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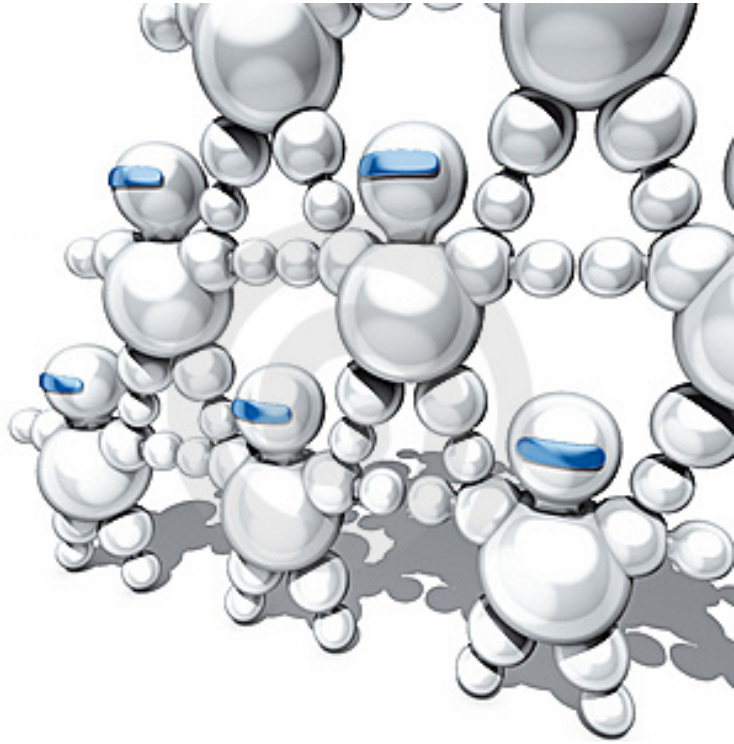
Tutorial on Norm Synthesis in Normative Multi-Agent Systems



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Universitat de Barcelona (UB)

- Tutor:

  Dr. Maite López-Sánchez

  University of Barcelona

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- Teaching material based on
  - SOAS subject from the interuniversitary master on Artificial Intelligence (UPC-UB-URV) http://www.fib.upc.edu/en/masters/mai.html
  - Related Research papers
  - Co-authored research work:
    - Ph.D. students: Eva Bou, Jordi Campos, **Javier Morales** and Master students: Patricio Petruzzi, Pedro Avila, David Sanchez, Iosu Mendizábal. Co-supervised with: **Dr. Juan Antonio Rodríguez- Aguilar** and Dr. Marc Esteva (IIIA-CSIC)
    - Research collaborations: Dr. Jaime S. Sichman (Univ. Sao Paulo), **Dr. Wamberto Vasconcelos (Univ. of Abeerdeen), Prof. Michael Wooldridge (Univ. of Oxford)**.

- Tutorial material available online at:
  - Tutorial slides:
    - http://www.maia.ub.es/~maite/Teaching.html
  - On-line Norm Synthesis source code:

    http://normsynthesis.github.io/NormLabSimulators/

    http://normsynthesis.github.io/NormSynthesisMachine/

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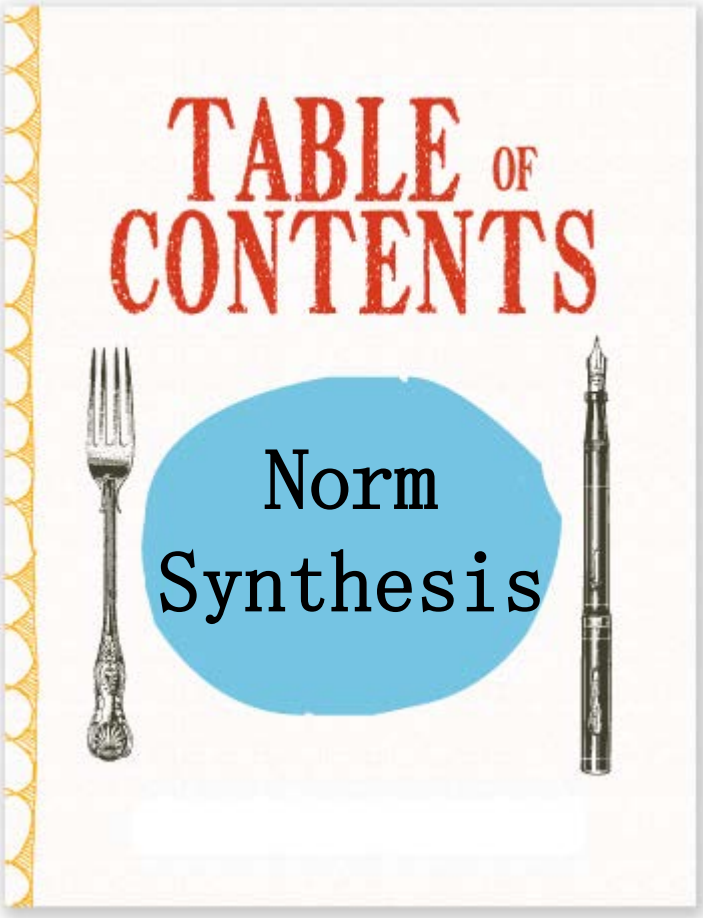
Tutorial Outline

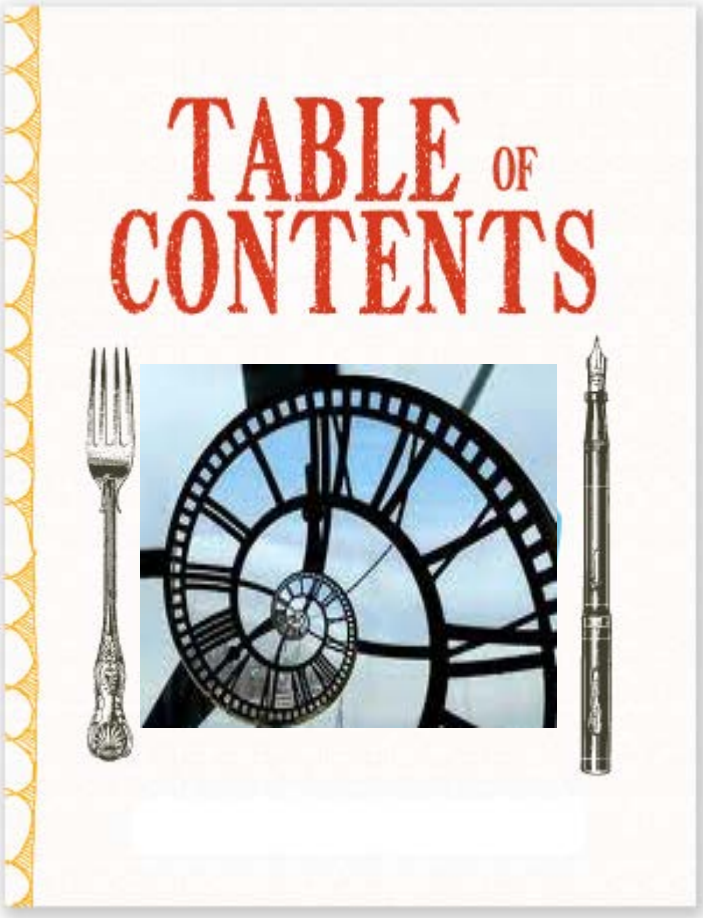
Contents



1. Introdution to Normative MAS
2. On-line automatic norm synthesis.
3. Demo and hands-on activity.

Tutorial Outline

Schedule



1. Introdution to Normative MAS
   - 30’
2. On-line automatic norm synthesis.
   - 30’
3. Demo and hands-on activity.
   - 60’

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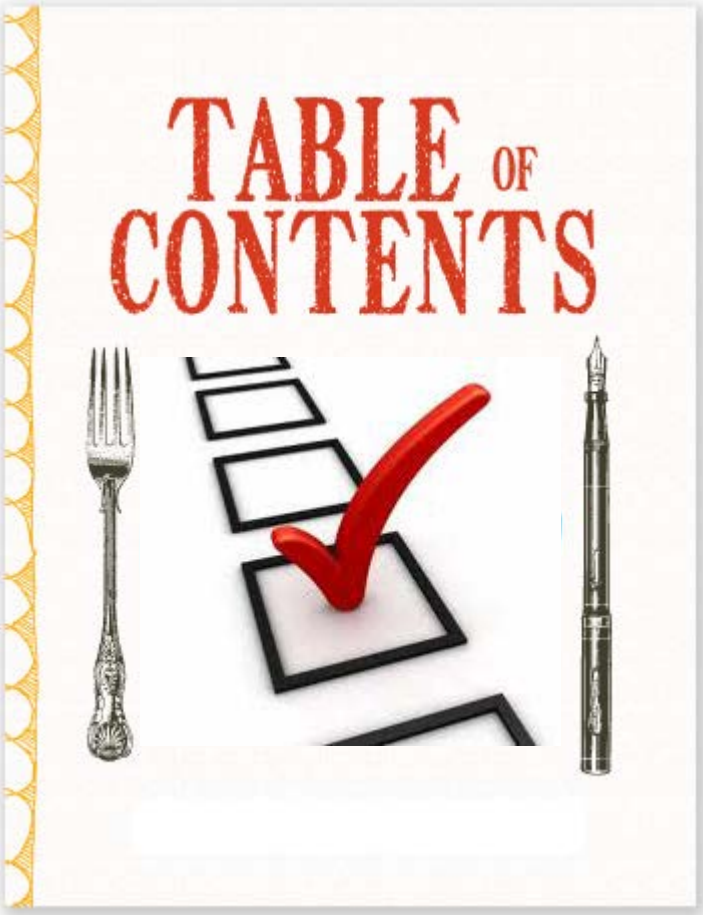
Tutorial Outline

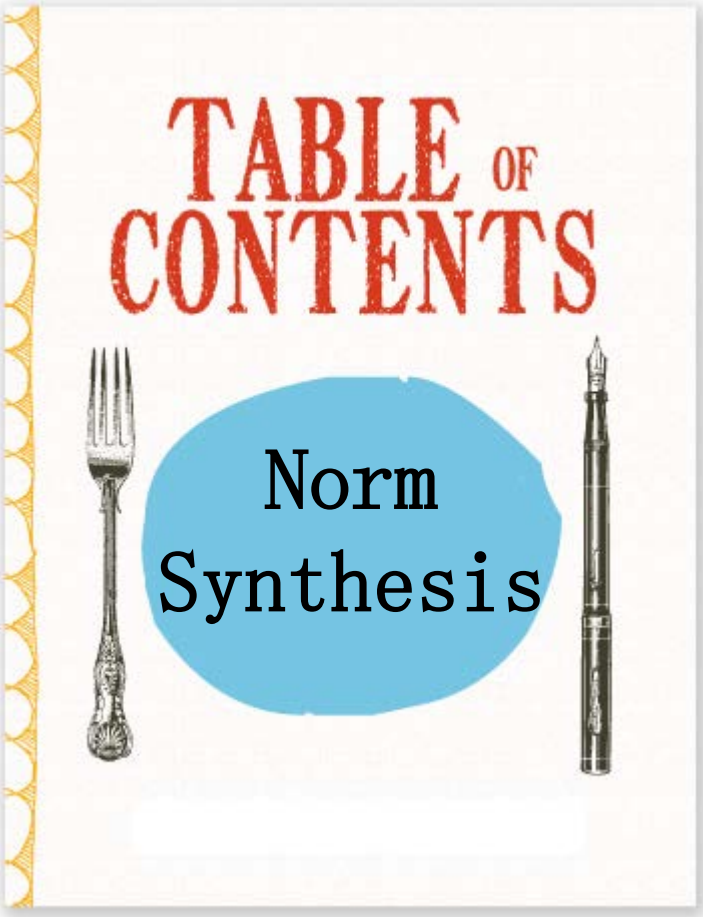
Objectives



1. Introdution to Normative MAS
   - Consider design questions
2. On-line automatic norm synthesis.
   - Learn one approach
3. Demo and hands-on activity.
   - Get familiar with a framework
   - Put it in practice

Tutorial Outline

Contents: Modules



1. **Introduction to Normative MAS and norm synthesis approaches.**
   - Off-line norm synthesis.
   - Norm emergence
   - Other
2. On-line automatic norm synthesis.
3. Demo and hands-on activity

Norms

Norm definition: Lewis

- Coordination by norms and social laws:
  - In our everyday lives, we use a range of techniques for coordinating activities. One of the most important is the use of norms and social laws (Lewis, 1969).

Norm categories

Social

- Tuomela:
  - Rule norms (e.g. to pay taxes),
  - Social norms (e.g. not litter),
  - Moral norms: (e.g. not steal),
  - Prudential norms: (e.g. max. expected utility).
- Elster:
  - Consumption norms (e.g. manners of dress),
  - Behaviour norms (e.g. the norm against cannibalism),
  - Norms of reciprocity (e.g. gift-giving norms),
  - Norms of cooperation (e.g. voting and tax compliance).

Norms in MAS

Norm definition in MAS: Wooldridge

- A norm is an **established, expected pattern of behaviour** (Wooldridge).
  - May not be enforced
  - Related to authority

Norms in MAS

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- Alternative defs.:
  - Constraints + punishment
  - Deontic Logic (DL)
    - Normative propositions
    - [Des/Pres]criptive obligations
  - Game Theory (GT):
    - Violation games,…
    - Decision Theoretic GT vs DL

Norms in MAS

Norm as a MAS coordination mechanism

- Norms are key for social processes:
  - Simplify agent's decision-making process (templates)
  - **Balance** between:
    - Individual freedom (autonomy)
    - The goal of the agent society

Norms in MAS

Norms and agents

- Norm Categories (Boella and van der Torre):
  - **Regulative norms**:
    - Obligations (O),
    - Prohibitions and
    - Permissions.
  - Constitutive norms:
    - Create institutional facts (e.g. property or marriage) and
    - Modify normative system itself.

Norms in MAS

Norms and agents

- Norm Categories (Boella and van der Torre):
  - **Regulative norms**:
    - Obligations (O),
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    - Permissions.
  - Constitutive norms:
    - Create institutional facts (e.g. property or marriage) and
    - Modify normative system itself.
- Noms and BDI agents:
  - Norm-based behaviour: BOID
    - Meneguzzi and Luck,
    - Dignum et al. ...

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Normative MAS

http://www.dagstuhl.de/15131

- Normative MAS: MAS + normative system

@Dagstuhl 2007

@Dagstuhl 2012

@Dagstuhl 2015

- **Agents** can **decide** whether **to follow** explicitly represented norms,
- Normative systems specify how agents can **modify norms**.
- **Sociological theories** from sociology, economics, legal science,..

Design questions

Design questions

Example: Answers for a Traffic scenario?

- How do we represent norms?
- Who dictates norms?
- How agents decide norm fulfillment?
- Who/how detects if agents comply with norms?
- Should a norm change?

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Design questions

Example: Answers for a Traffic scenario?

- How do we represent norms?
  - Are norms implicit, hierarchichal, local, imprecise,..?
  - Are there norm exceptions, contradictions?
- Who dictates norms?
  - Are norms related to organisations?
  - Who spreads them?
- How agents decide norm fulfillment?
  - What norms apply to an agent?
  - Do agents internalise norms?
- Who/how detects if agents comply with norms?
  - If other agents do not comply with a norm, should an agent bother?
  - Are there infringement consequences?
- Should a norm change?
  - Do we need additional incentives? (rewards, environment ,..)

Design questions

Exercise: Answers for a regulated scenario?

- How do we represent norms?
- Who dictates norms?
- How agents decide norm fulfillment?
- Who/how detects if agents comply with norms?
- Should a norm change?

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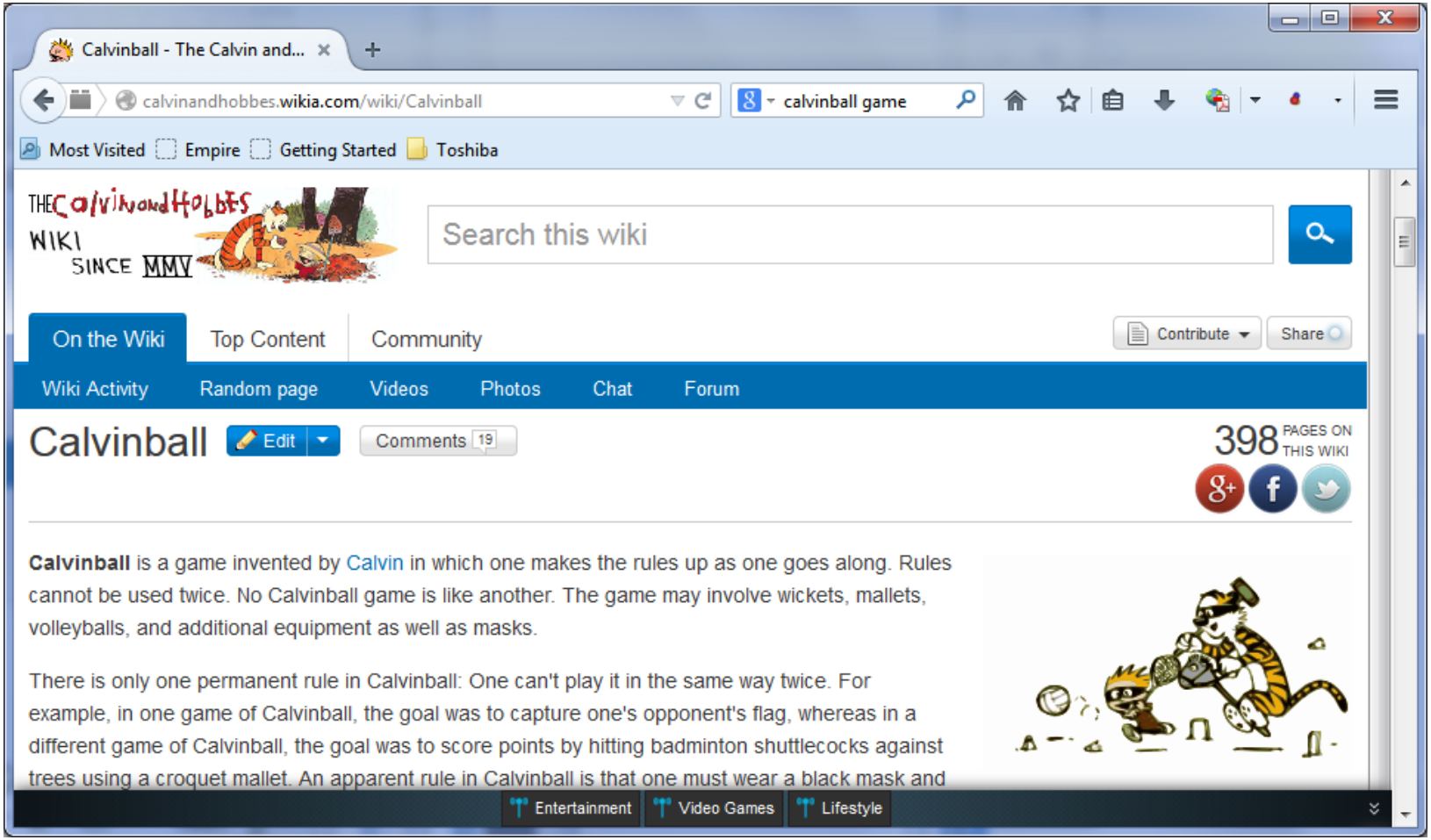
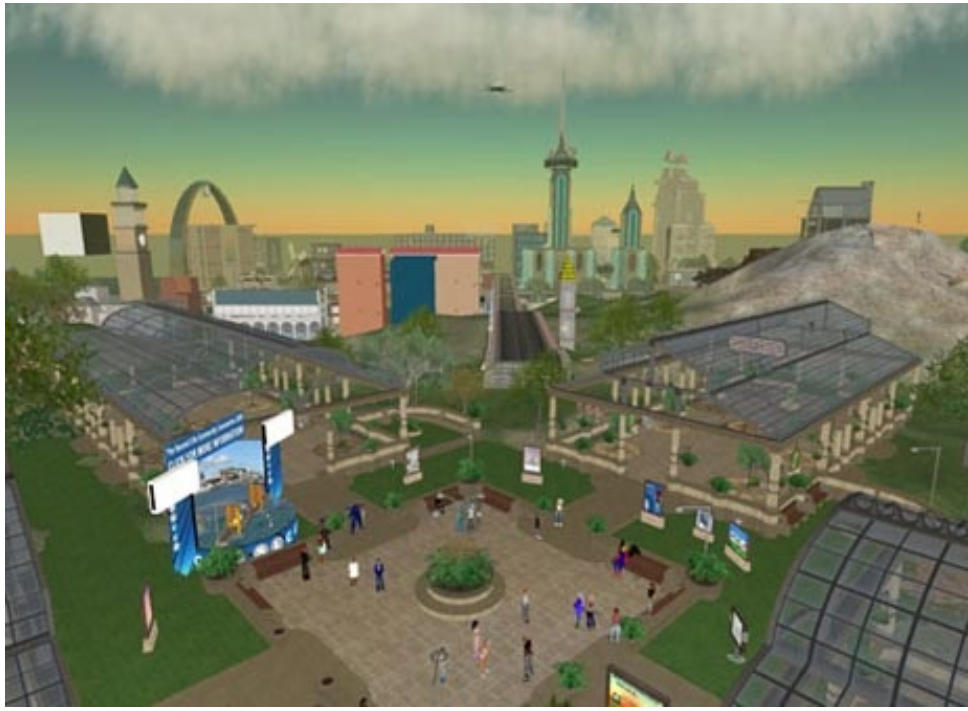
Norm changes



Applications

- Applications:
  - Contracts (e-commerce)
  - International trade
  - Social norms in 3D VW (e.g. NPC in Second Life)
  - Human Computer Interaction
  - “What if” scenarios for policy makers
  - Organizations
  - What else?



