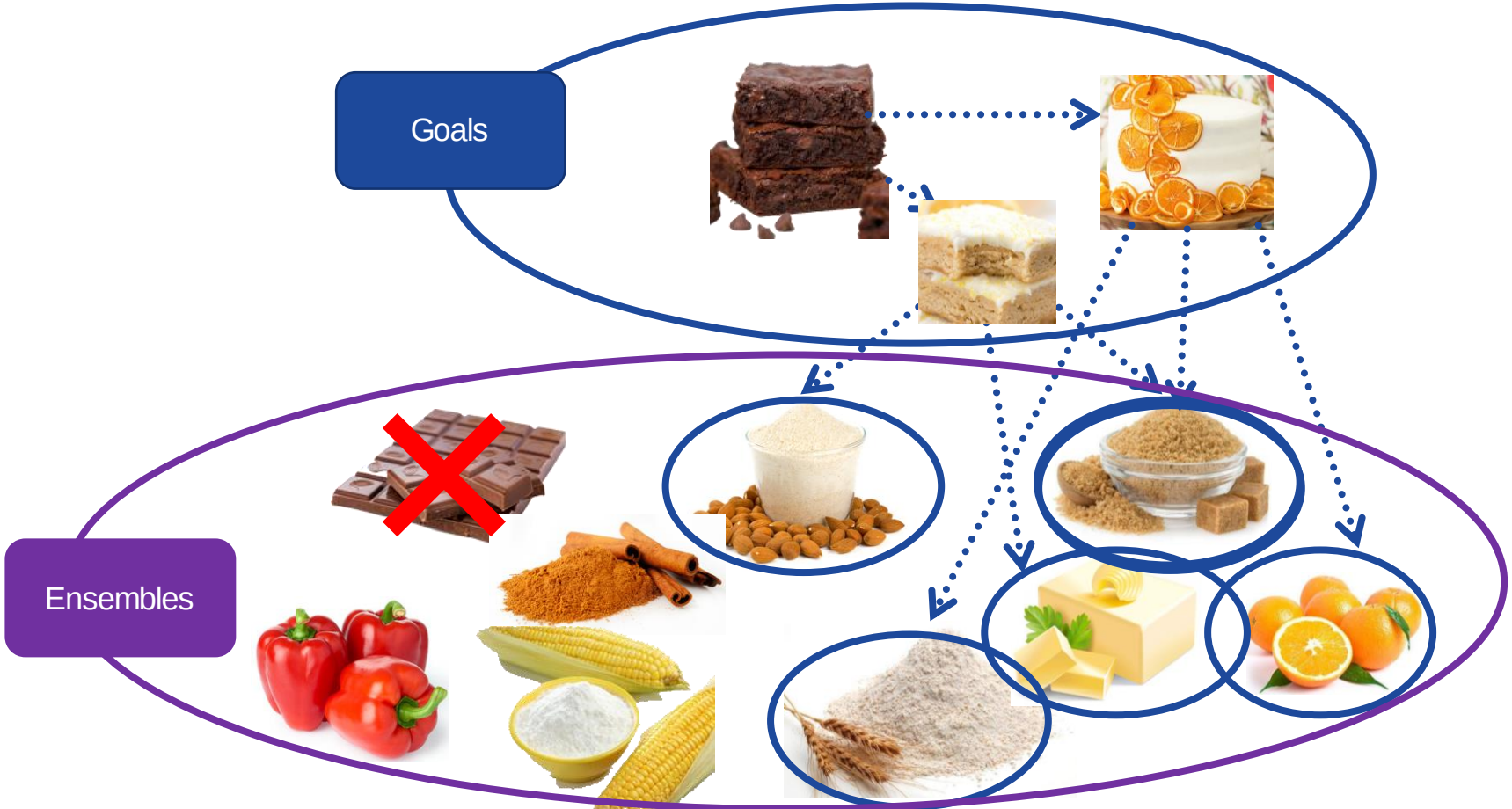
Example - Goal-driven Composition



Example - Substitution



Example - Resource-driven Goal Adaptation



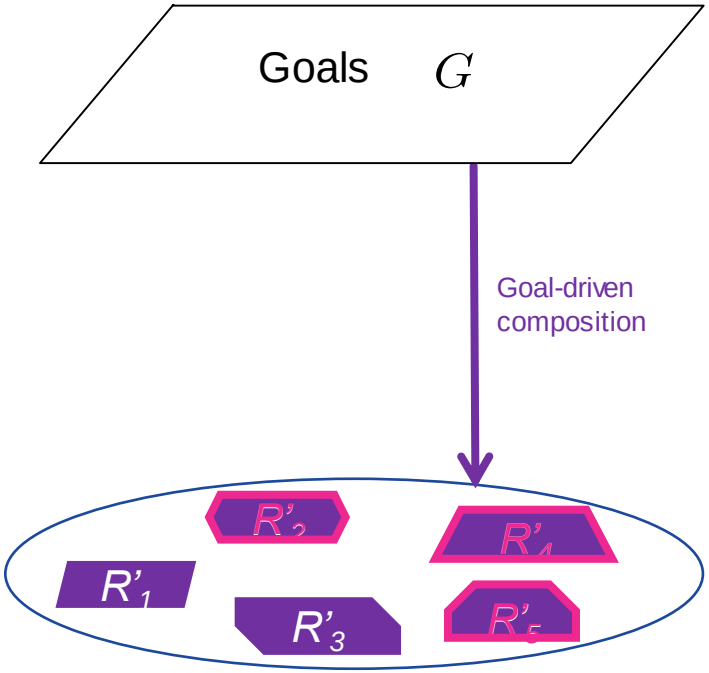
Goal-driven Composition – Top Down

Let G be the set of goals we seek to achieve

$\mathcal{R}'$ the set of available resources

Seek a set of resources to achieve the goals

Find $S \subseteq \mathcal{R}'$ such that $S \models G$



Substitution – Top Down

Let $G, \mathcal{R}'$ ...

$M \subseteq 2^R \times 2^R \times \mathbb{Z}$ matching function

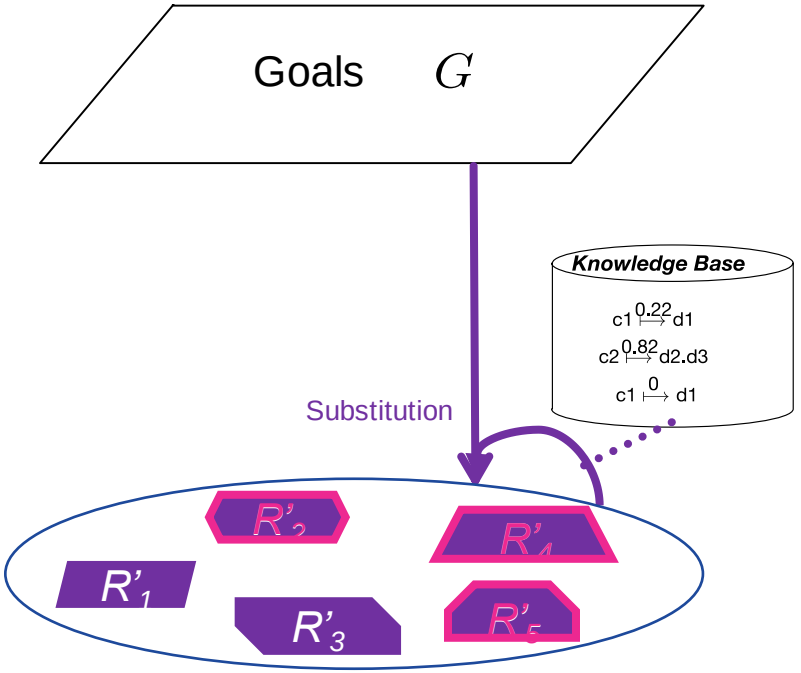
$\mathcal{R}$ the set of all resources

Seek a set of resources to achieve the goals

Find $S \subseteq R'$ and $S' \subseteq R$

such that $S \approx S'$ $\left[max \prod_{s' \in R',\ s \in R} M(s', s) \right]$