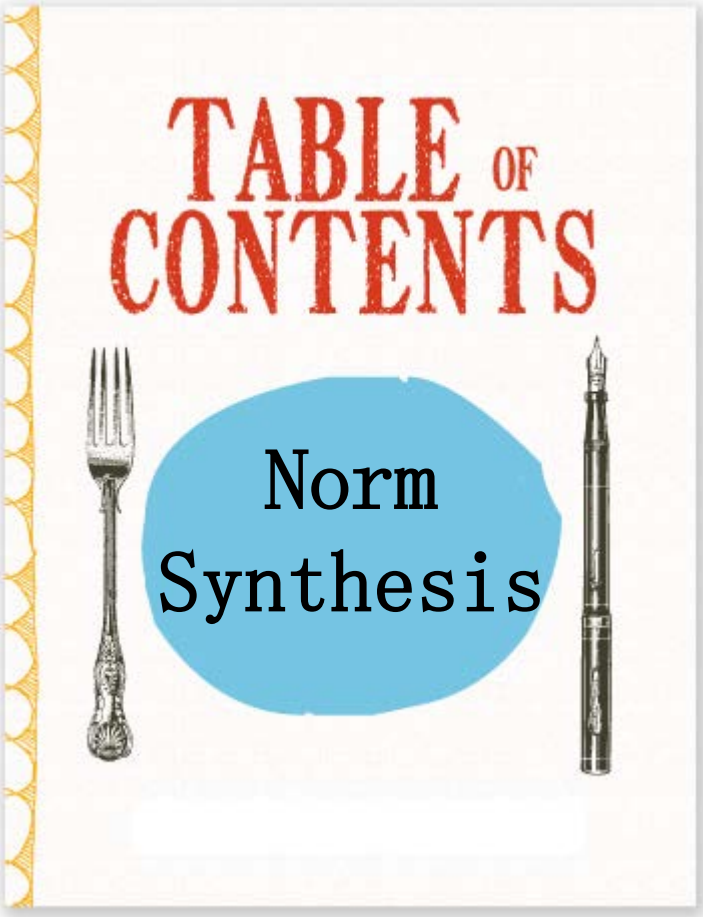
Norm design

Norm origin

- How do norms come to exist within a society?
  - Off-line design
  - Emergence
  - Other ways:
    - Norm agreement
    - Norm Learning
    - On-line generation

Tutorial Outline

Contents: Modules



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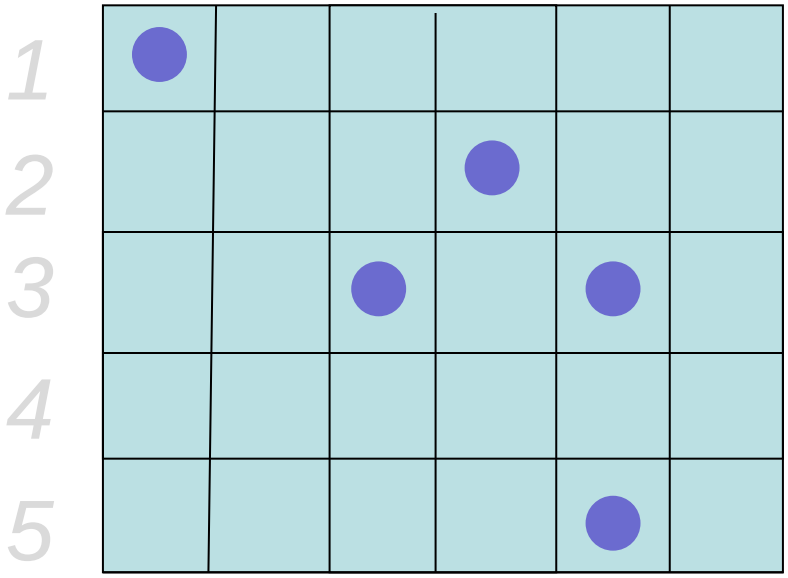
Off-line norm design

practice I

- Shoham and Tennenholtz (1996): Traffic law for preventing robot collisions in 2D a grid.

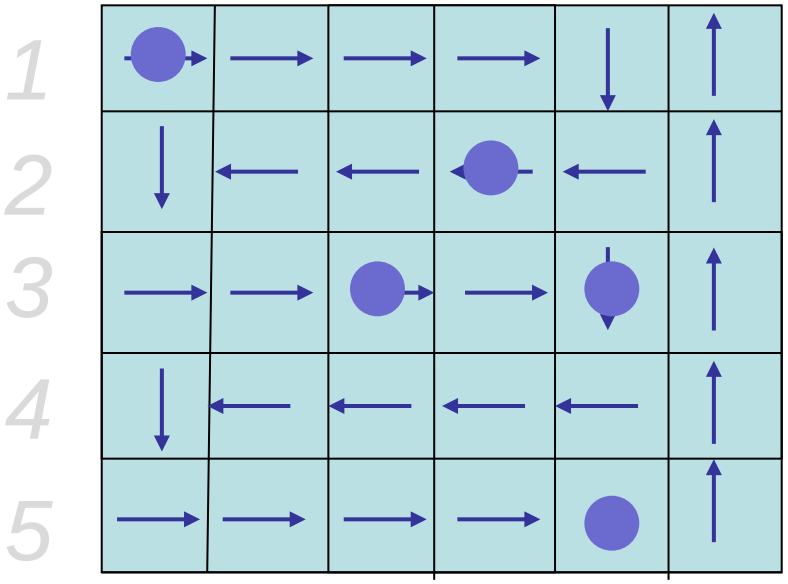
Which norm would you define?



Off-line norm design

practice I

- Shoham and Tennenholtz (1996): Traffic law for preventing robot collisions in 2D a grid.
  - Each robot is required to move constantly. The direction of motion is fixed as follows. On even rows each robot must move left, while in odd rows it must move right. It is required to move up when it is in the right-most column. Finally, it is required to move down when it is on either the leftmost column of even rows or on the second rightmost column of odd rows. The movement is therefore in a 'snake-like' Structure, and defines a Hamiltonian cycle on the grid



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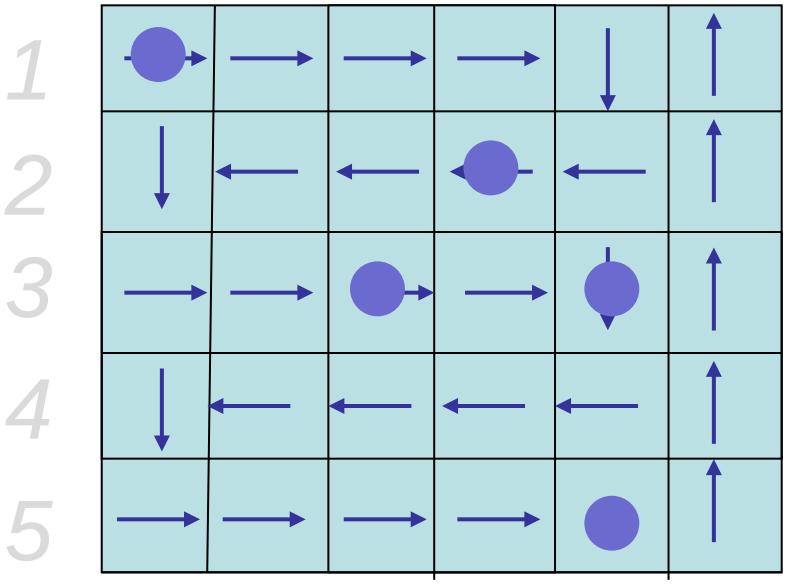

- Determines uniquely the next movement of agents
- Provides paths to any destination cell
- Does not require perceptual capabilities of the robots
- Is **effective but not very efficient** (fixed directions)

Off-line norm design

Abstract Model of Environment & Agents

- E a finite set of environment discrete **states**: $E = \{e, e', \ldots\}$.
- Agent **actions** transform the environment:

$$Ac = \{\alpha, \alpha', \ldots\} \qquad r : e_0 \xrightarrow{\alpha_0} e_1 \xrightarrow{\alpha_1} \cdots \xrightarrow{\alpha_{u-1}} e_u$$

- A **constraint** is then a pair < E',α> where
  - $E' \subseteq E$ set of environment states, α ∈ Ac an action
  - "IF environment is in some state e ∈ E', THEN action α is forbidden"
- A **social law** is a set of constraints
  - Useful social law: Disallows (& ensures) access to undesirable (& goal) states in the state space.
  - An **agent is legal** respect a social law if it never attempts to perform a forbidden action in this law.

Offline norm design

- Formal, exhaustive, **NP-complete**
- Norms are hardwired in agents
- Designer has more control
- But:
  - Some characteristics may not be known at design time
  - Agent goals may be constantly changing: requires agent reprogramming
  - Complex systems are hard to predict (and to design norms)

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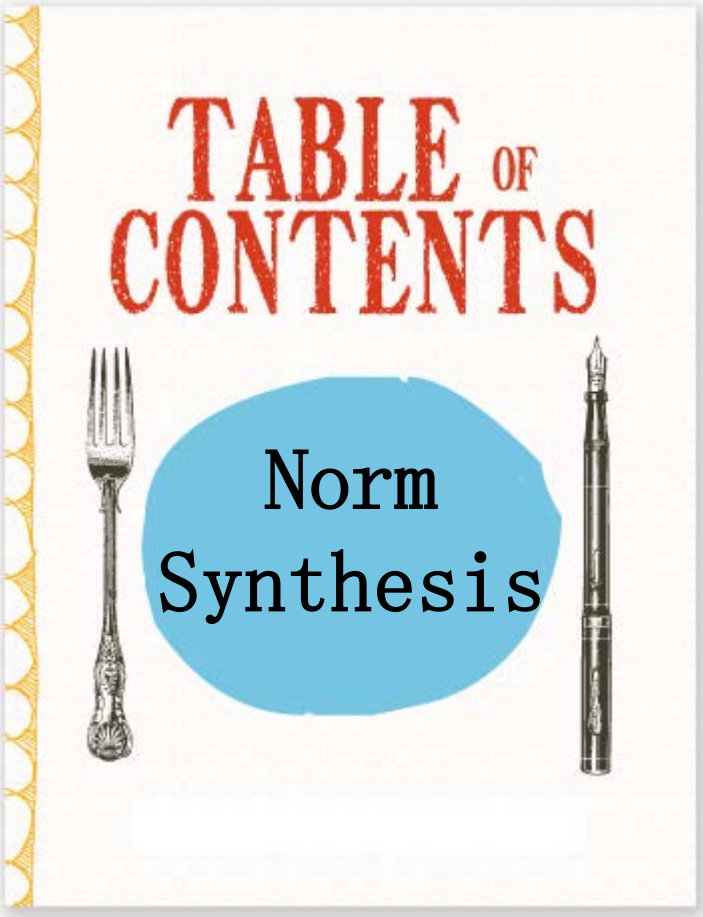

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Norm emergence

- Norm Emergence:
  - Agents reach global agreement on social conventions by using only locally available information :

- Global: all agents adopt norms
- Local: each agent decides to adopt one based solely on its own experiences

Norm emergence

Tee Shirt Game

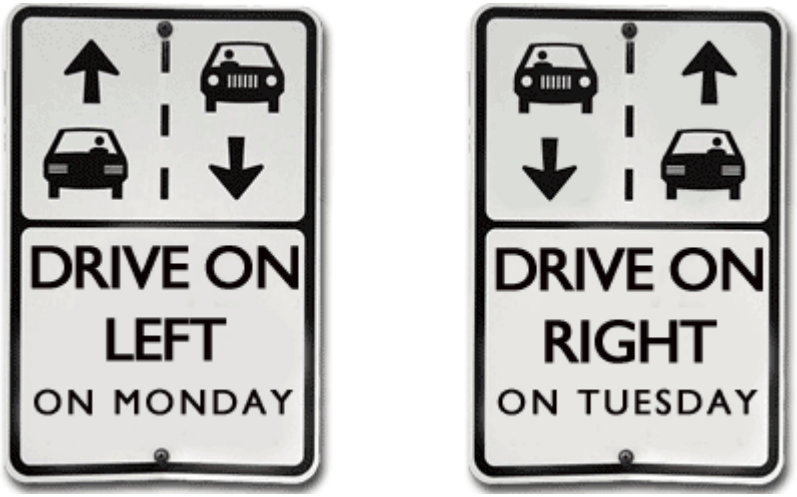
- The tee shirt game: Let's play it!
  - All agents have a blue and a red T-shirt
  - They should end up wearing the same colour
    - Colour adoption as a strategy or convention to adopt
  - Agents:
    - Decide what to dress
    - based on their memory about encountered agents (initially, can be random)
  - Form agent populations, select a monitor and play in rounds:
    - Monitor agent detects convergence (same colour)
    - Each round:
      - » Form pairs of agents: each one sees the t-shirt colour of the other agent.
      - » Agents can change colour (dress again) after each round.

Norm emergence issues

- Search space:
  - Agents choose a solution from a space of alternative solutions (**known at design time).**
  - Repeated two-player games.
  - Agents open to new ideas can periodically forget everything.
- Convergence:
  - Initial conditions.
  - Stability: keep agreements in the society.
  - Efficiency measure: time to norm convergence.
- Norm changes:
  - Strategy changing cost.

Norm emergence

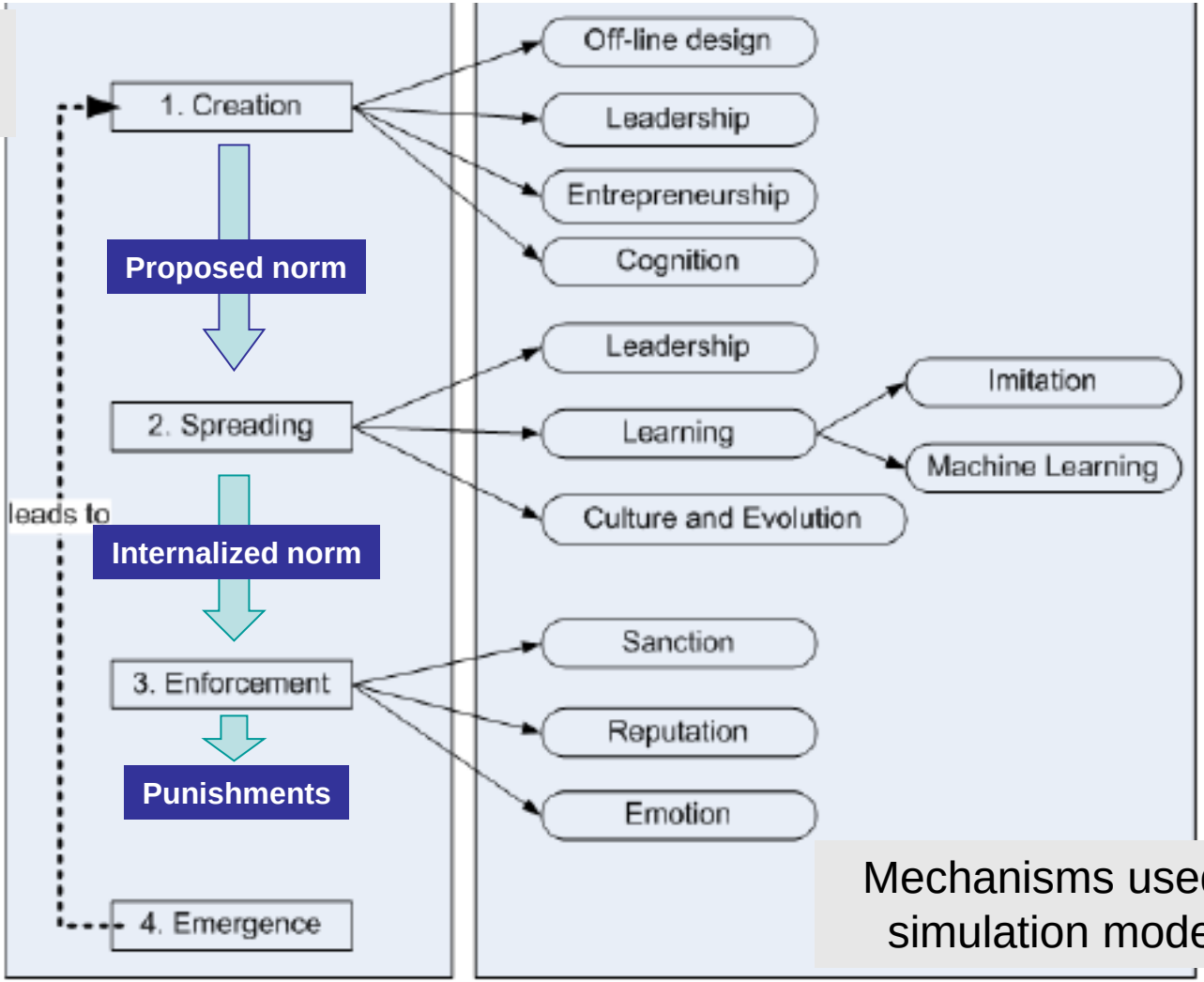
- Research on:
  - Norm adoption & internalisation (Conte et al.)
  - Topology of relationships (Luck et al., Sen et al.,)
  - …
  - Norm life-cycle:
    - Savarimutu and Cranefield