and $S' \models G$



Constraint Optimisation Problem

Substitution – Bottom Up

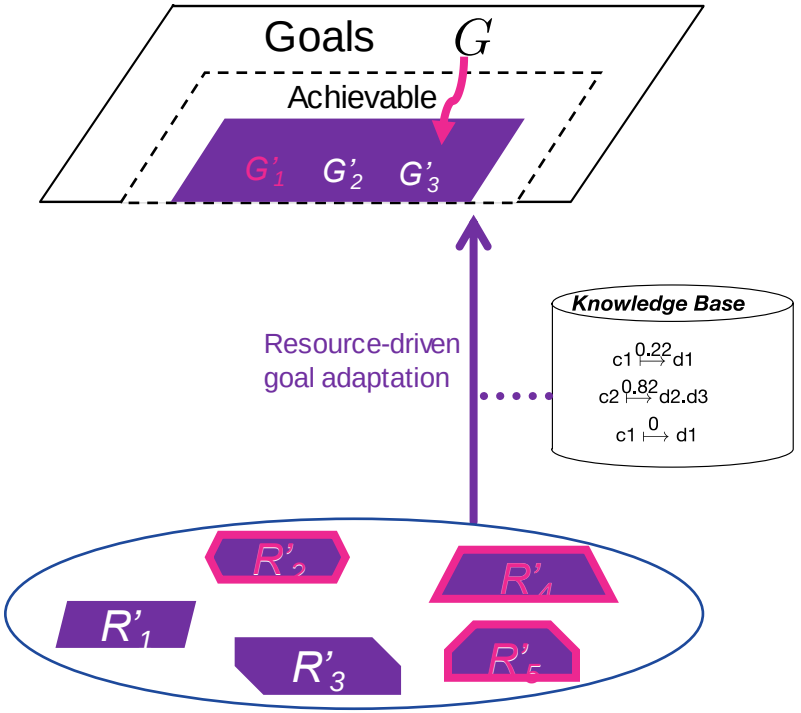
Let $G, \mathcal{R}', \mathcal{R}, M \subseteq 2^R \times 2^R \times \mathbb{Z}$ ...

Seek a set of resources to achieve the goals

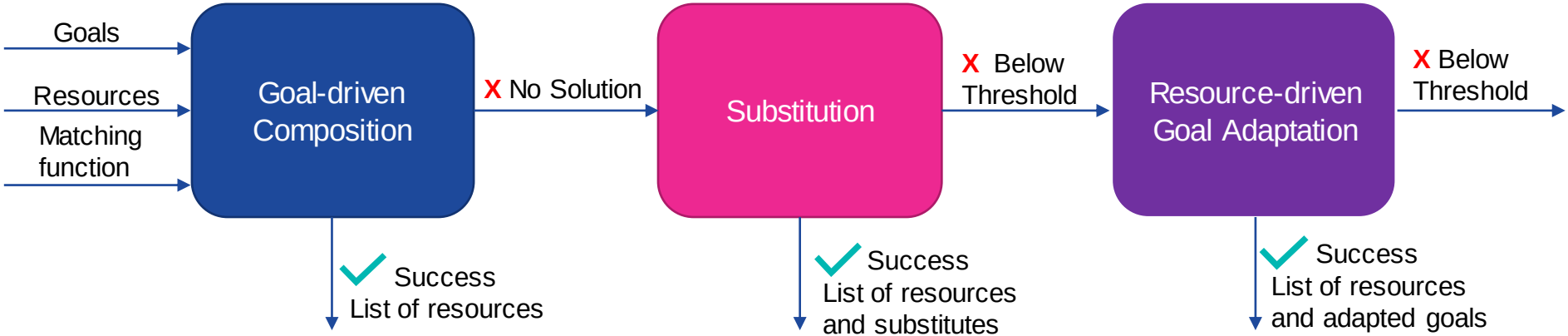
Find $G' \approx_G G$ and $S \subseteq R'$

such that $S \models R'$

$\approx_G$ is application/domain specific



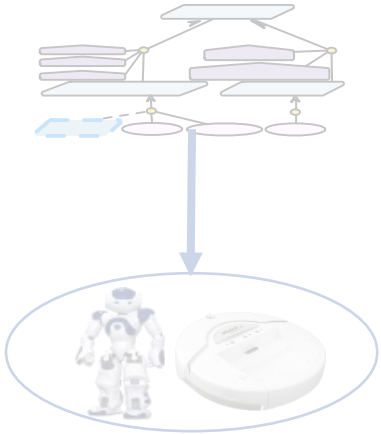
Putting it Together – Three Way Adaptation



Bennaceur, Zisman, McCormick, Barthaud, Nuseibeh: Won't take no for an answer: resource-driven requirements adaptation. SEAMS@ICSE (2019)

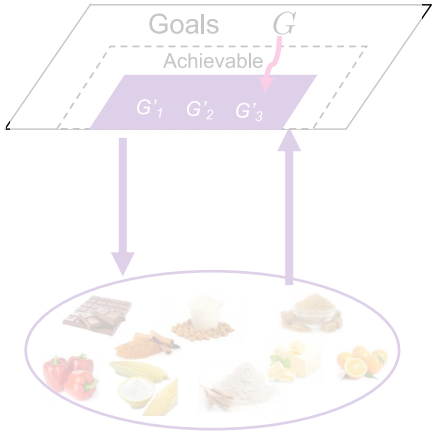
The Journey

Goal-driven mediation



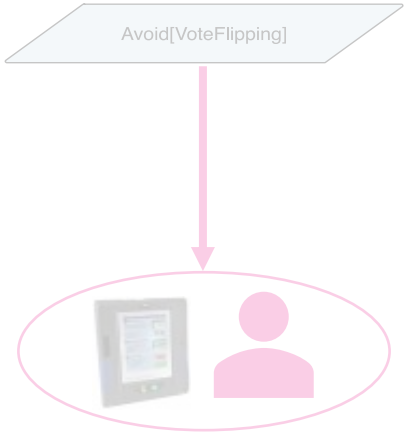
Collaborative Security

Resource-driven Goal Adaptation



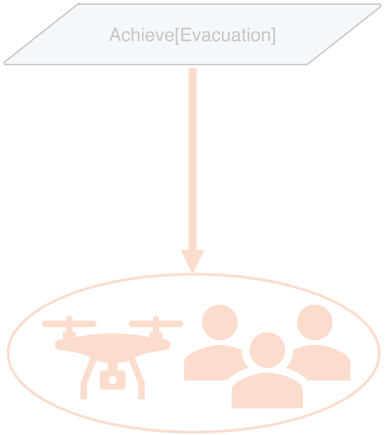
Adaptive Recipe Recommendations

Relaxing User Obligations



Revised eVoting System

Group Identity Awareness



Adaptive Rescue Robot

Cyber — Physical — Social

Vote Flipping Example

ES&S iVotronic system and Election Fraud in Kentucky

Voter Should:

1. Key in the voter ID personal **password**

o back to Step 2
to Step 3

? How to optimally revise existing software systems to prevent failure?

If voter exits the booth before confirming, an official could select another candidate

Vote Flipping Example

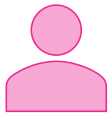
Goals

Avoid Vote Flipping

Ensembles

Voter (v)

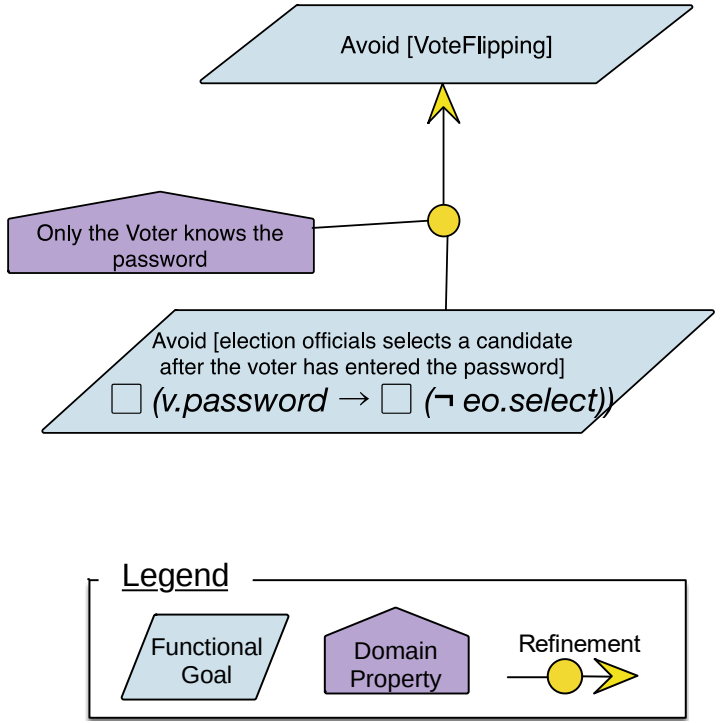
Voting Machine (v)



Election Official (eo)

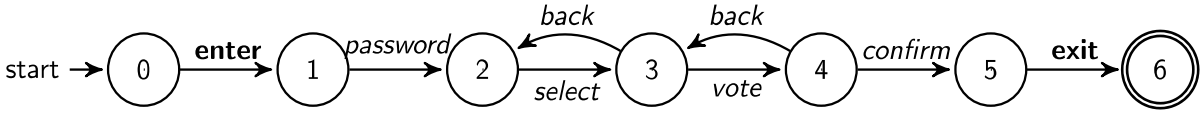
Defining the Goal

1. The confirmed vote in every voting session is for the candidate selected by the voter in the session
2. The person who confirms the vote must be the voter of the session
3. In every session, it must be the voter who chooses the candidate, confirms the vote.
4. The election officials can never select a candidate after the voter has entered the password

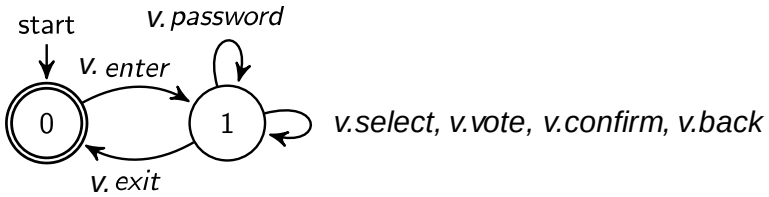


Relaxing User Obligations

Assumed Voter Behaviour

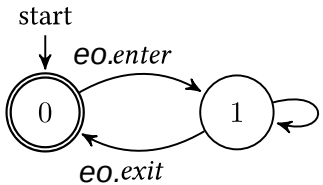


Relaxed Voter Behaviour



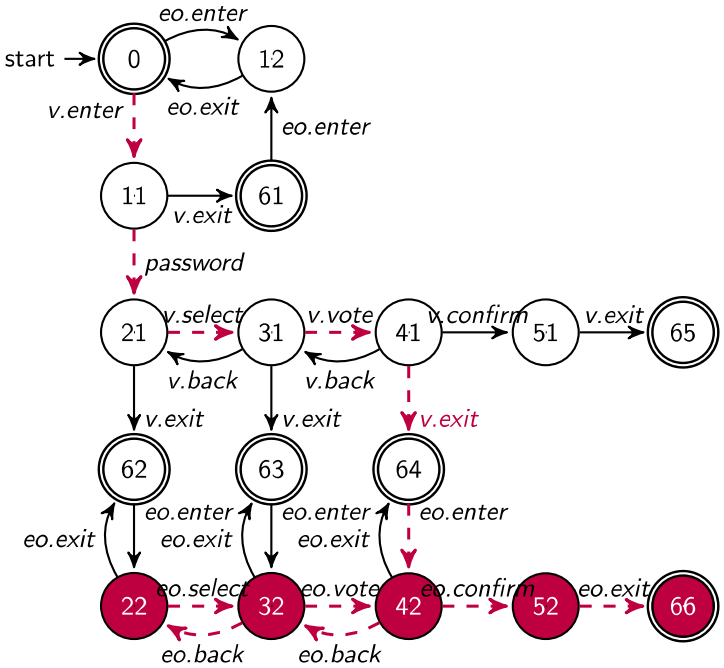
v.select, v.vote, v.confirm, v.back

Relaxed Voting Official Behaviour



eo.select, eo.vote, eo.confirm, eo.back

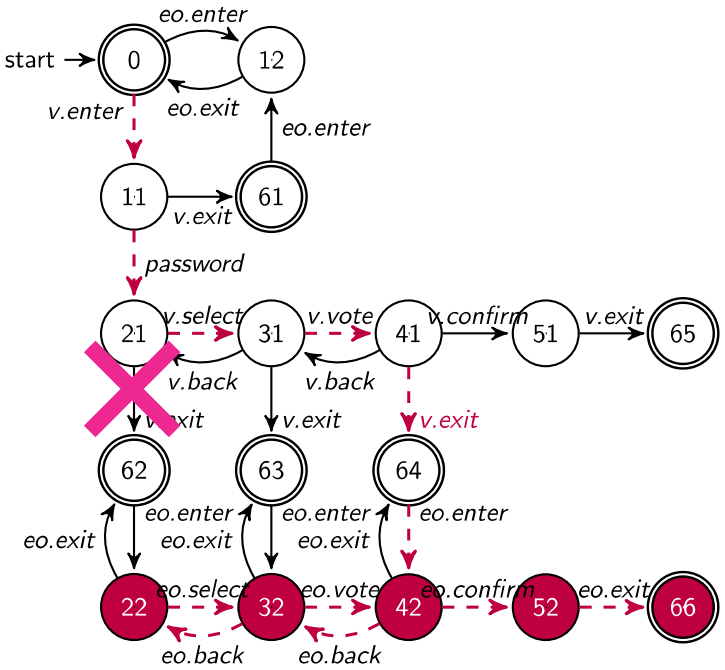
Identify a Failure Scenario



Avoid [election officials selects a candidate after the voter has entered the password]

$\square\ (v.password \rightarrow \square\ (\neg\ eo.select))$

Synthesis?



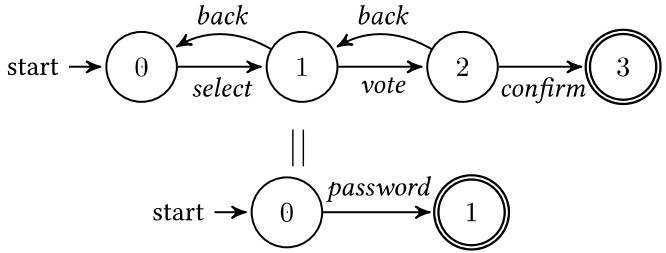
Avoid [election officials selects a candidate after the voter has entered the password]

$\square\,(v.password \rightarrow \square\,(\neg\ eo.select))$

Abstract First then Synthesise

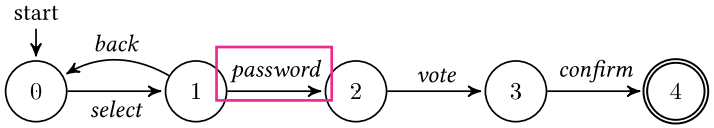
Synthesise

Abstract

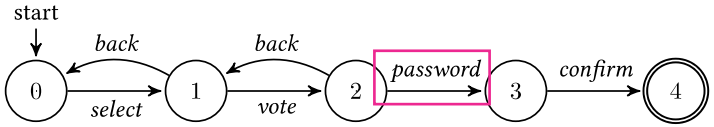


Synthesise

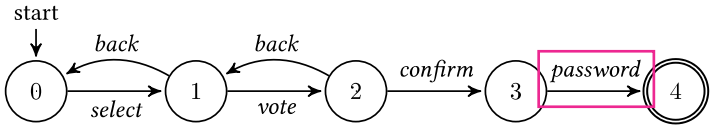
(a)



(b)