Norm emergence

Norm life-cycle: Savarimutu and Cranefield

Phases of norm construction



Mechanisms used by simulation models

Tutorial Outline

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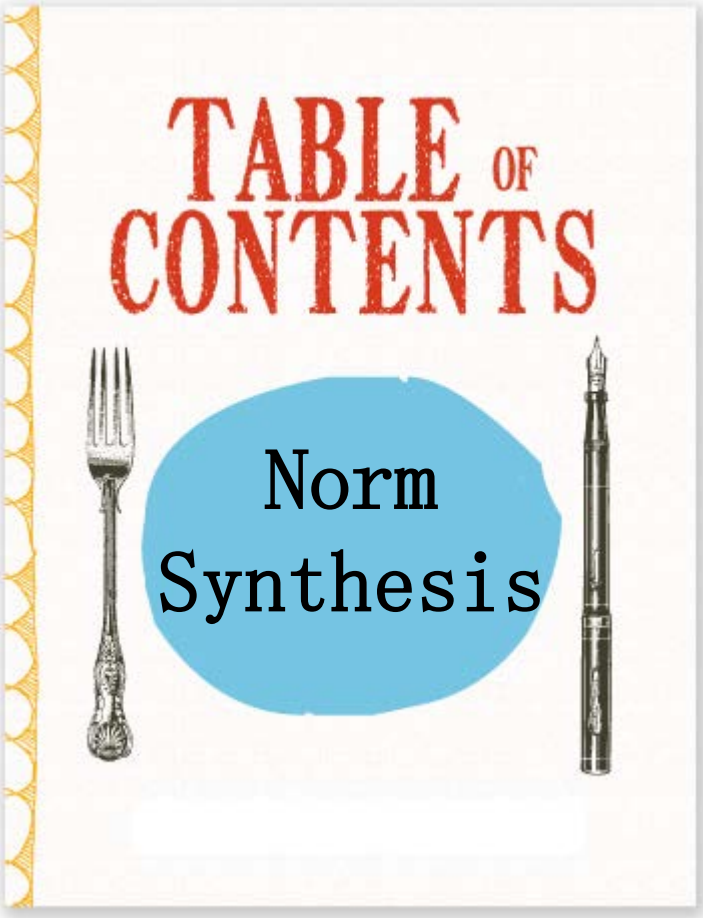

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   - **Other: agreement, learning, on-line**
2. On-line automatic norm synthesis.
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Norm design

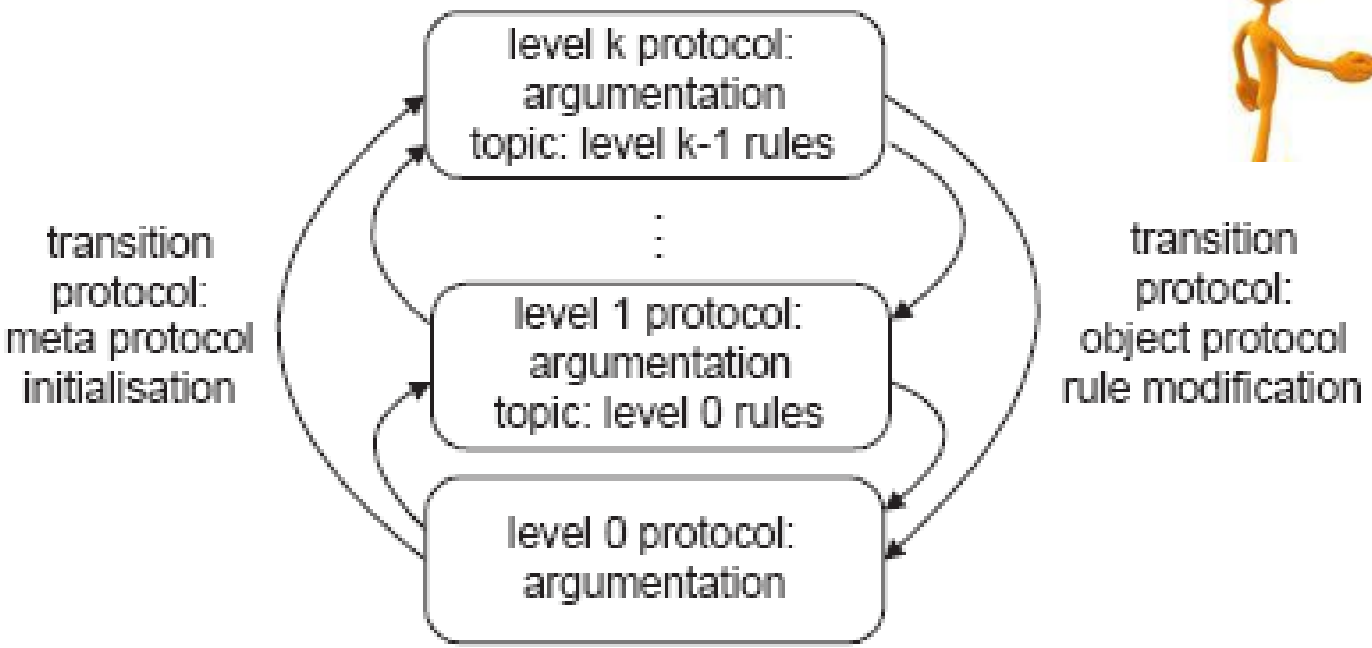
Norm origin

- How do norms come to exist within a society?
  - Off-line design
  - Emergence
  - Other ways:
    - Norm agreement
    - Norm Learning
    - On-line generation

Norm agreement

by Artikis, Kaponis, Pitt

- Empowered members use a (meta-level) argumentation protocol to modify norms at run-time.
- Democratic
- Agents enriched with agreement capabilities



Norm learning

Norm origin

- Norm learning:
  - Genetic Algorithms: Punishment learning (Bou et al.)
  - Case Based Reasoning: Norm parameter adaptation (Campos et al.)

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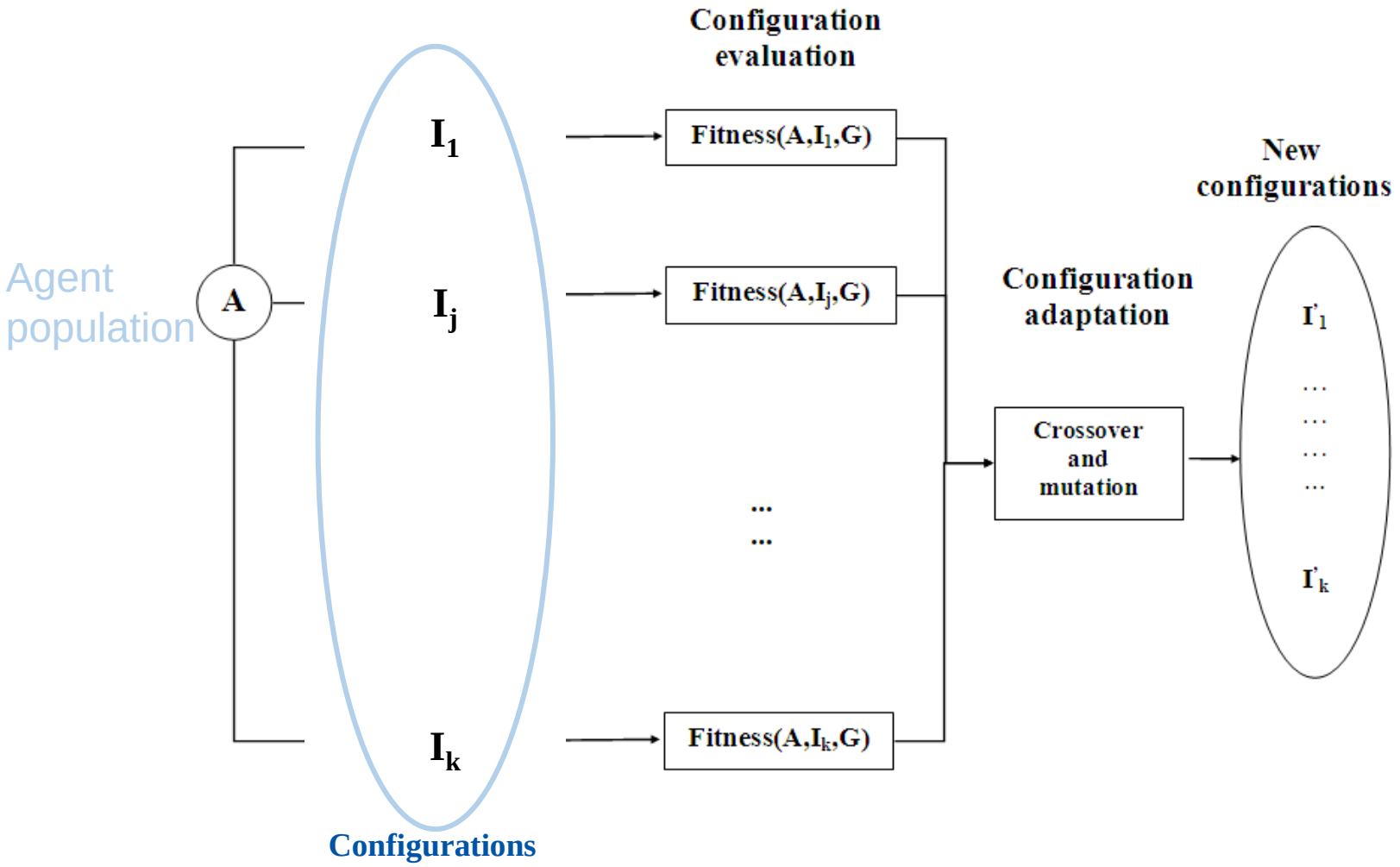
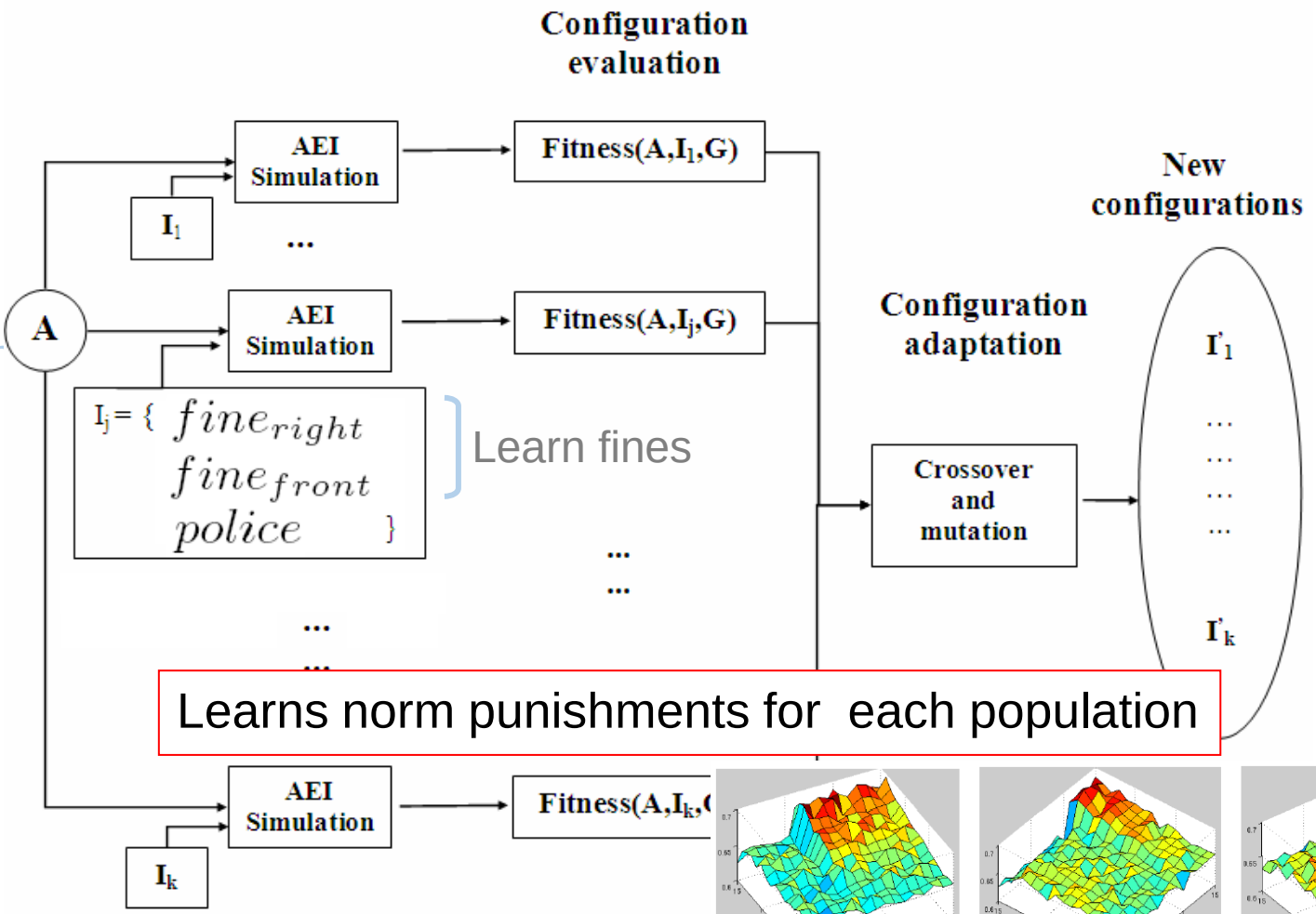
Genetic Algorithms

Learning effective norm punishments



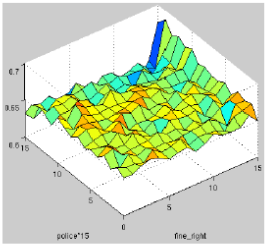
Genetic Algorithms

Learning effective norm punishments for the traffic domain



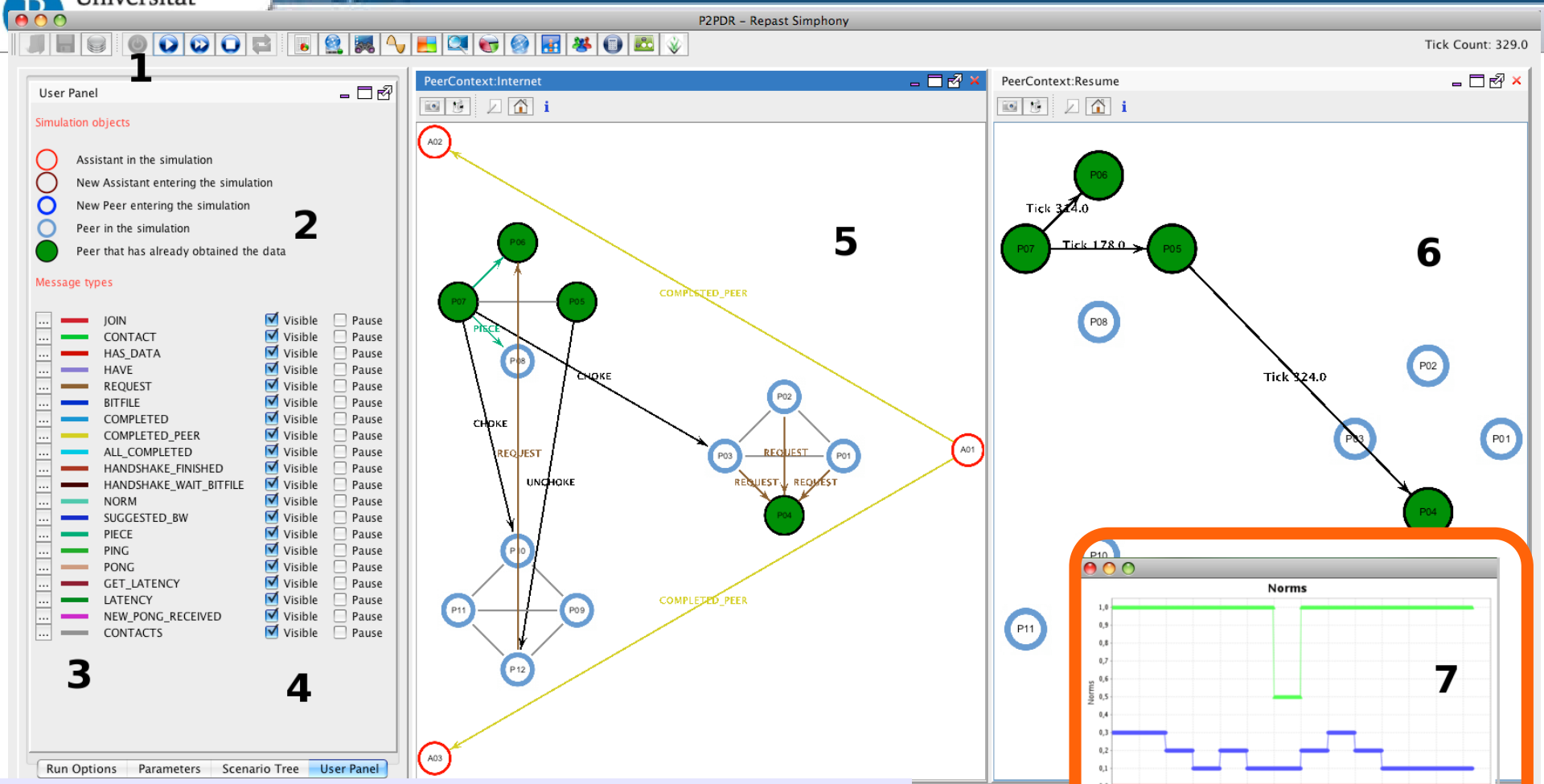
(a) Population1

(b) Population3



(c) Population5

CBR: P2P sharing network



Norms:

- *$norm_{FR}$: a peer cannot send data to >max_{FR} simult.*
- *$norm_{BW}$: a peer cannot use >max_{BW} bandwidth.*

Norm parameter evolution

Norm design

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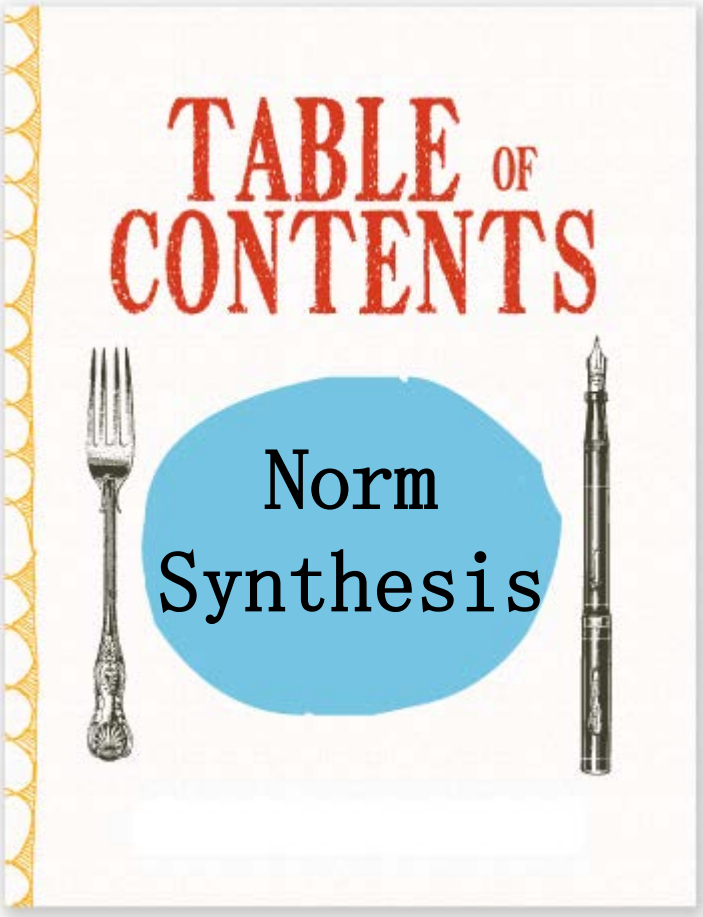