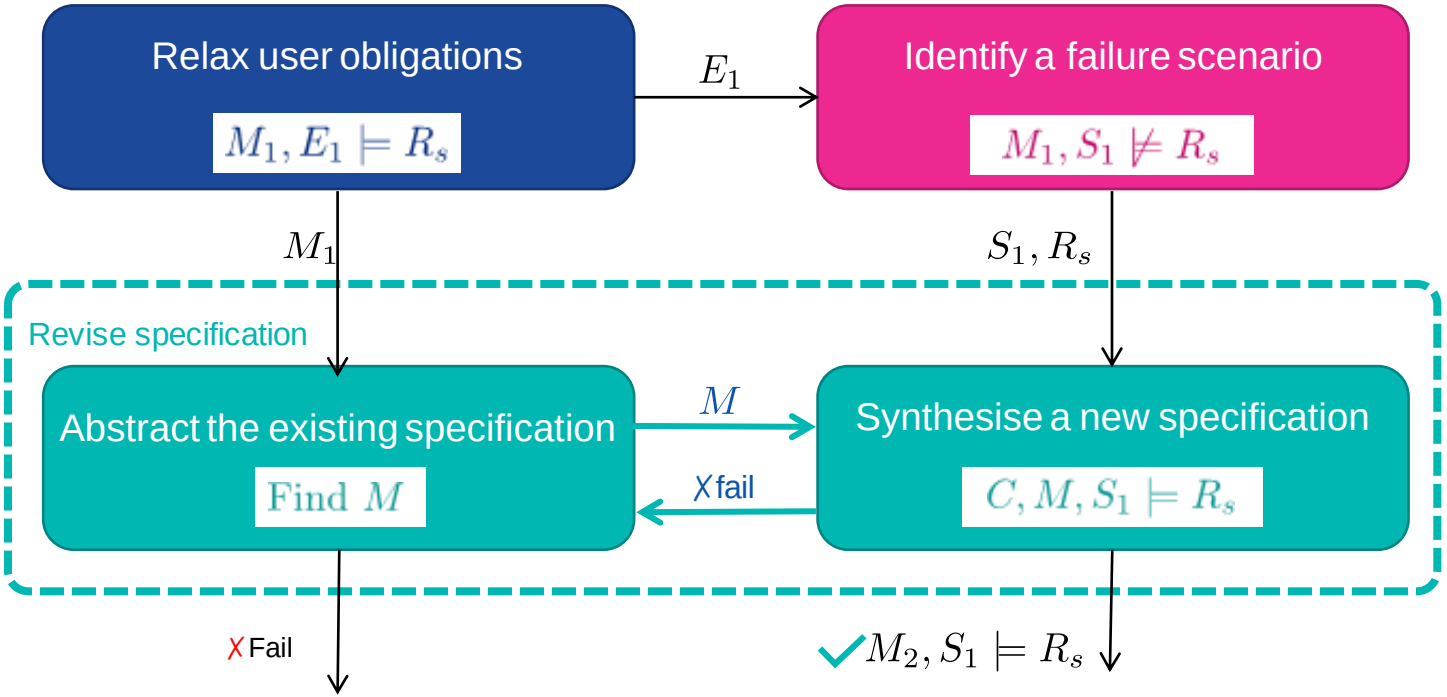
(c)



Avoid [election officials selects a candidate after the voter has entered the password]

□ (v.password → □ (¬ eo.select))

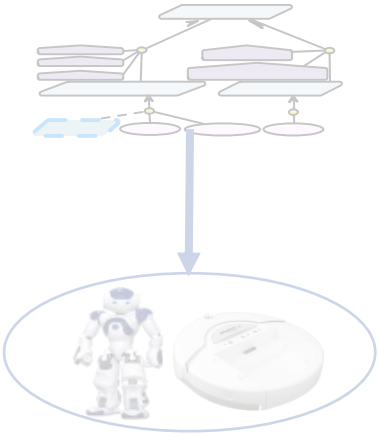
Putting it Together
OASIS - Obligations, Attack, Specification abstraction, and Synthesis



Tun, Bennaceur, Nuseibeh: OASIS: Weakening User Obligations for Security-critical Systems. 28th IEEE International Requirements Engineering Conference (2020)

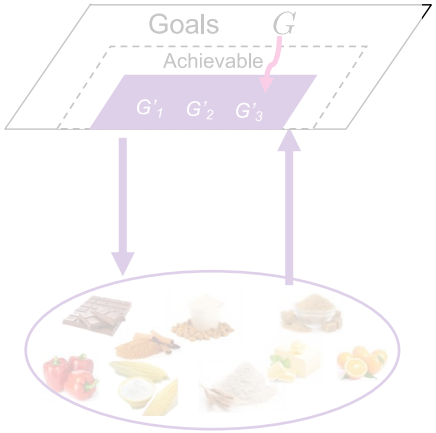
The Journey

Goal-driven mediation



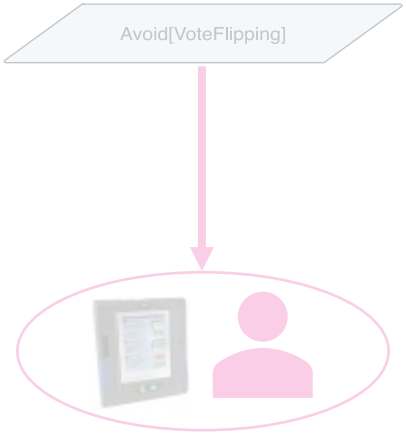
Collaborative Security

Resource-driven Goal Adaptation



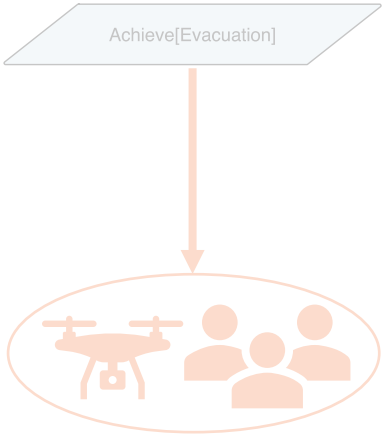
Adaptive Recipe Recommendations

Relaxing User Obligations



Revised eVoting System

Group Identity Awareness

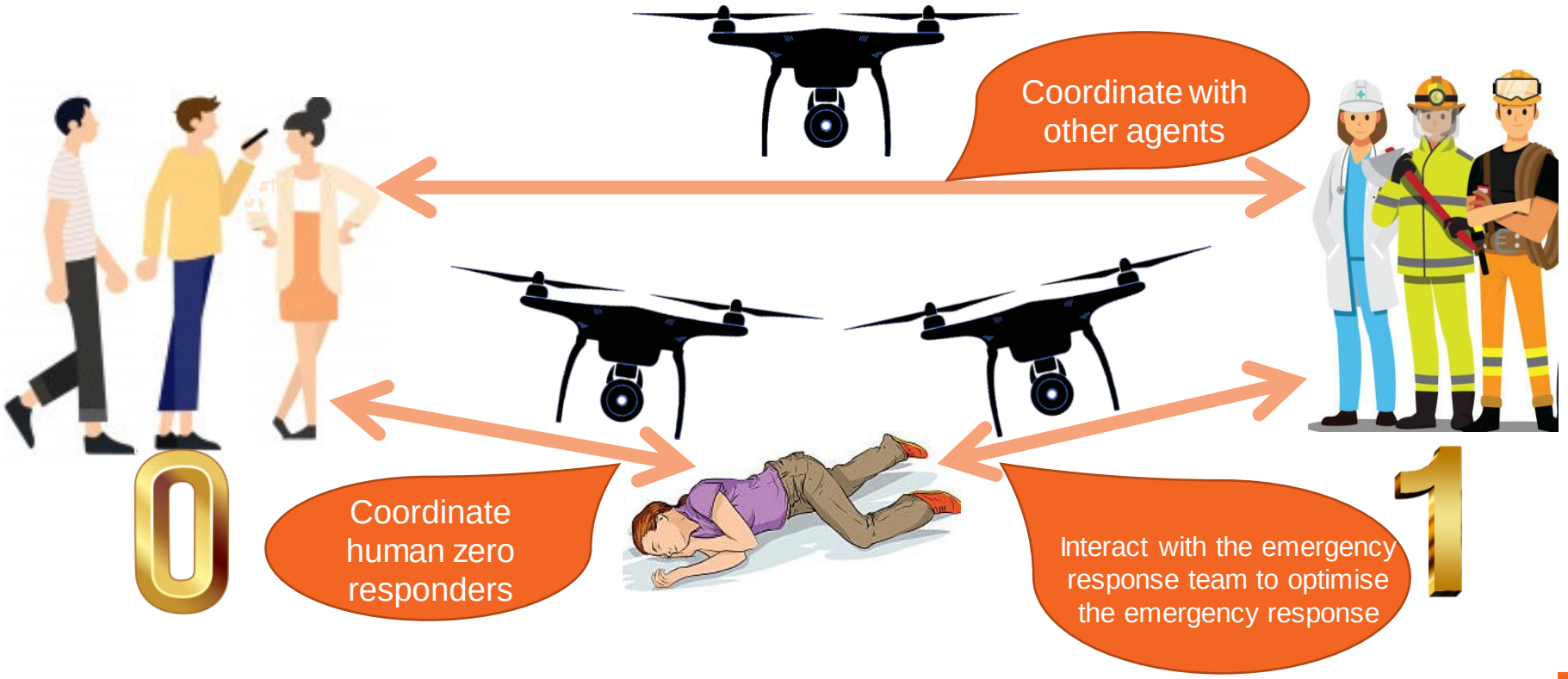


Adaptive Rescue Robot

Cyber — Physical — Social

Groups in Emergencies

Need for Zero Responders' Help



Emergency Response Example

Goals

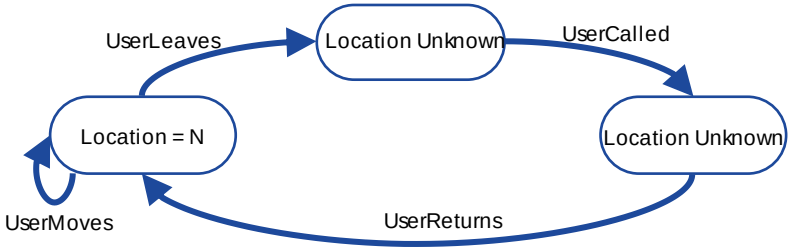
Minimise Evacuation time

Maximise number of evacuations

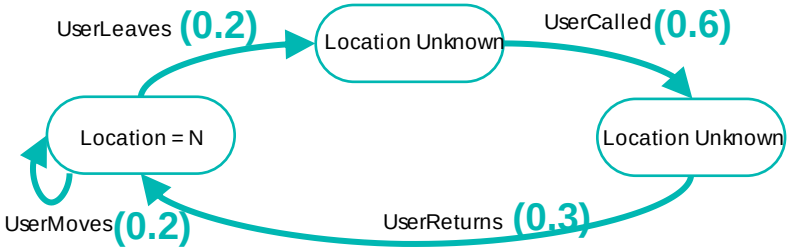
Maximise zero responder participation

Ensembles

Reasoning about Humans



Behaviourist View



Behaviourist View with Uncertainty

Opportunity Willingness Capability

Ontological View

Using Social Identity Theory to Reason about Human's Behaviour 1/2

During an emergency, the sense of common fate favours the emergence of a *shared identity* among survivors. Survivors sharing an identity provide support to each other, expect to be supported and cooperate towards common goals

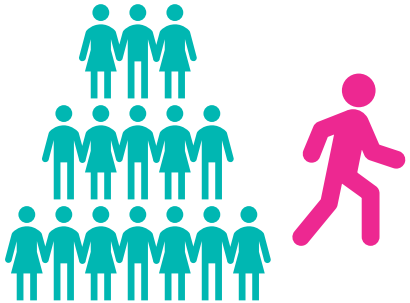
Levine & Manning, Social identity, group processes, and helping in emergencies. European Review of Social Psychology (2013)

Not every person in an emergency shares a social identity

von Sivers, Isabella, et al. "Modelling social identification and helping in evacuation simulation." *Safety science* 89 (2016)

Using Social Identity Theory to Reason about Human's Behaviour 2/2

When members behave differently from identity expectations, this transgression produces a payoff loss in the offender and the rest of the group members. This loss takes the form of anxiety from disappointing the group and for lack of group cohesion



Akerlof, George A., and Rachel E. Kranton. "Economics and identity." *The quarterly journal of economics* 115.3 (2000)

? How to enable autonomous systems to reason about (and leverage) identity to achieve goals?

Understanding Social Identity

Social identity is a psychological state that cannot be observed directly

Identity markers as indirect variables
e.g., proximity, moving in the same direction, …

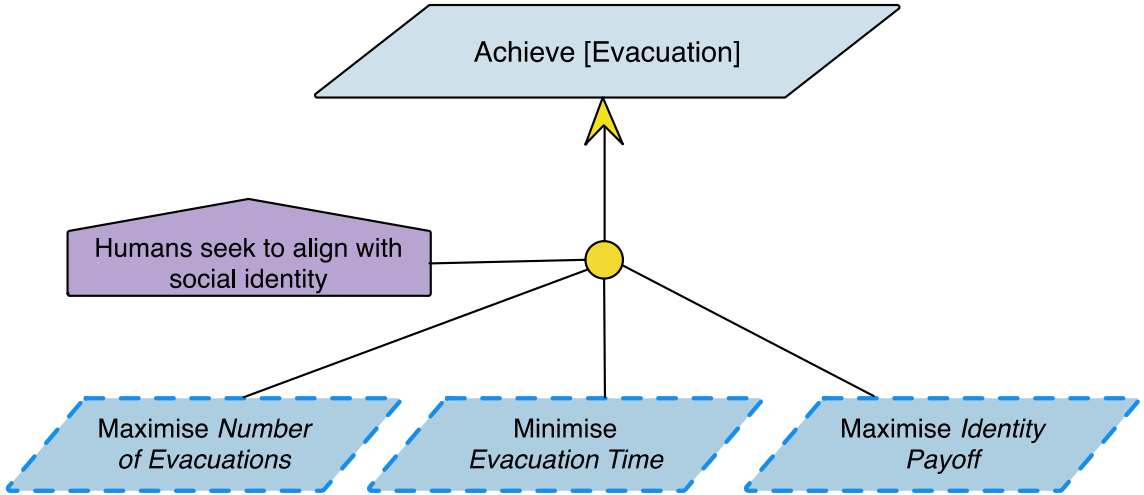
Identity Markers

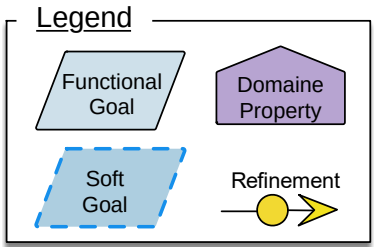
Identity in language
1) References to *we* and *us*, *together, everybody*
e.g., *it would be best for us not to go?*