1. Introdution to Normative MAS
2. **On-line automatic norm synthesis.**
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Research Problem

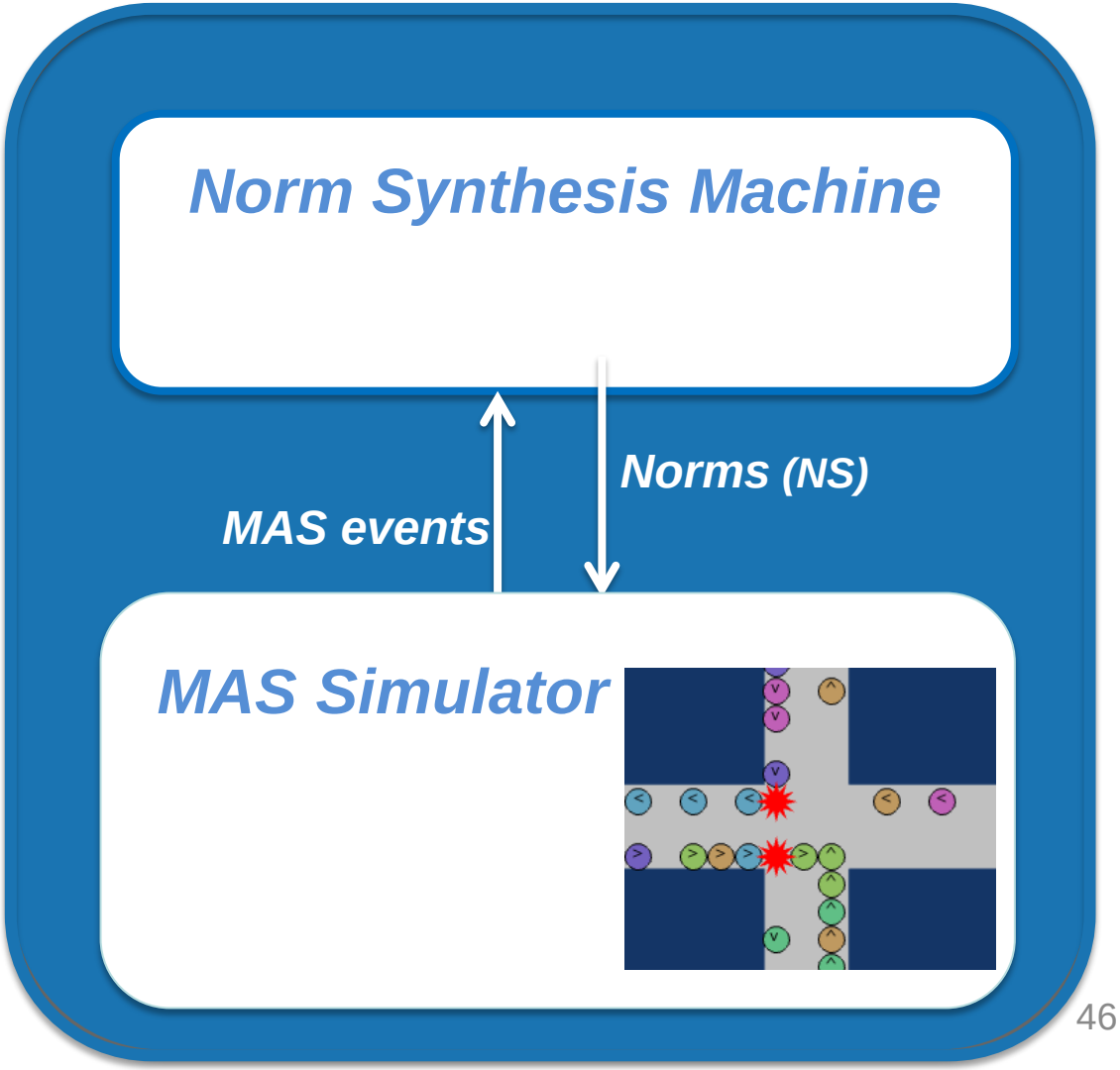
Automatic Synthesis of Normative Systems

- How to synthesise a Normative System (NS) that avoids undesirable states (i.e., conflicts) in a MAS?
  - If limited previous knowledge and/or dynamic MAS, then: **on-line** empirical approach.

- Is the resulting NS good enough?
  - Avoids conflicts?
  - Is it compact? (avoids overregulation and is easy to reason about)

On-line norm generation

Architecture



On-line norm generation

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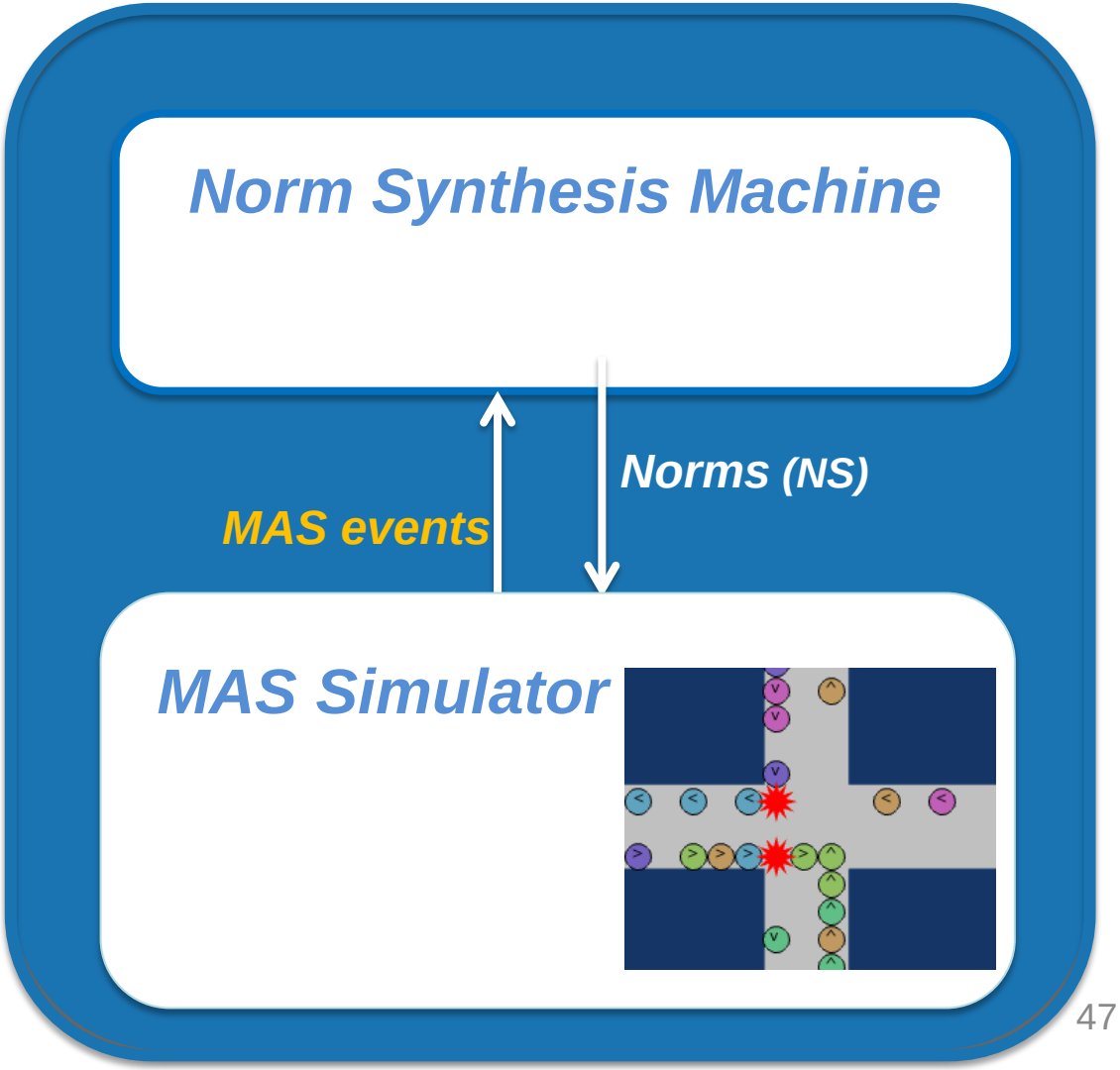

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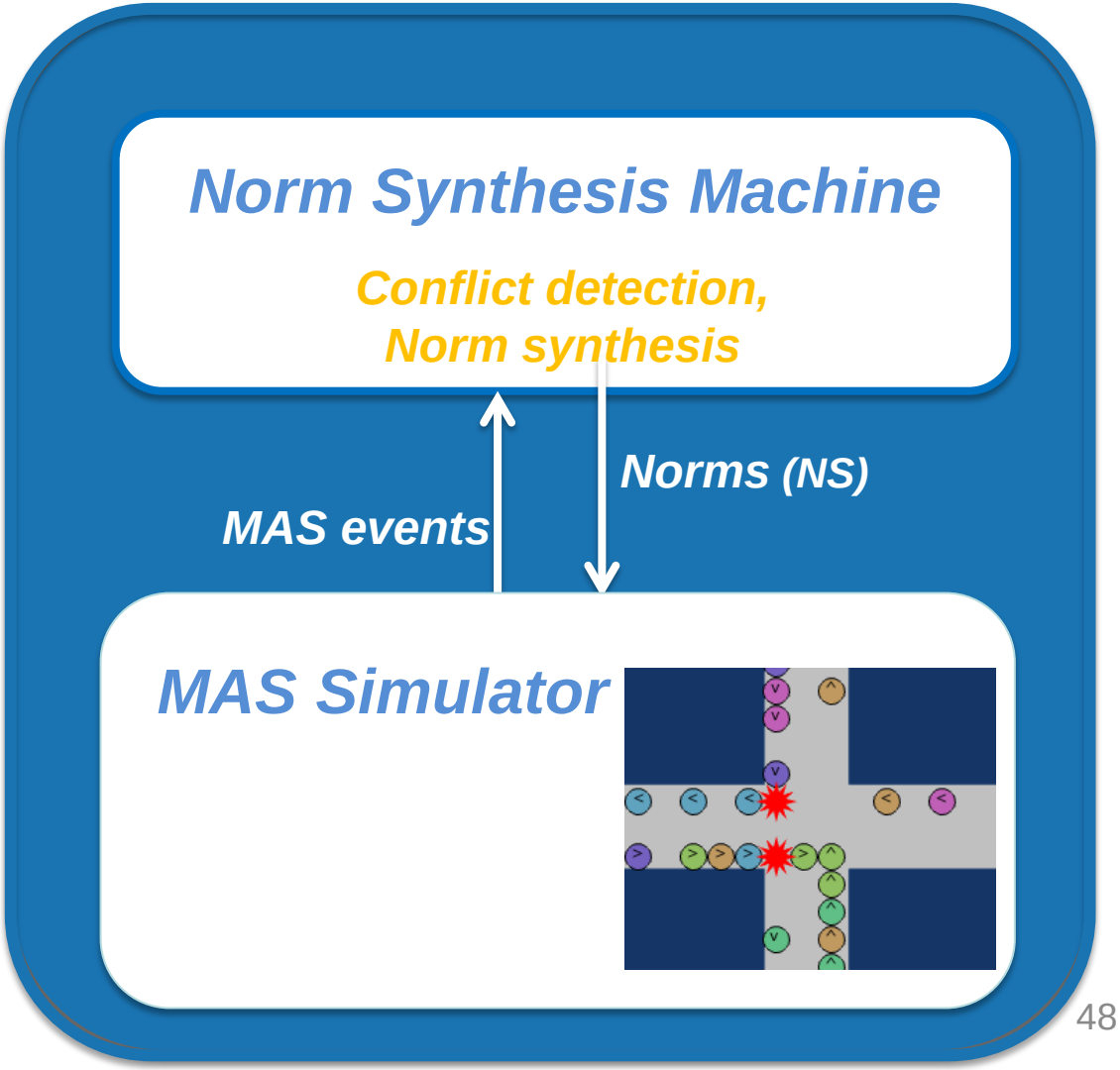

On-line norm generation

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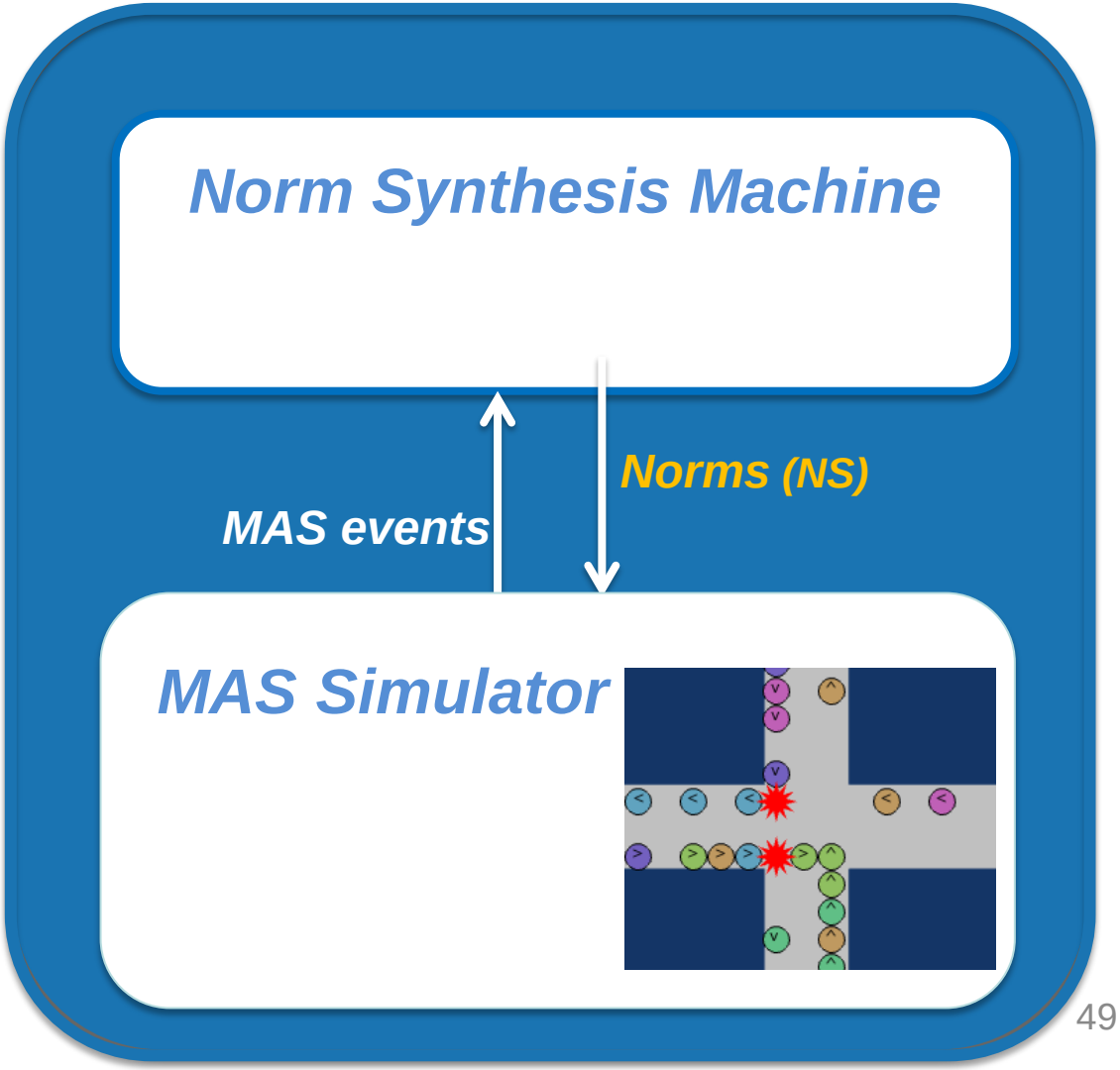

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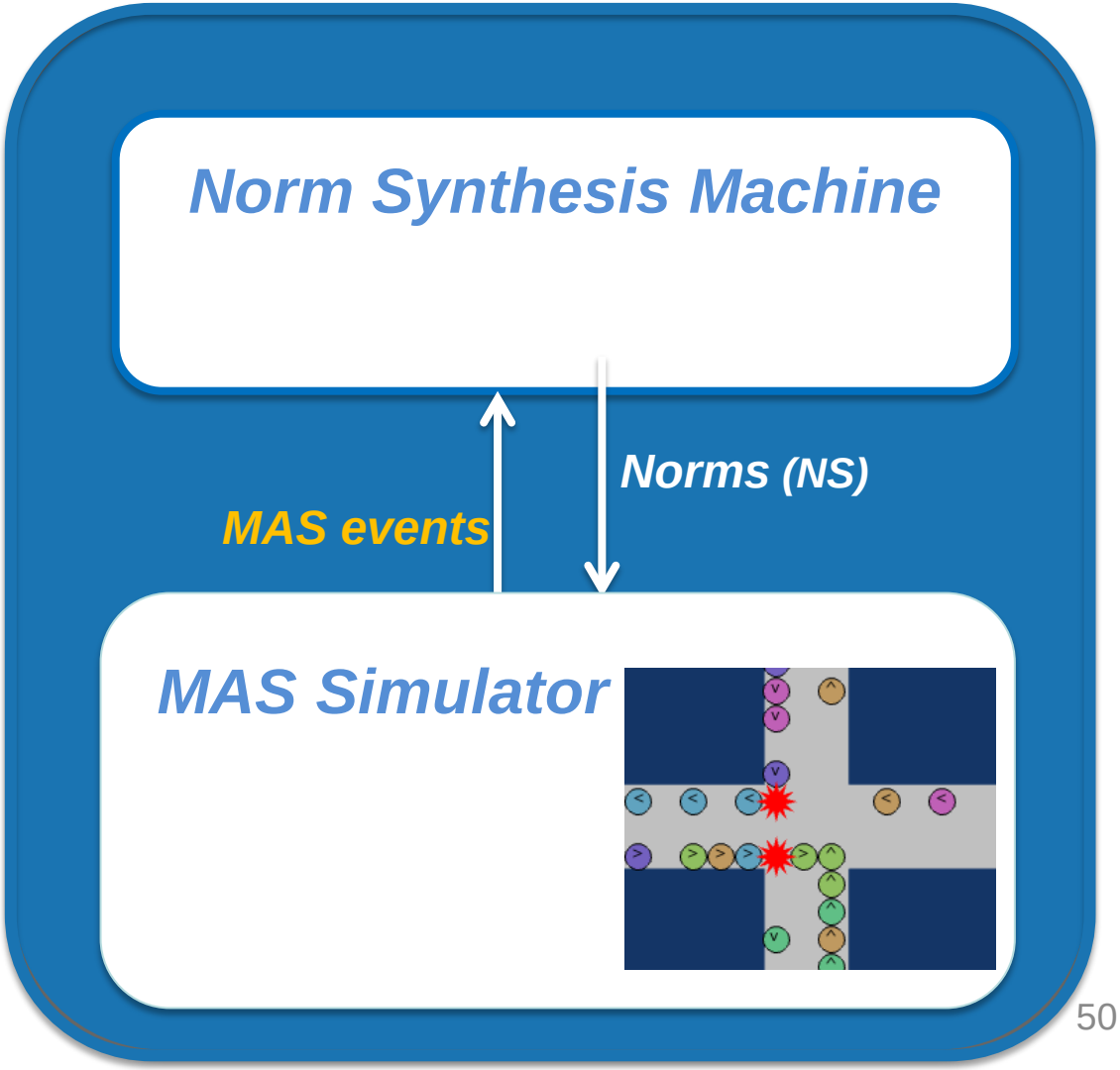