2) Social interactions, social bonds, and coordination
e.g., *what do I do now?*

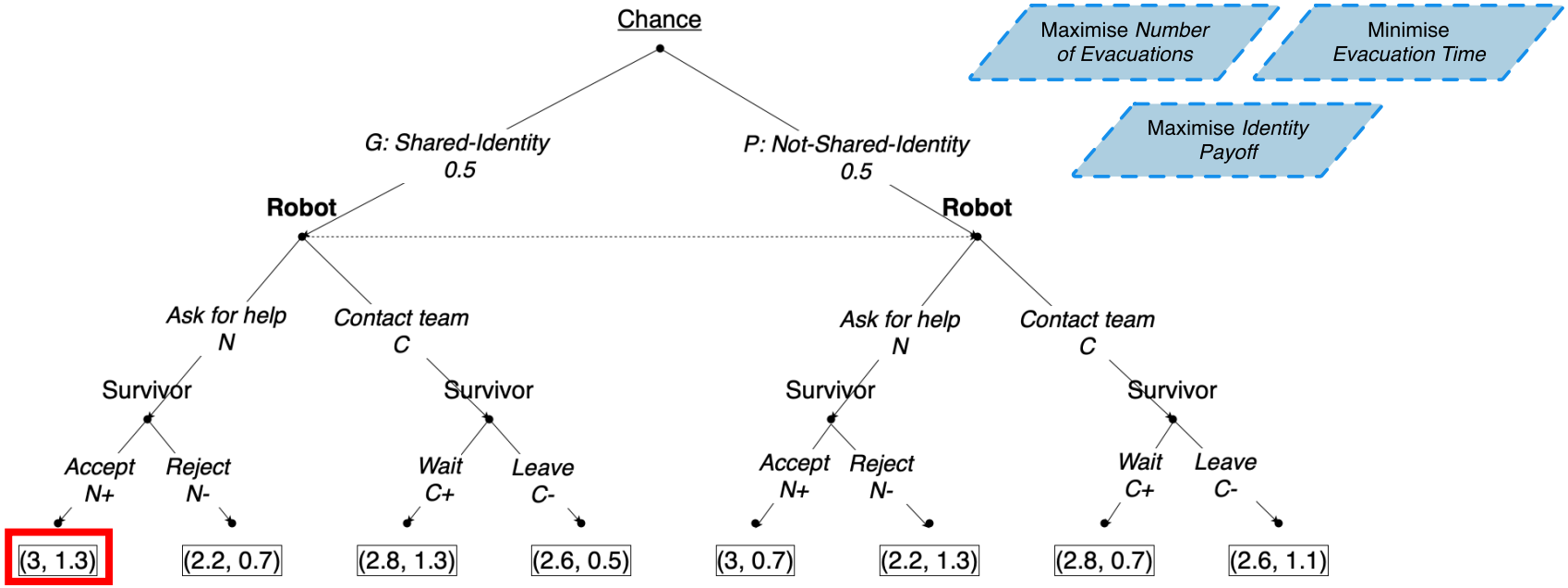
3) Shared emotions, emotional support, and empowerment
e.g., *you have to think about your family … you have to do it!*

Reasoning about Identity for Emergencies



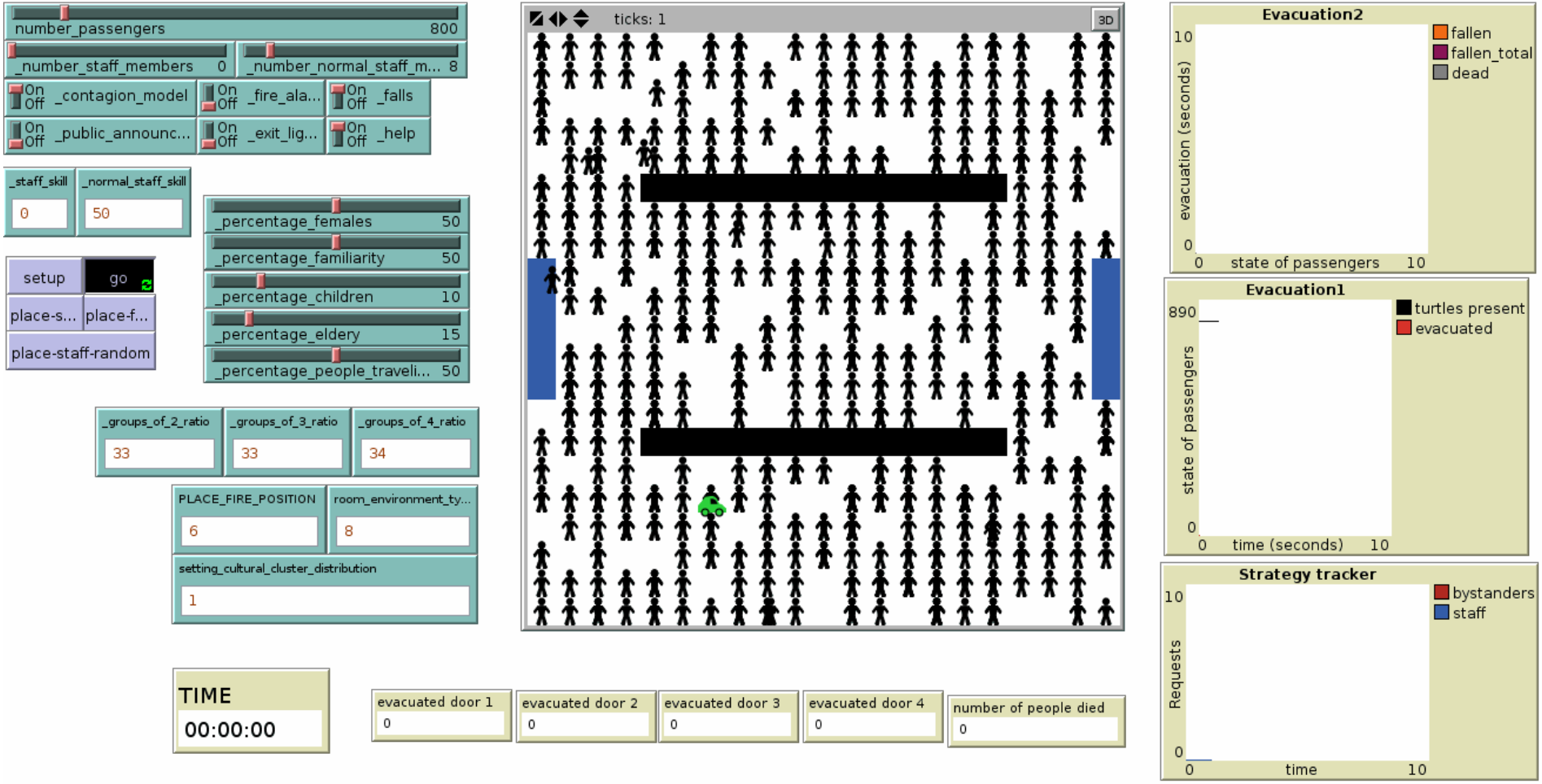


Adapting to Identity

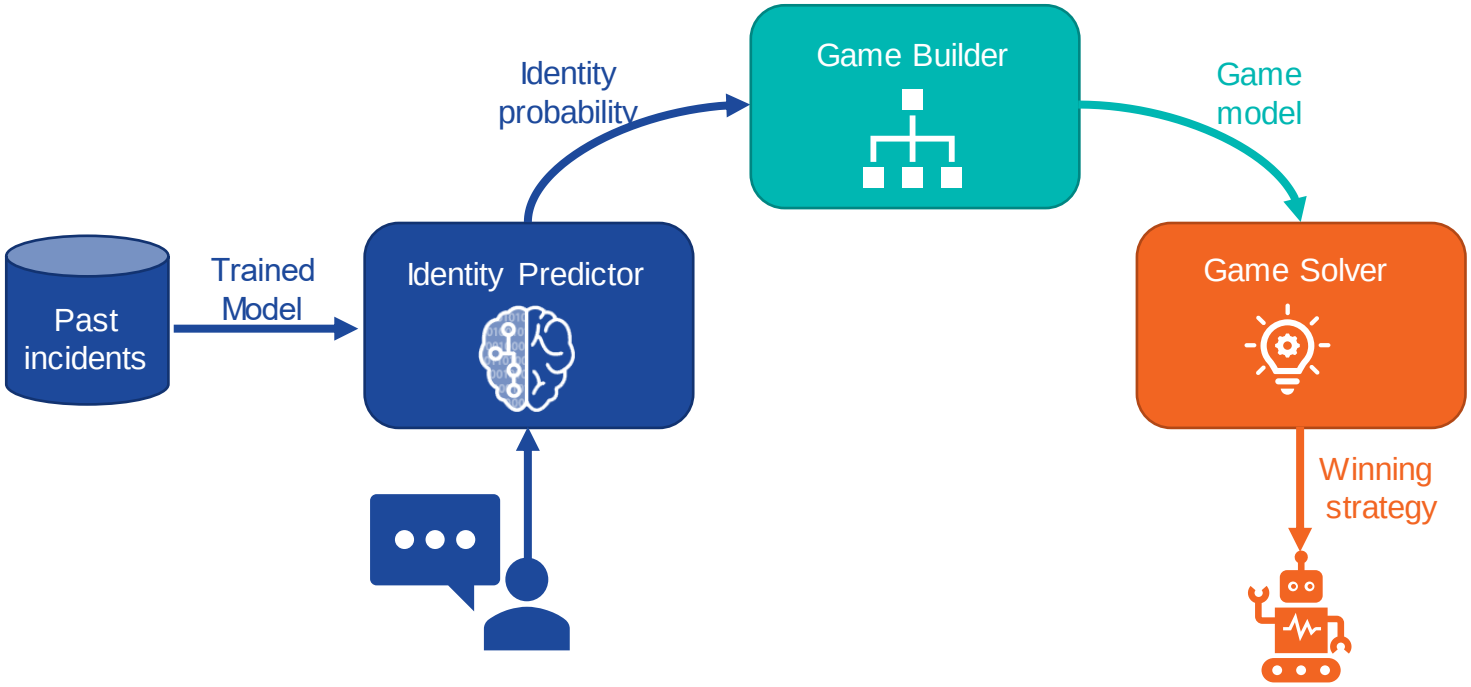


A Bayesian Game Model with two agents: Robot + Survivor/Zero-Responder

The robot locates a survivor and a victim. It can guide them or request first-responder support.