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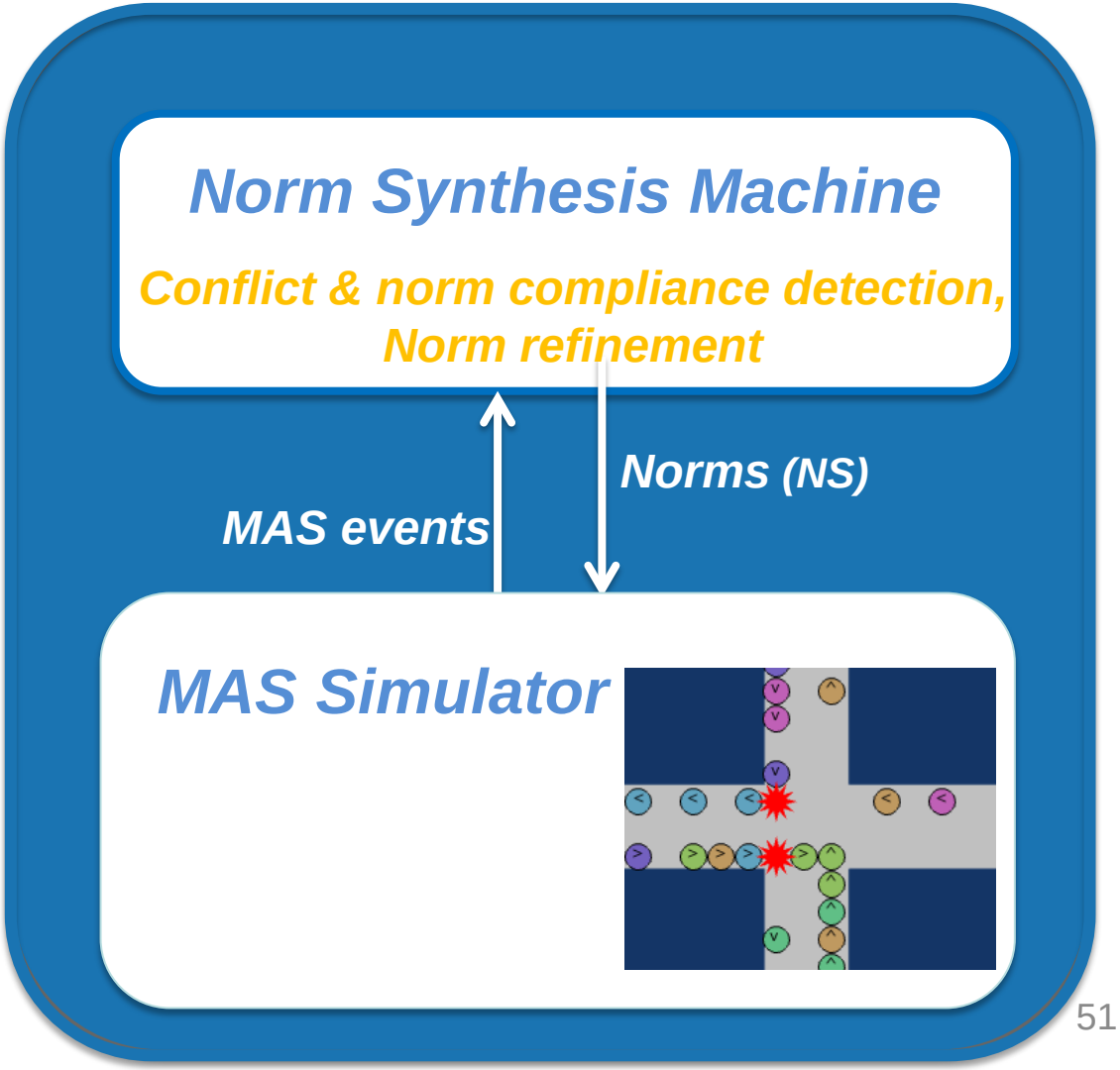

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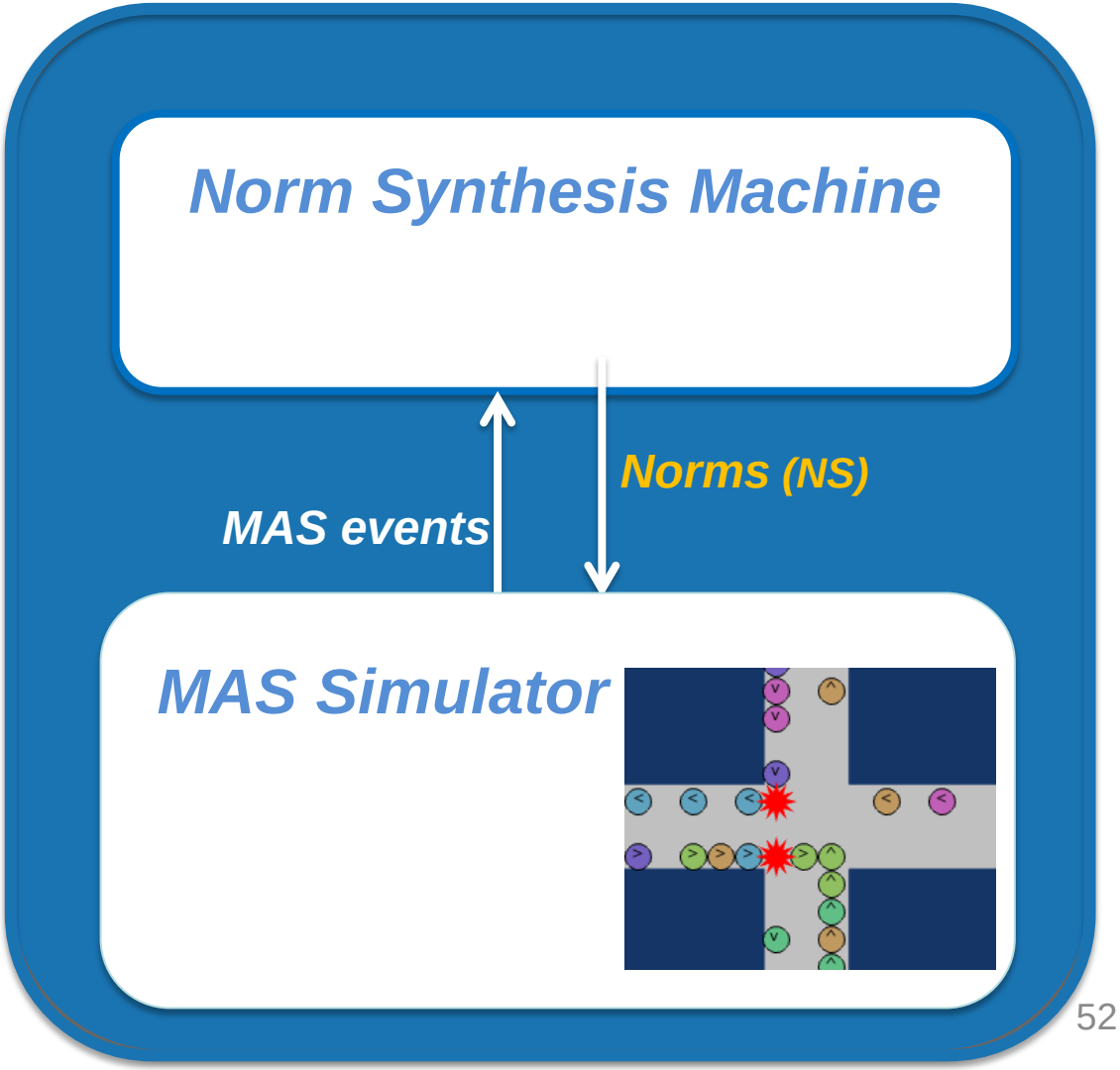

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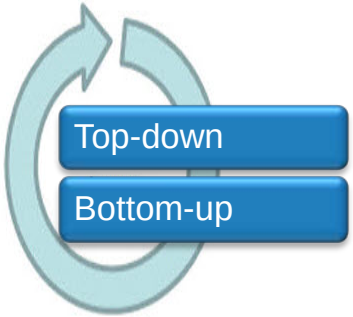
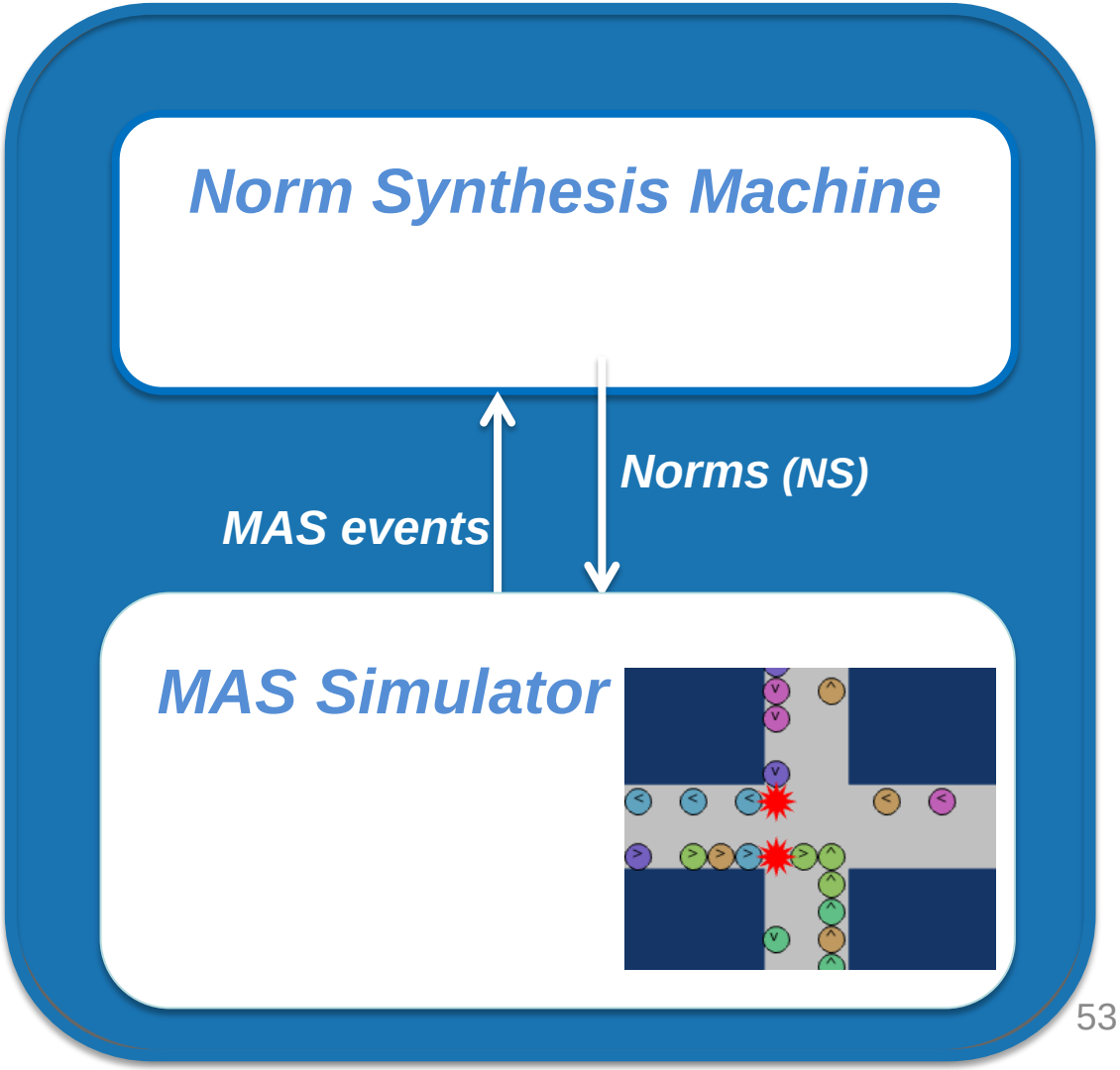


- Goal: conflict avoidance
- Dynamicity
- Division of concerns
-



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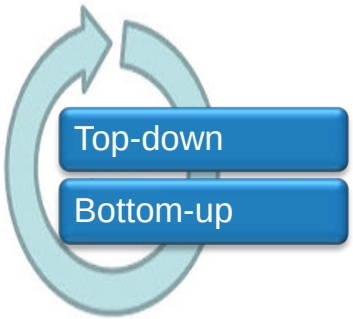
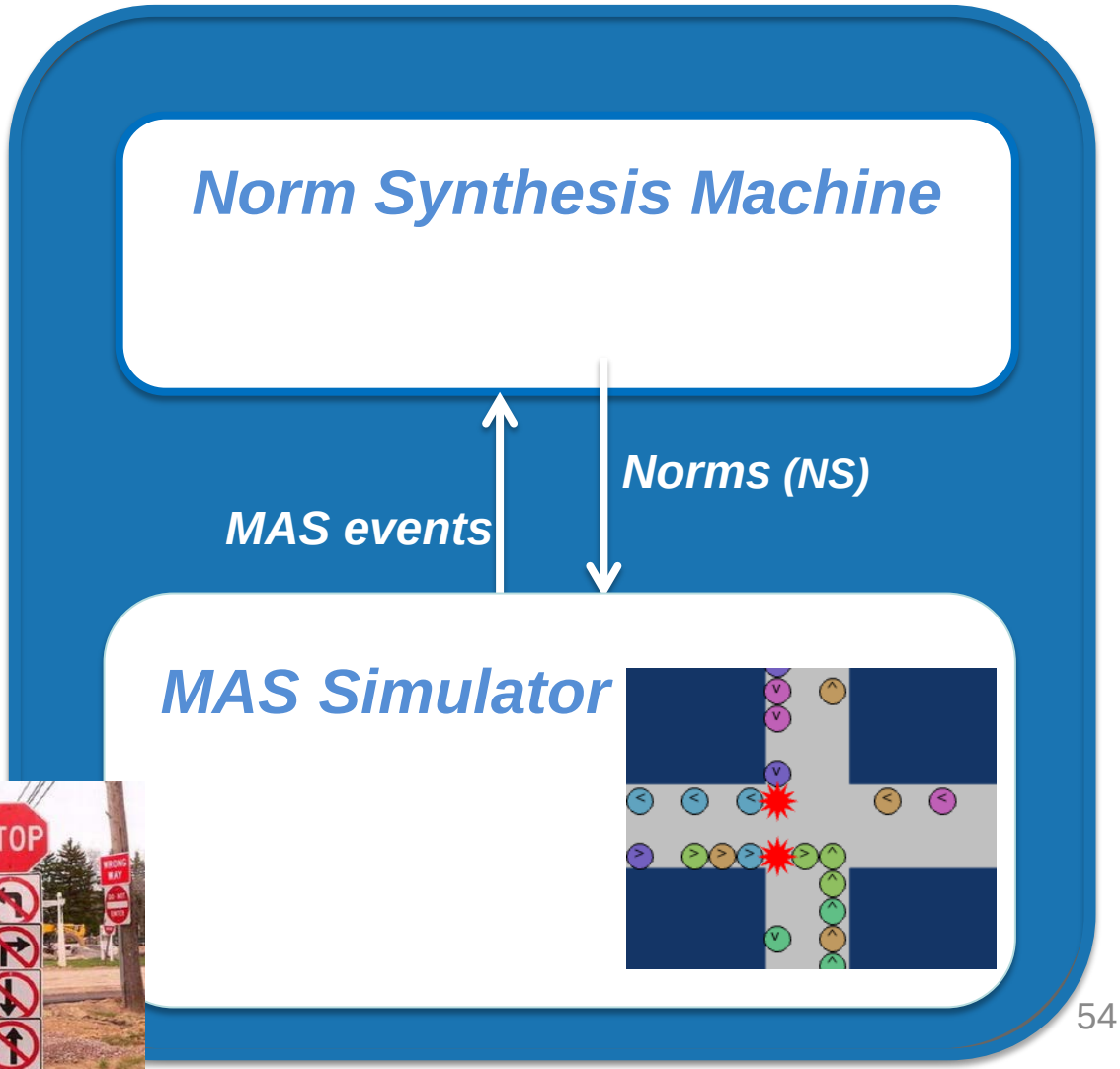


- Goal: conflict avoidance
- Dynamicity
- Division of concerns
- Similar to human socities



On-line norm generation

Morales, López-Sánchez, Rodríguez-Aguilar, Wooldridge, Vasconcelos

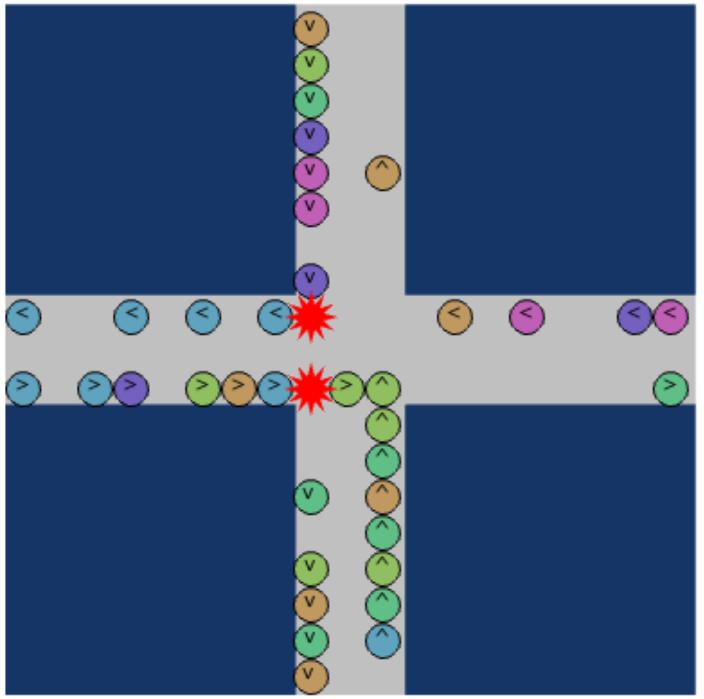
- Regulatory agents propose norms to avoid conflicts in agent interactions
  - Non intrusive, preserves agent autonomy
  - Requires **conflict** detection
  - Does not search the complete state space
- Norm evaluation based on
  - Agent responses (infringements and compliances)
  - Consequences (conflicts ≈ system goals)
  - Normative system compactness

Simulated Scenario

MAS

Simulated discretized traffic intersection:

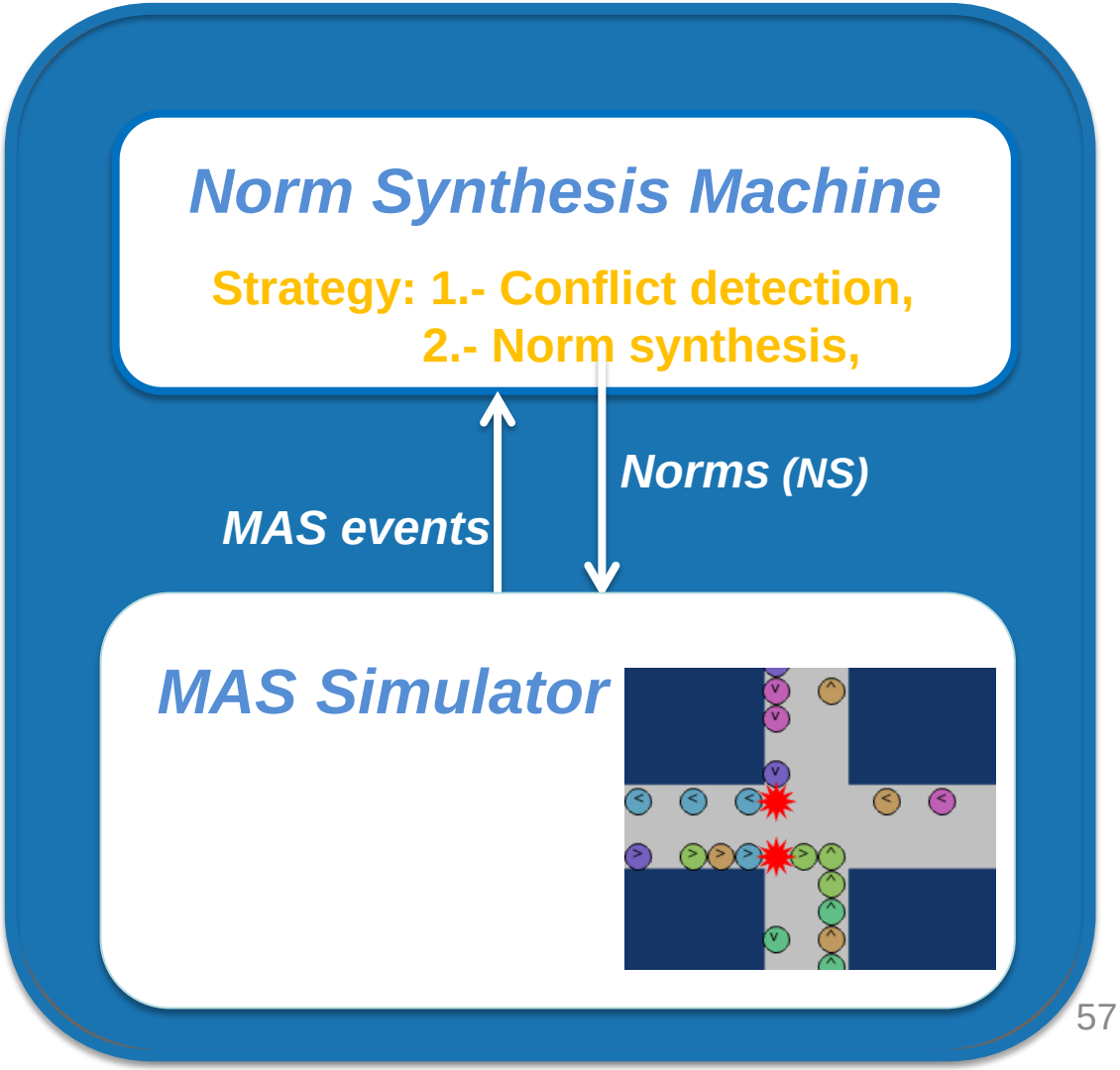
- Agents : cars.
- Conflicts: car collisions.
- MAS goal: collision avoidance.



Simulated traffic intersection scenario

On-line norm generation

Norm synthesis Strategy



Automated norm synthesis

Norm synthesis Strategy

1. **Conflict detection** by MAS observation.
2. For each detected **conflict** → **Synthesis** of a new norm
   - to avoid that conflict in the future.

Norm creation

Conflict Description

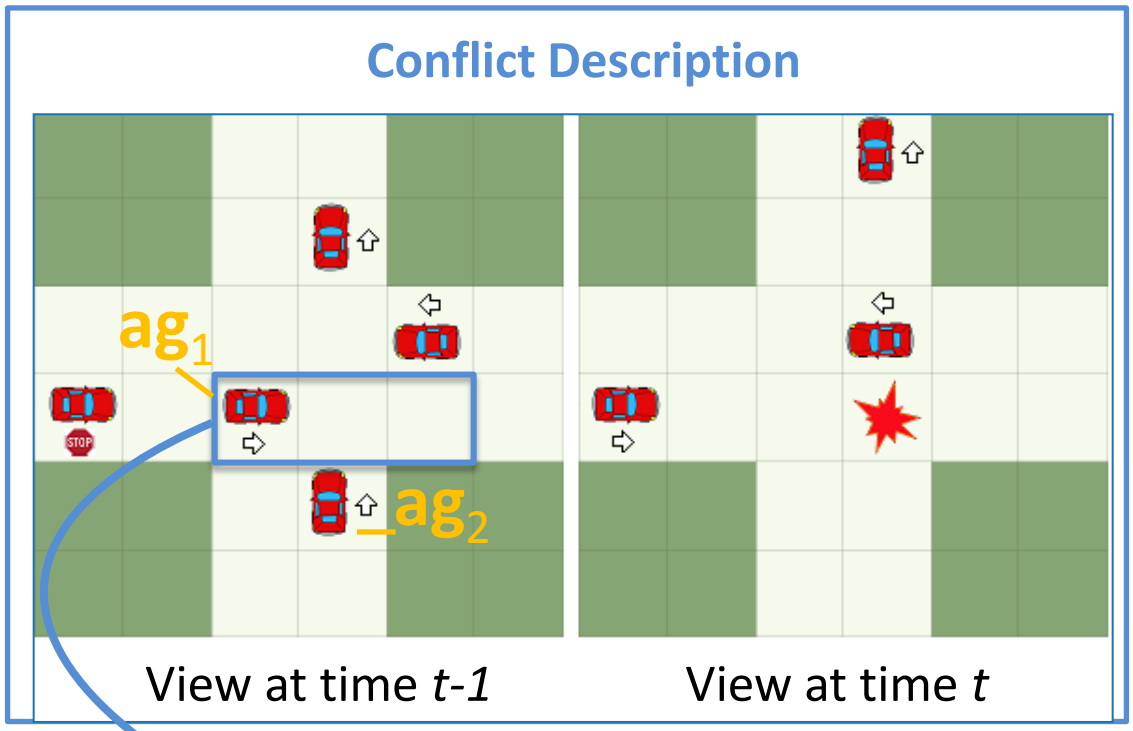
View at time *t-1* View at time *t*

Conflicting agents: $\{ag_1, ag_2\}$

Agent actions (*t-1* → *t*):

$\{ag_1$: Go, ag_2: Go$\}$

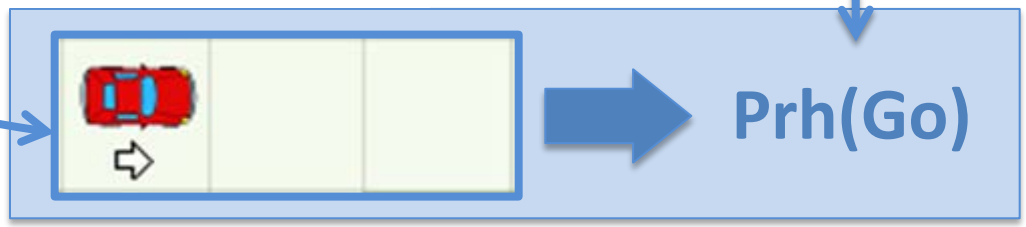
Norm creation



Conflicting agents: $\{ag_1, ag_2\}$

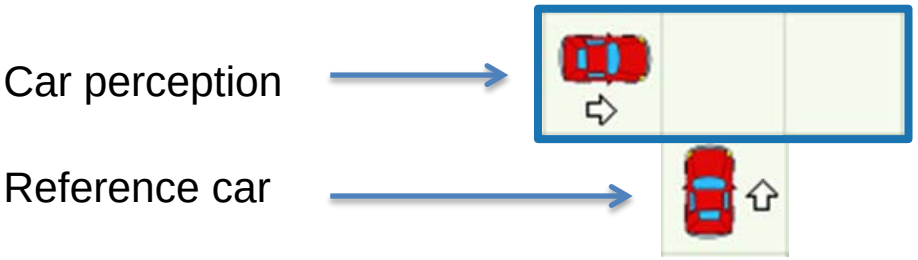
Agent actions ($t\text{-}1 \rightarrow t$):

$\{ag_1$: Go, ag_2: Go$\}$



Norm syntax

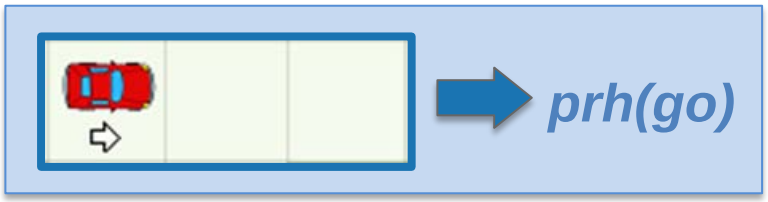
In the traffic simulator, cars perceive three cells in front:



$$
\begin{aligned}
Norm &::= \langle \phi, \Theta(ac) \rangle \\
\phi &::= \langle \phi \ \& \ \phi \rangle \mid \alpha \\
\Theta &::= obl \mid perm \mid prh \\
Ac &::= ac_1 \mid ac_2 \mid \ldots \mid ac_n \\
\alpha &::= p^n(\tau_1, \ldots, \tau_n)
\end{aligned}
$$

Norms are…

- **IF** … **THEN**… rules: **<φ, Θ(ac)>**
  - Whenever the local perception of an agent satisfies the precondition of a norm (**φ**), then the norm **applies to the agent**: the deontic operator specifies the modality of its action **ac**
  - **α** : unary **predicates**: α ∈{left, front, right}
  - τ_i : terms τ_i ∈{car-to-right, car-same-dir, car-to-left, car-opp-dir, nothing, wall, anything }
- Ex.: **IF** **left**(car-to-right) **&** **front**(nothing) **&** **right**(nothing) **THEN** **prohibition**(go)



Graphical representation

Automated norm synthesis

Norm synthesis Strategy

1. **Conflict detection** by MAS observation.
2. For each detected **conflict** → **Synthesis** of a new norm.
   - to avoid the conflict in the future.

But… are synthesised norms good enough for avoiding conflicts?

Automated norm synthesis

Norm synthesis Strategy

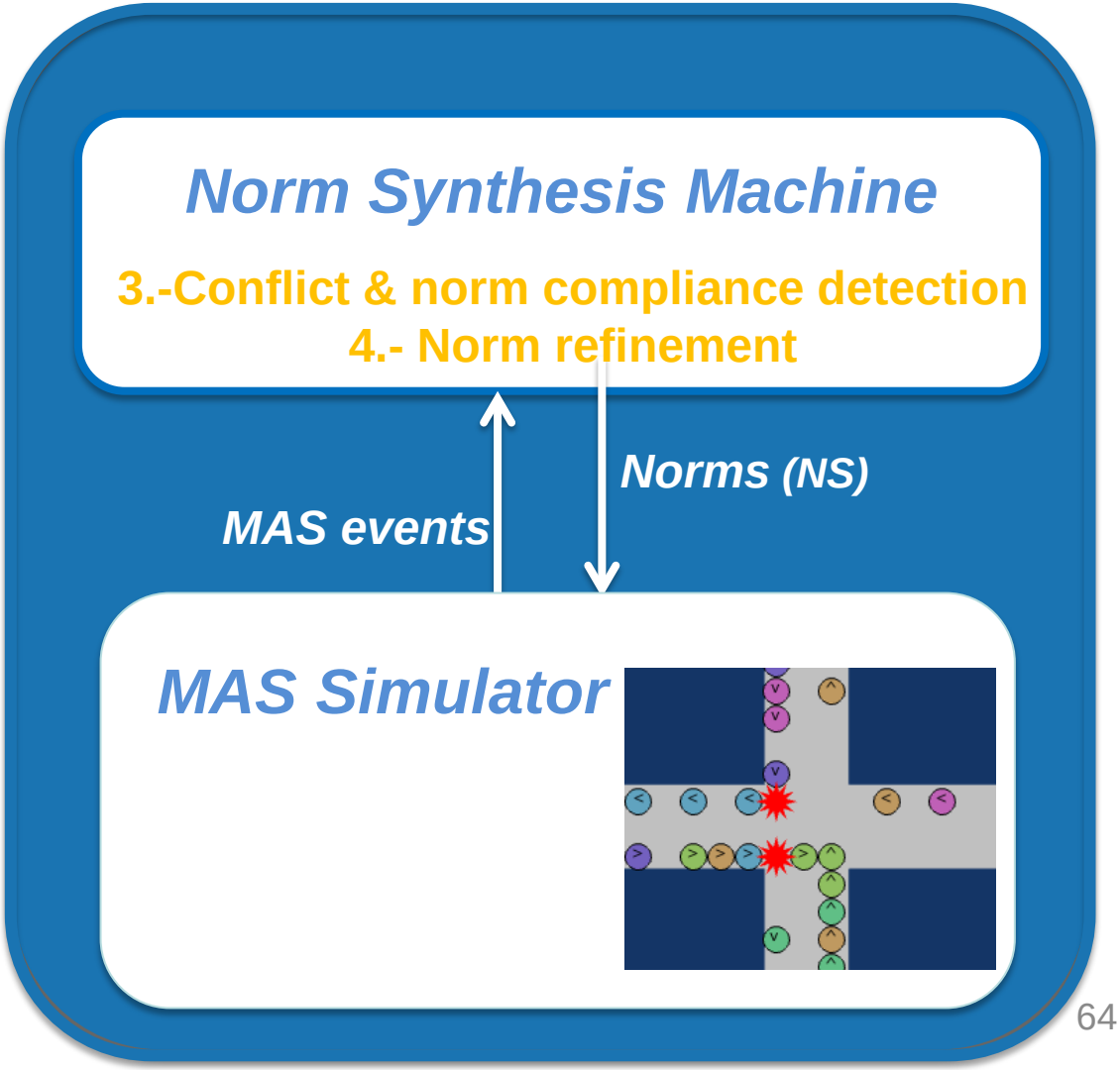
1. **Conflict detection** by MAS observation.
2. For each detected **conflict** → **Synthesis** of a new norm.
   - to avoid the conflict in the future.

But… are synthesised norms good enough for avoiding conflicts?

3. Evaluate norms in terms of:
   - **Effectiveness:** Do norms avoid conflicts when agents comply with them?
     - *If complied & no conflicts* → ***Effectiveness*** ↑↑ *(ex. Left hand side priority)*
     - *If complied & conflicts* → *Effectiveness* ↓↓ *(ex. Never give way)*
   - **Necessity:** Do conflicts arise when agents infringe norms?
     - *If infringed & no conflicts* → *Necessity* ↓↓ *(ex. Stop if no car in view)*
     - *If infringed & conflicts* → ***Necessity*** ↑↑ *(ex. Left hand side priority)*

On-line norm generation

Architecture

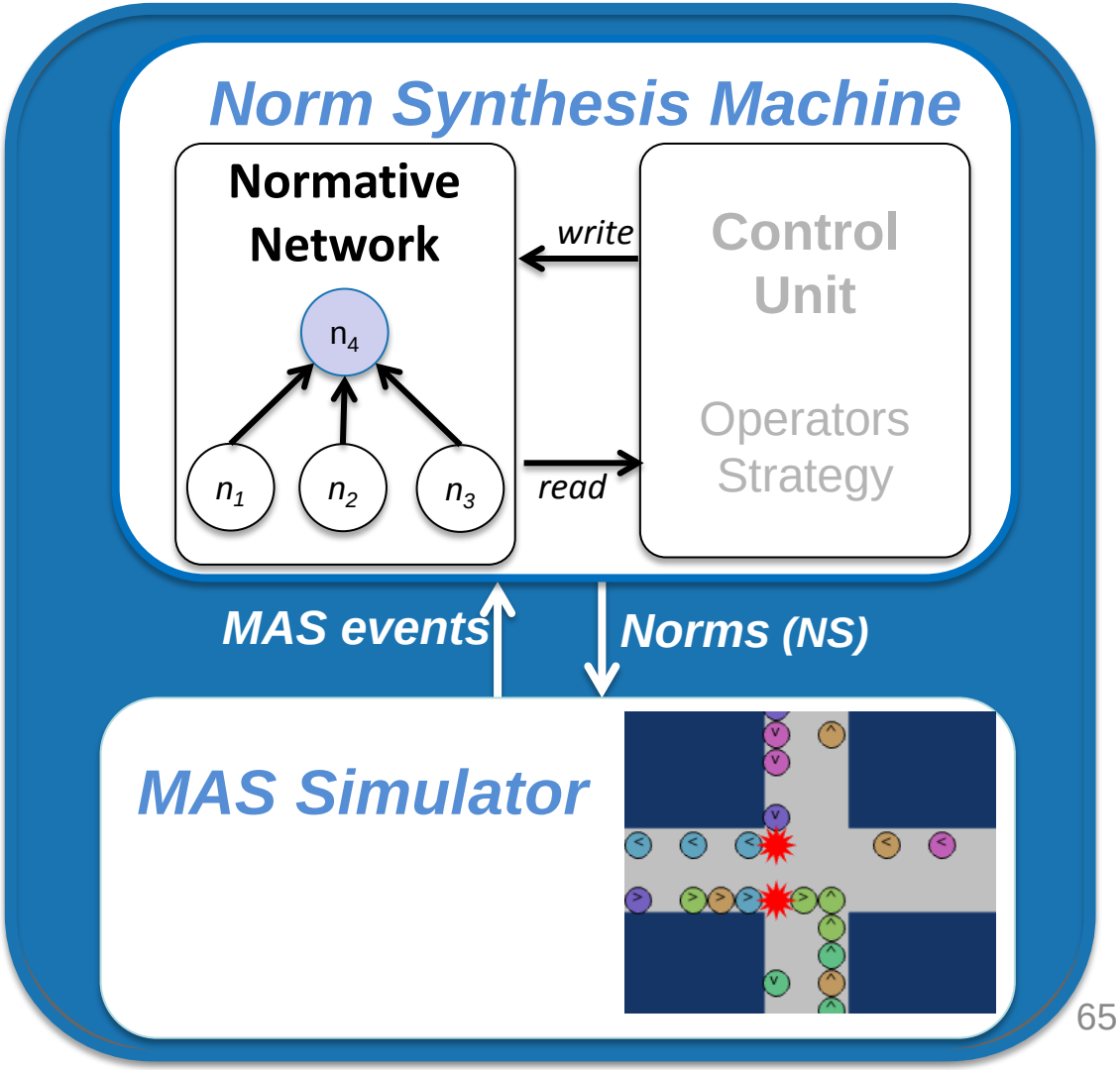


Norm Synthesis Machine

Normative Network

Normative Network
(Data Structure):