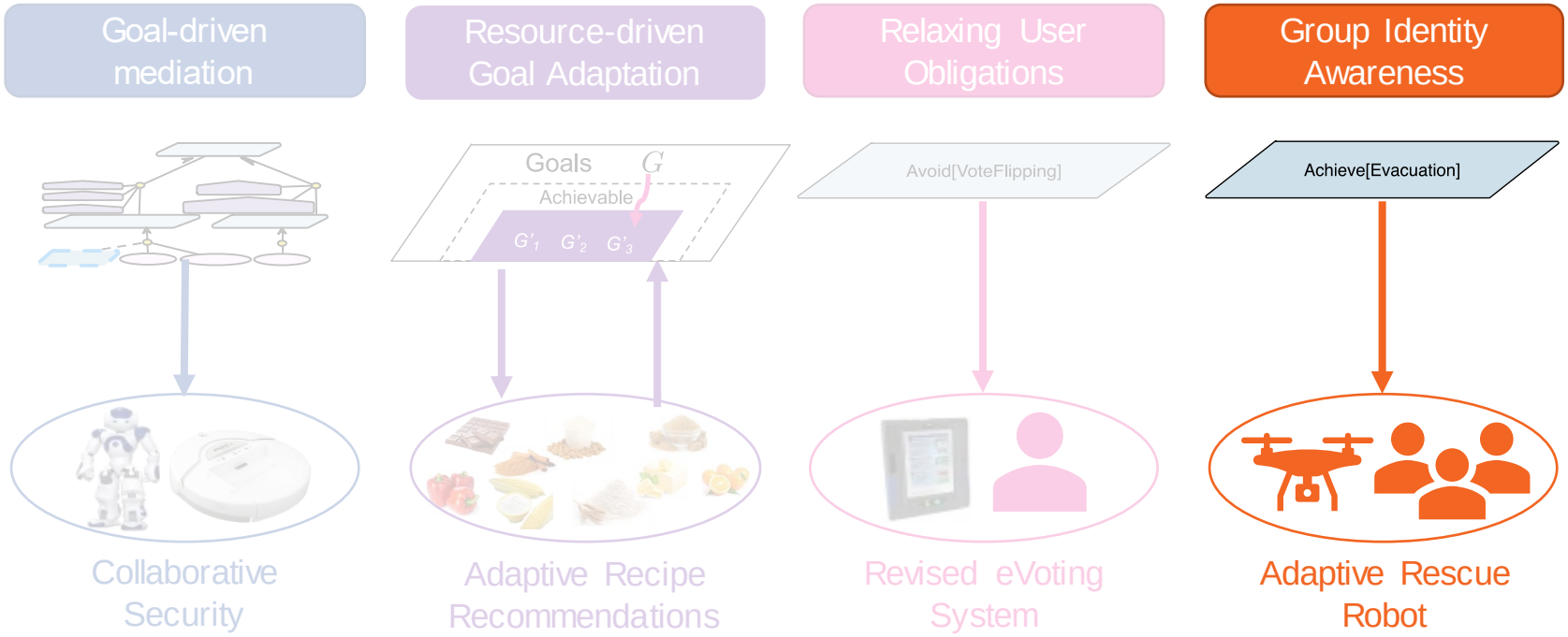

number_passengers 800
_number_staff_members 0
_number_normal_staff_m... 8
On Off _contagion_model
On Off _fire_ala...
On Off _falls
On Off _public_announc...
On Off _exit_lig...
On Off _help
_staff_skill
0
_normal_staff_skill
50
setup
go
place-s...
place-f...
place-staff-random
_percentage_females 50
_percentage_familiarity 50
_percentage_children 10
_percentage_eldery 15
_percentage_people_traveli... 50
_groups_of_2_ratio
33
_groups_of_3_ratio
33
_groups_of_4_ratio
34
PLACE_FIRE_POSITION
6
room_environment_ty...
8
setting_cultural_cluster_distribution
1
ticks: 1
3D
Evacuation2
10
evacuation (seconds)
0
0
state of passengers
10
fallen
fallen_total
dead
Evacuation1
890
state of passengers
0
0
time (seconds)
10
turtles present
evacuated
Strategy tracker
10
Requests
0
0
time
10
bystanders
staff
TIME
00:00:00
evacuated door 1
0
evacuated door 2
0
evacuated door 3
0
evacuated door 4
0
number of people died
0

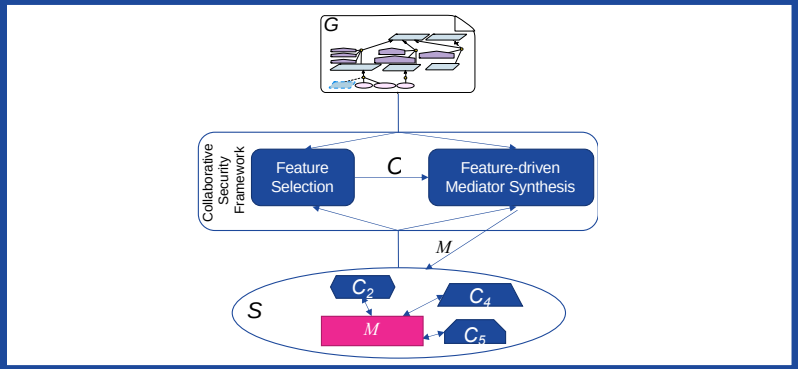
Putting it Together - An Identity-Aware Autonomous Agent



Gavidia-Calderon, Bennaceur, A. Kordoni, M. Levine, Nuseibeh: What do you want from me? adapting systems to the uncertainty of human preferences, ICSE-NIER´ (2022)

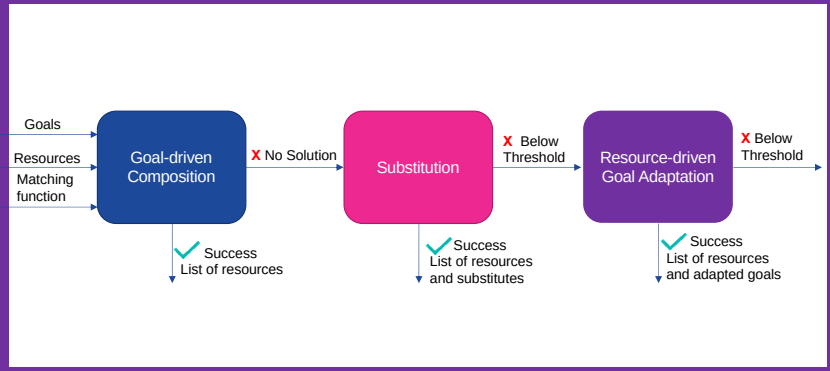
The Journey


Goal-driven mediation
Resource-driven Goal Adaptation
Relaxing User Obligations
Group Identity Awareness
Goals G
Achievable
G'1 G'2 G'3
Avoid[VoteFlipping]
Achieve[Evacuation]
Collaborative Security
Adaptive Recipe Recommendations
Revised eVoting System
Adaptive Rescue Robot
Cyber
Physical
Social



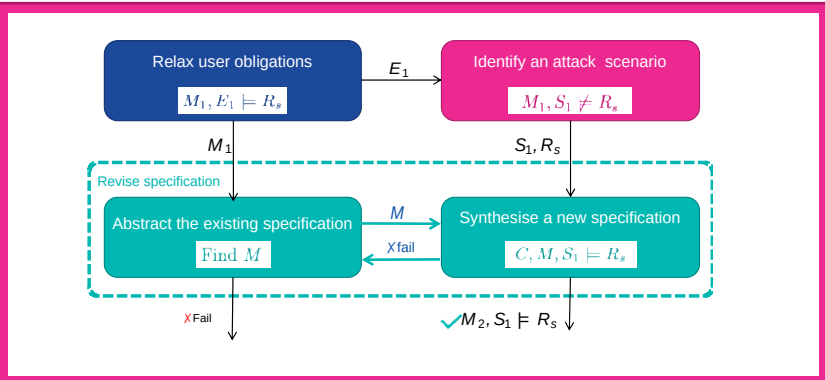
✓ How to reason about goals to assure collaboration

? How about goals expressed in non-computational way?



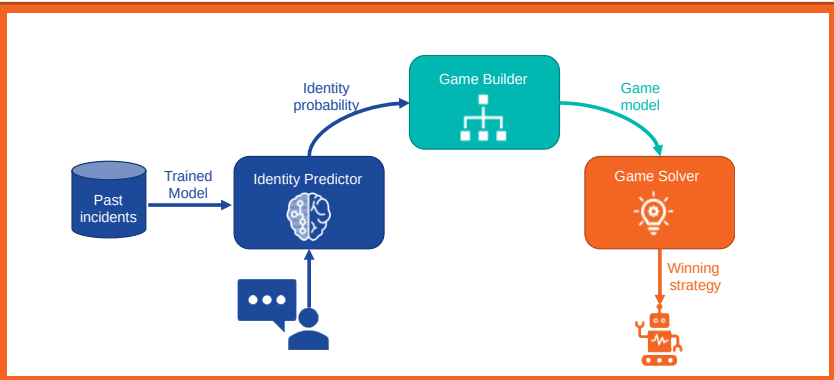
✓ How to adapt goals to achievable collaborations

? How far can we deviate from original goals?



✓ How to reason about goals requiring human collaboration

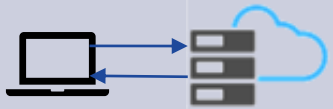
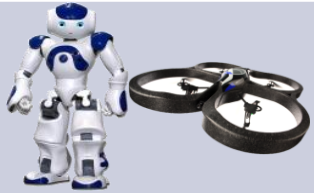
? How to engage humans to collaborate?



✓ How to reason about group behaviour for collaboration

? How to think strategically about goals?

How about Reflection?

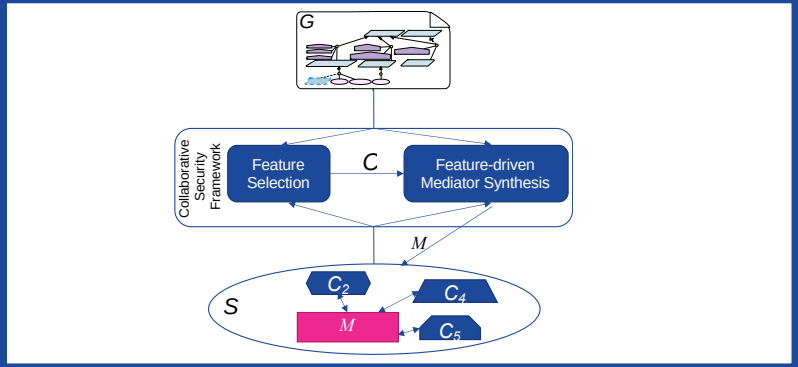
	Reflexive	Reactive	Reasoned
Ensemble			
	Distributed	Connected	Collaborative
Individual			
	Automatic	Adaptive	Autonomous

Castro, Mosterman, Rajhans, Valenti, Challenges in the Operation and Design of Intelligent Cyber-Physical Systems (2019)

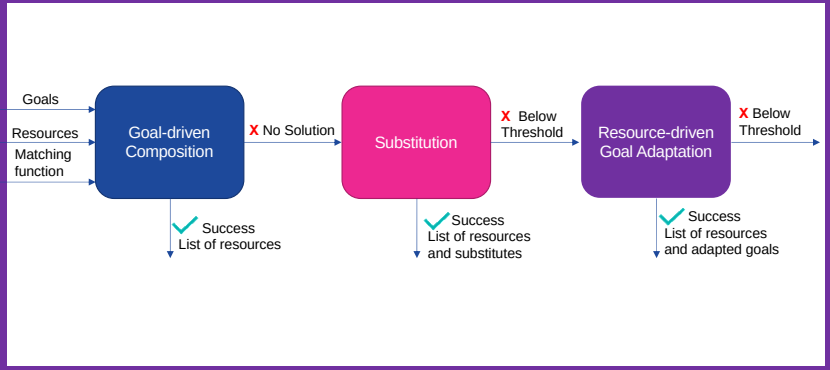
THANK YOU

amel.bennaceur@open.ac.uk

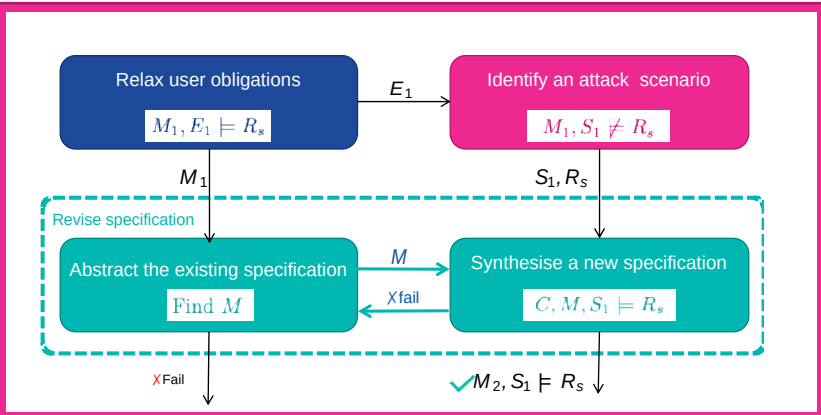
The Open University



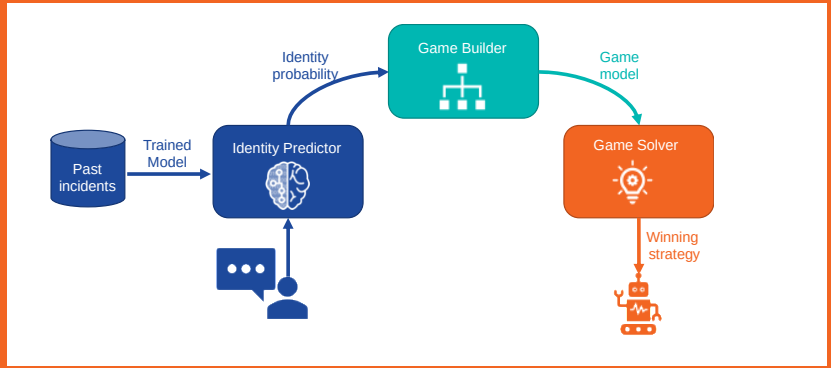
Bennaceur, Tun, Bandara, Yu, Nuseibeh: **Feature-Driven Mediator Synthesis: Supporting Collaborative Security in the Internet of Things**. ACM Trans. Cyber Phys. Syst. (2018)



Bennaceur, Zisman, McCormick, Barthaud, Nuseibeh: **Won't take no for an answer: resource-driven requirements adaptation**. SEAMS@ICSE (2019)



Tun, Bennaceur, Nuseibeh: **OASIS: Weakening User Obligations for Security-critical Systems**. 28th IEEE International Requirements Engineering Conference (2020)



Gavidia-Calderon, Bennaceur, A. Kordoni, M. Levine, Nuseibeh: **What do you want from me? adapting systems to the uncertainty of human preferences**, ICSE-NIER´ (2022)