- Nodes*:* explored norms.
- Edges*:* norm generalisation relationships



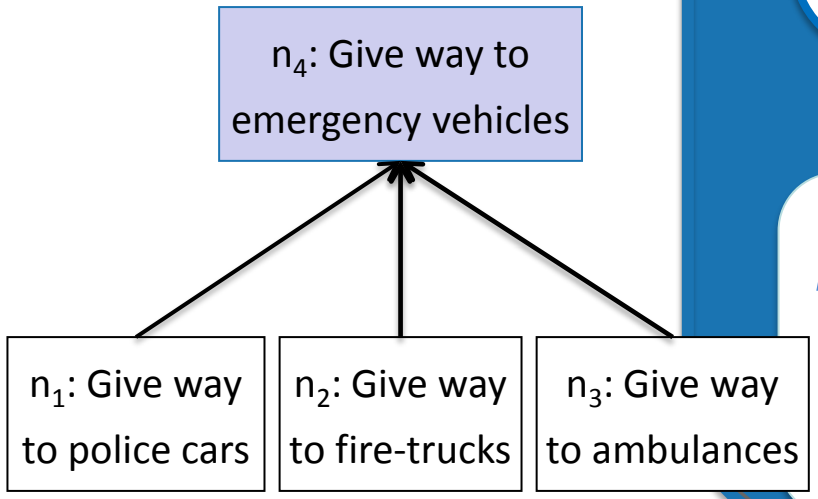
Norm Synthesis Machine

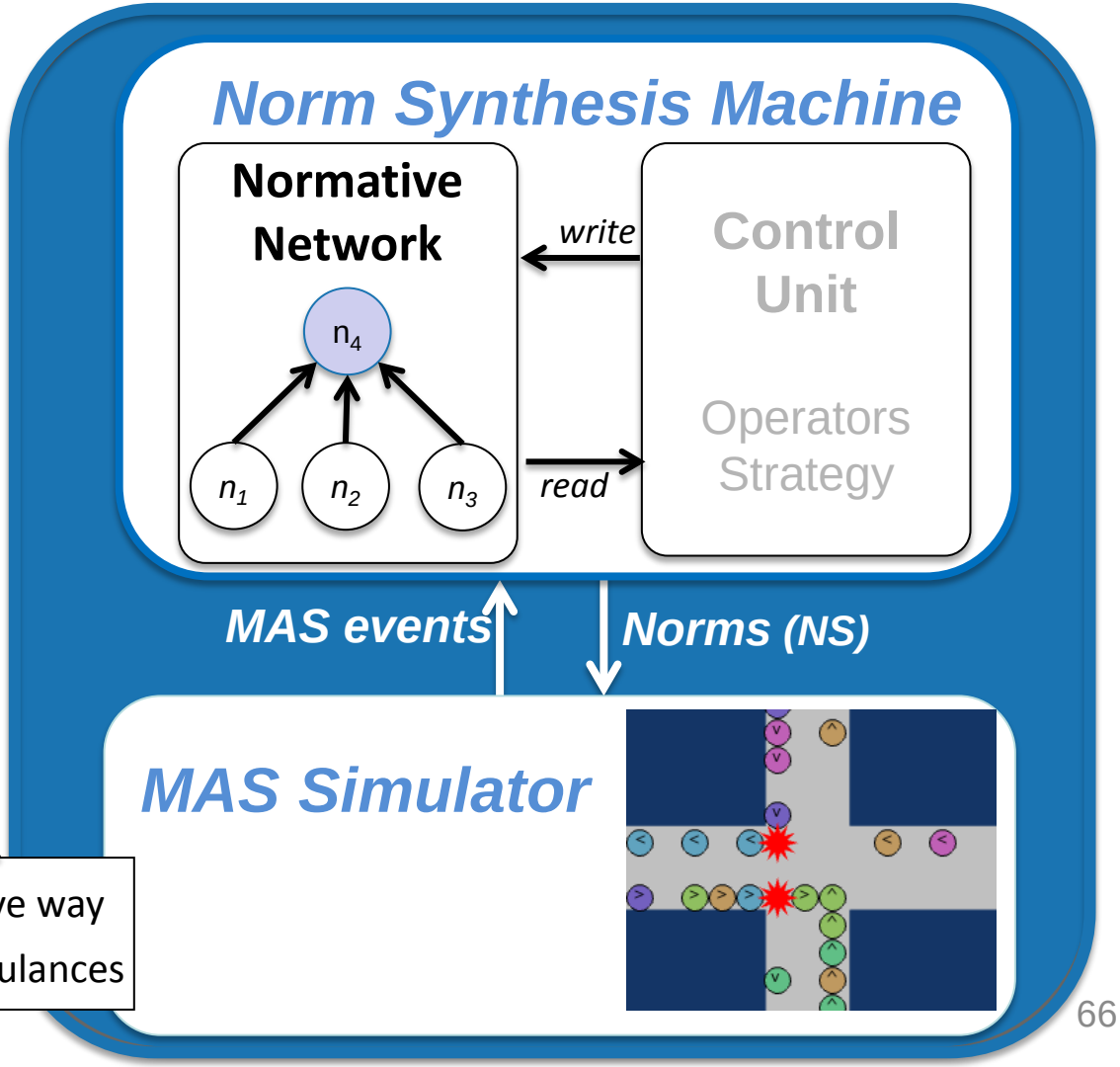
Normative Network

Normative Network

(Data Structure):

- Nodes: explored norms.
- Edges: norm generalisation relationships





Norm Synthesis Machine

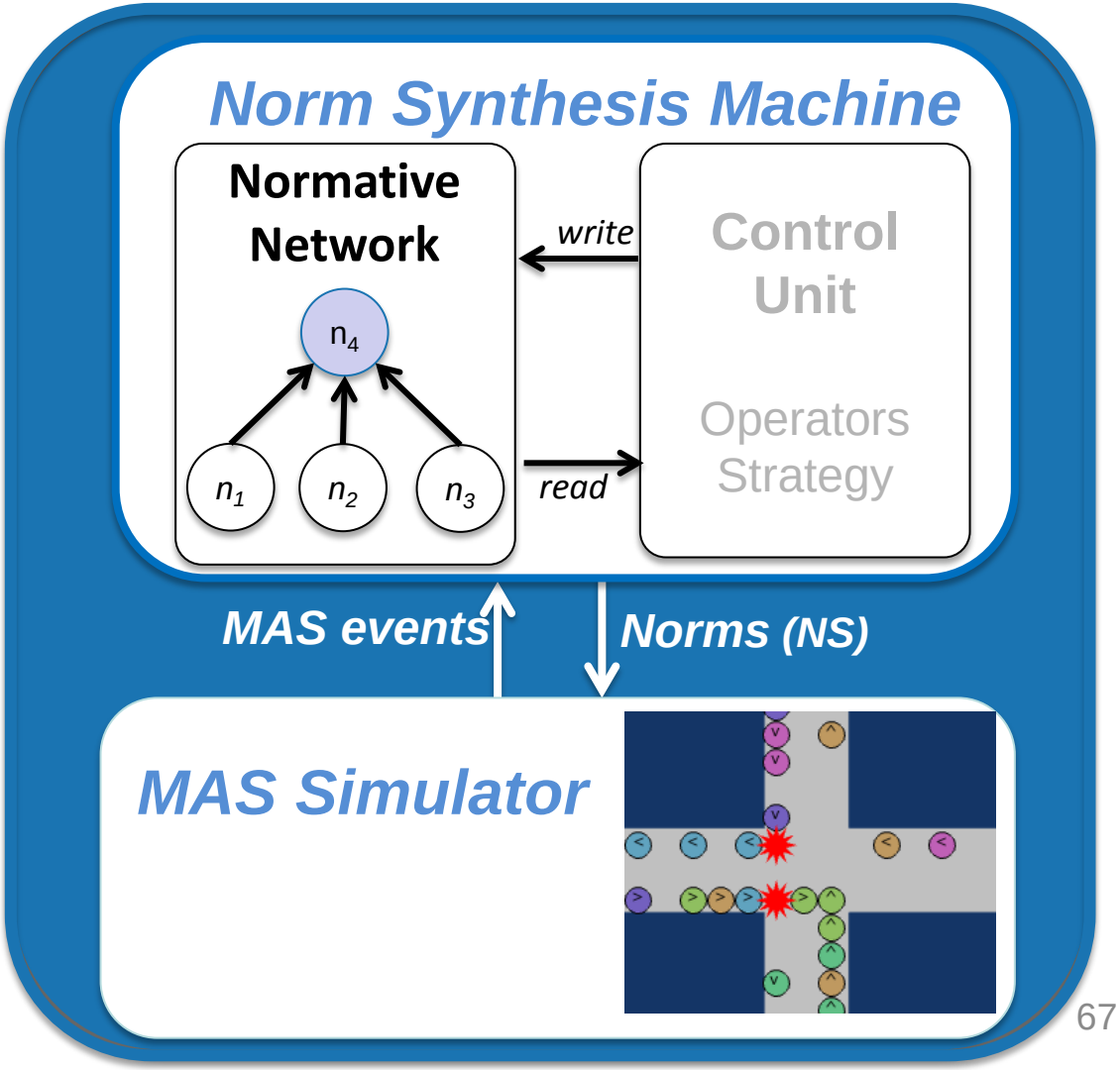
Normative Network

Normative Network (Data Structure):

- Nodes*:* explored norms.
- Edges*:* norm generalisation relationships

A Normative Network represents a **Normative *System*** *Ω as its* **active norms**.

Ex: $\Omega = \{n_4\}$



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Automated norm synthesis

Norm synthesis Strategy

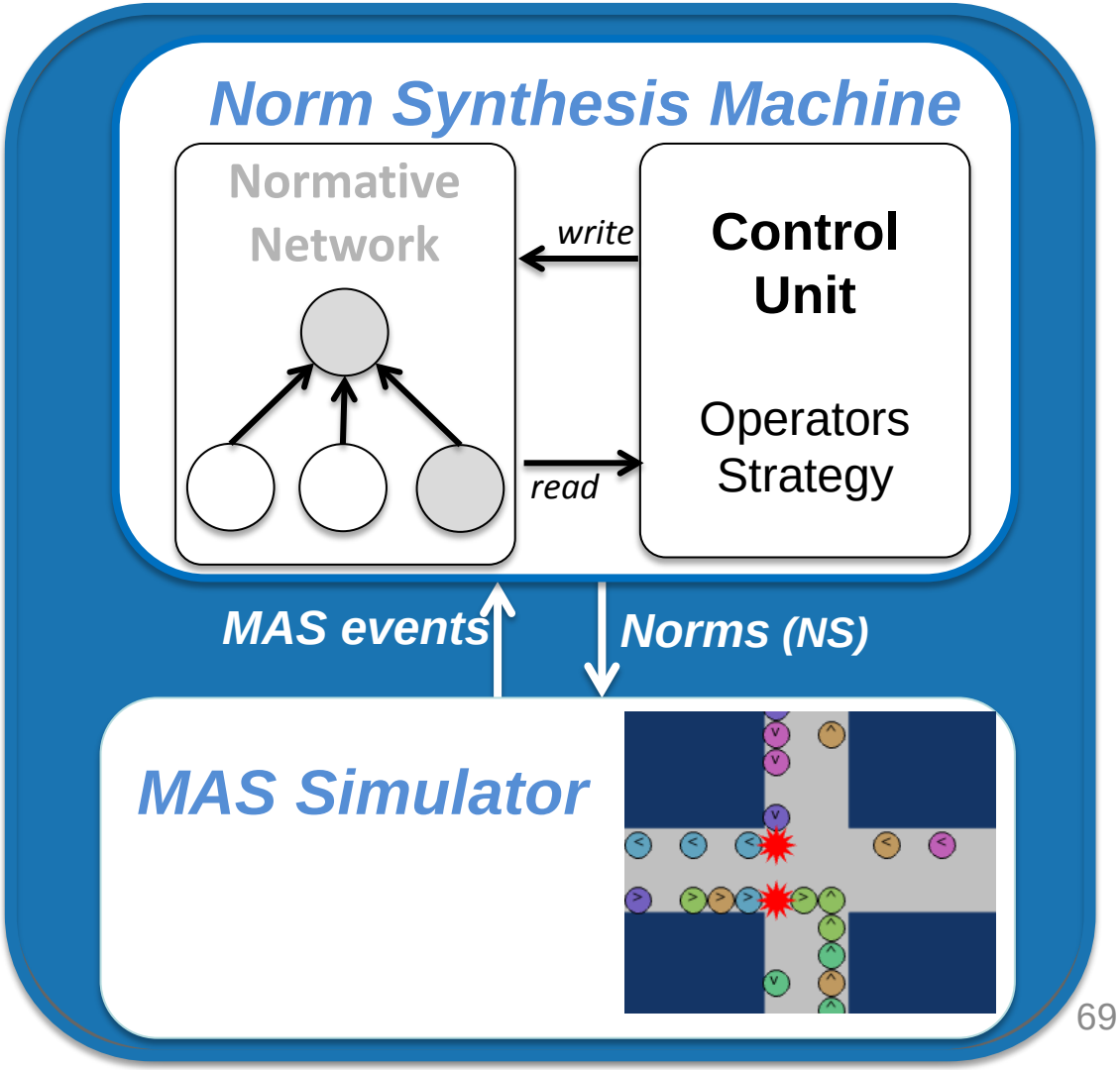
1. **Conflict detection** by MAS observation.
2. For each detected **conflict** → **Synthesis** of new norms.
   - New norms are aimed to avoid the conflict in the future.

But… are synthesised norms good enough for avoiding conflicts?

3. Evaluate norms in terms of:
   - **Effectiveness:** Do norms avoid conflicts when agents comply with them?
   - **Necessity:** Do conflicts arise when agents infringe norms?
4. Refine norms:
   - Deactivate/Specialise norms that do not perform well
   - Generalise well performing norms (if enough evidence)

On-line norm generation

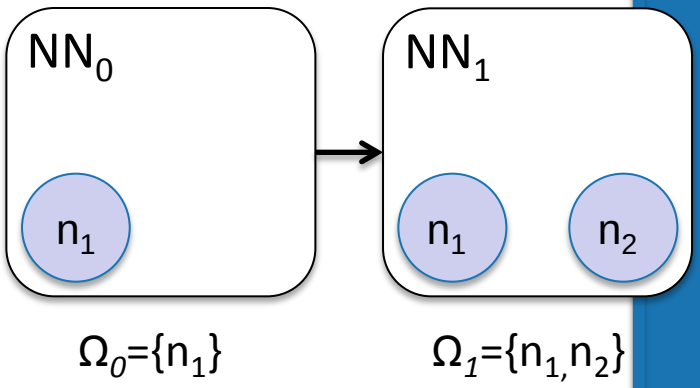
Architecture

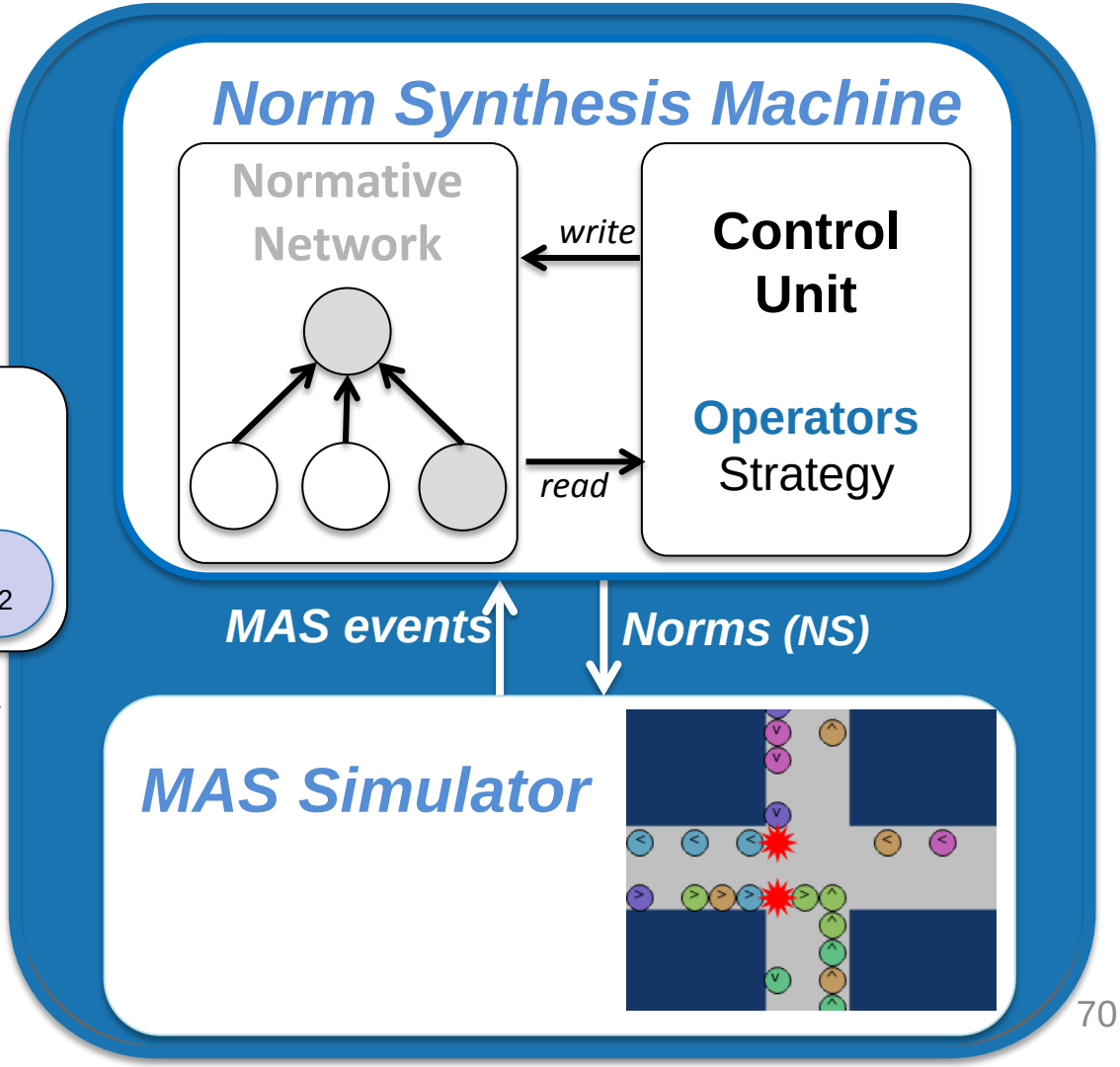


Normative Network Operators

Create operator

create: Synthesises a norm and adds it to the Normative Network

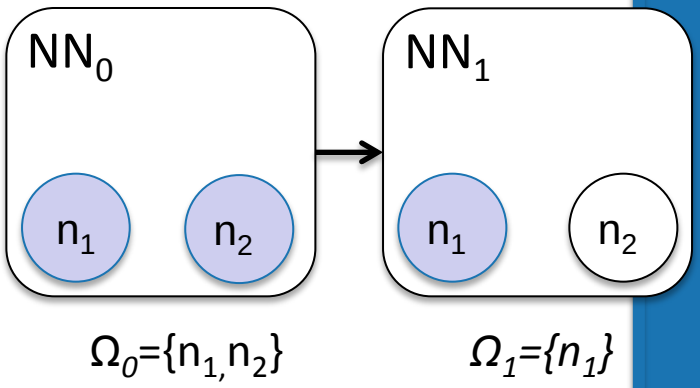


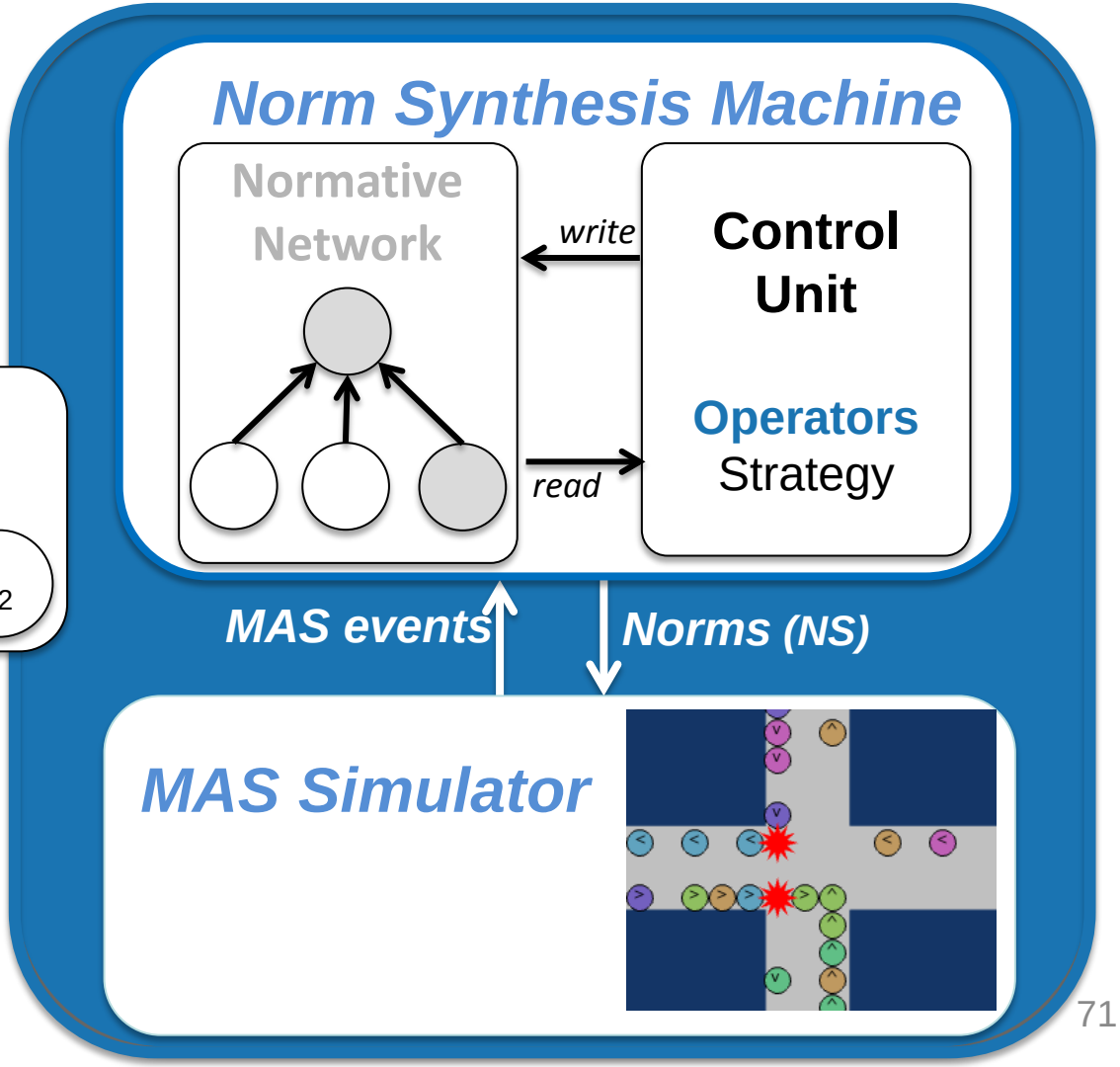


Normative Network Operators

Deactivate operator

deactivate: Deactivates a norm in the Normative Network

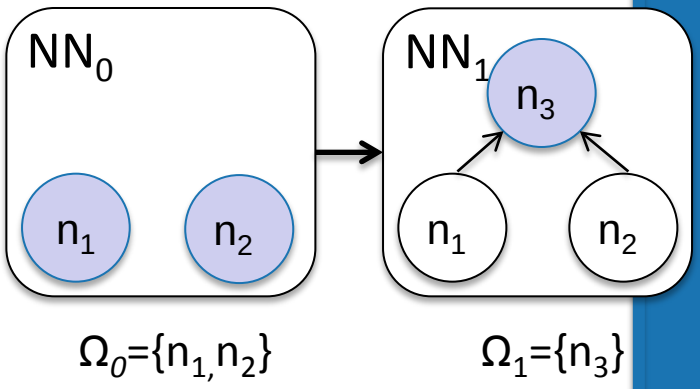


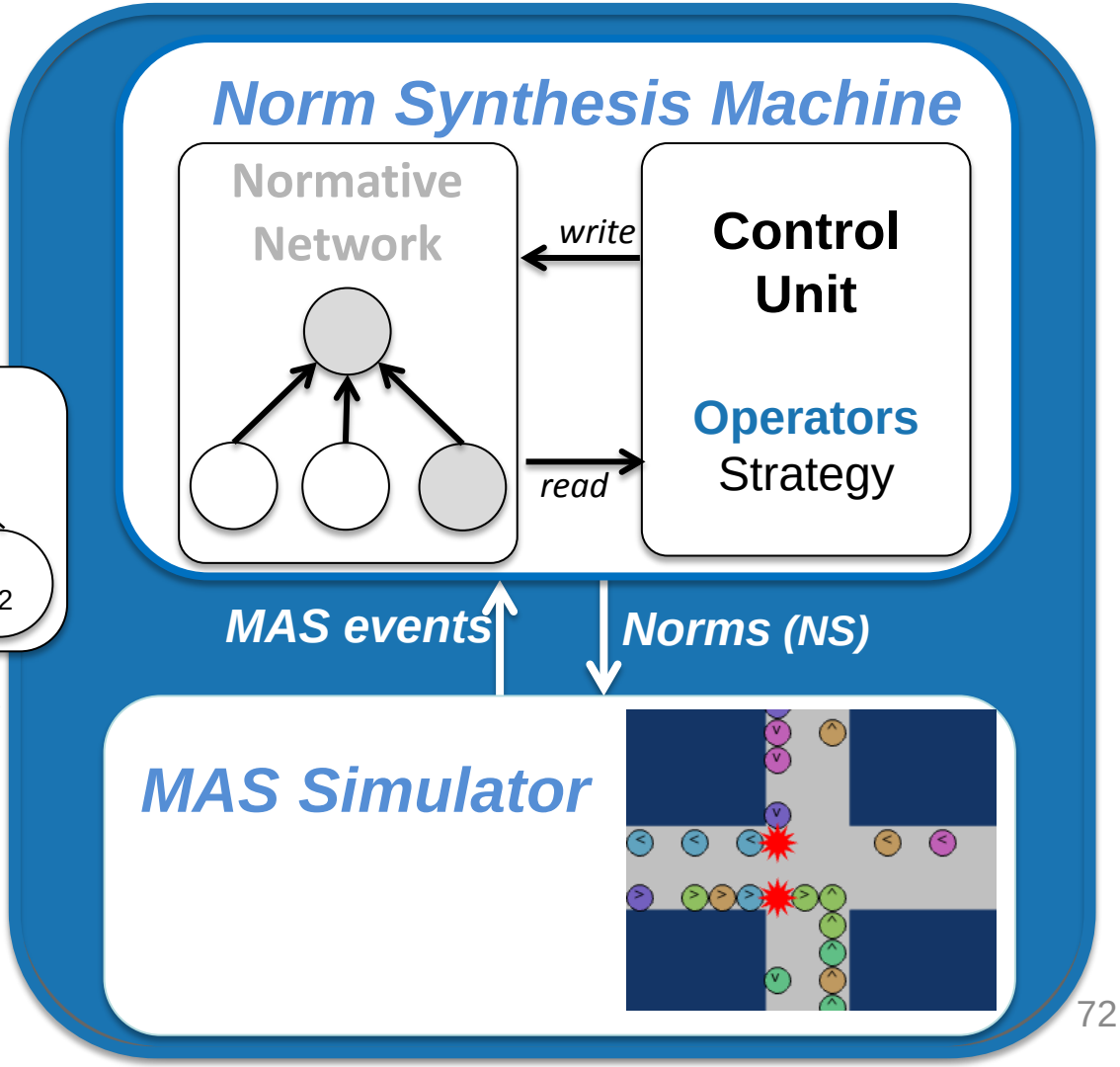


Normative Network Operators

Generalise operator

***generalise*: Generalises a set of norms into a parent norm**

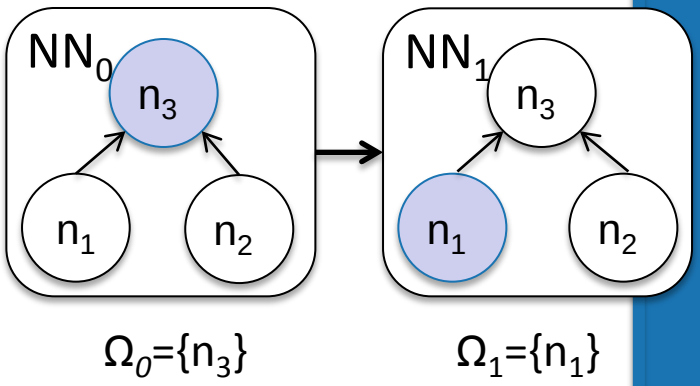


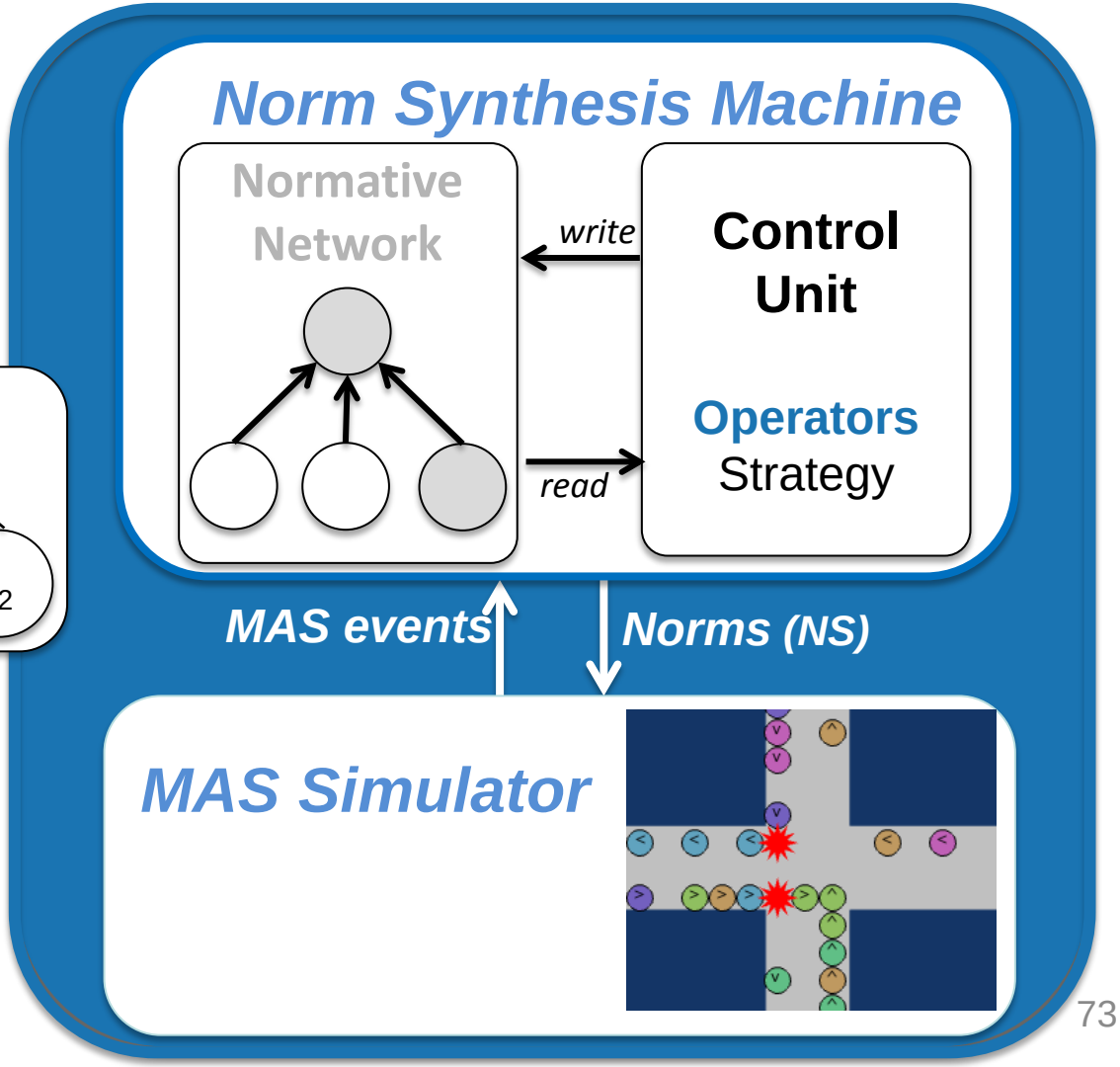


Normative Network Operators

Specialise operator

specialises: Undoes a norm generalisation



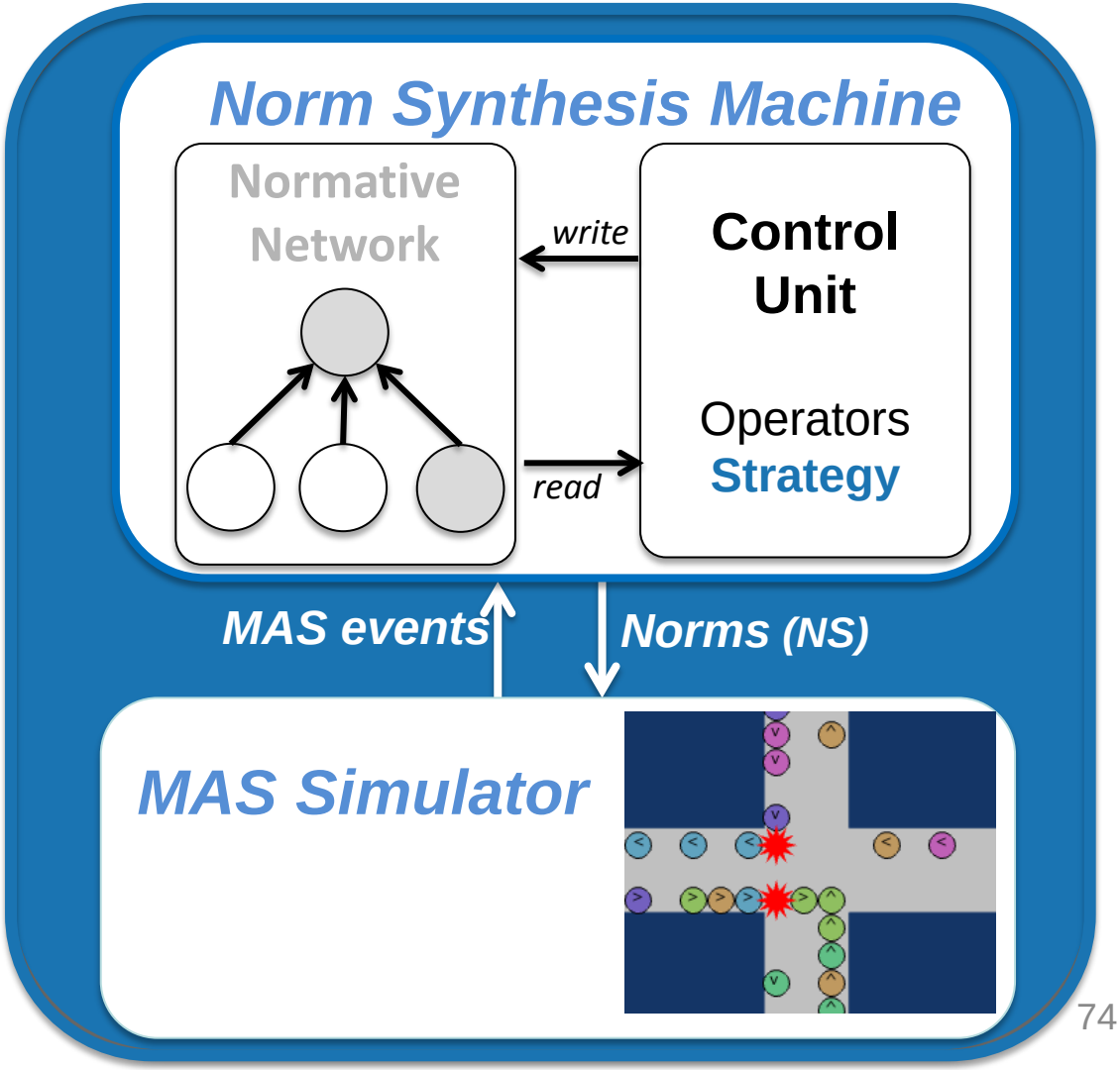


On-line norm generation

Norm synthesis strategy

Norm Synthesis Strategy:

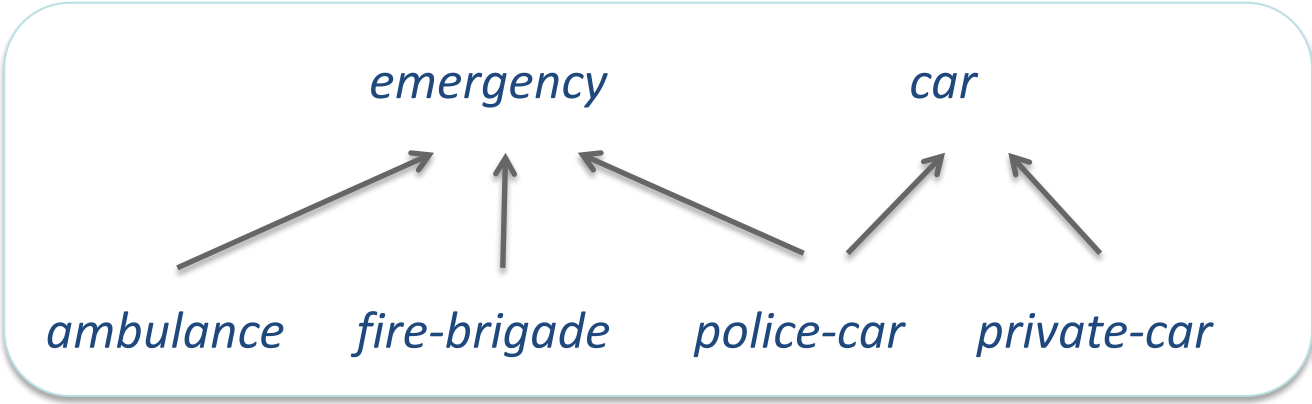
1. Conflict detection
2. Norm creation
3. Norm evaluation
4. Norm Refinement:
   - Deactivate/specialise norms that do not perform well
   - **Generalise** well performing norms (if enough evidence)



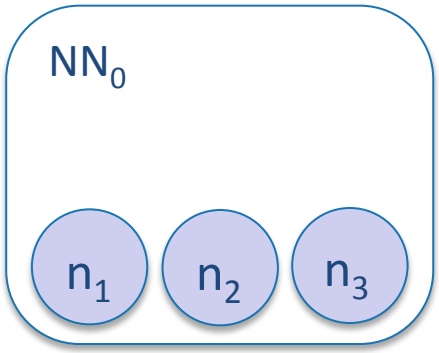
Norm generalisation

Taxonomy of terms

- Term taxonomy



- Norm generalisation



Normative System

$\Omega_0 = \{n_1, n_2, n_3\}$

n_1: Give way to **ambulances**

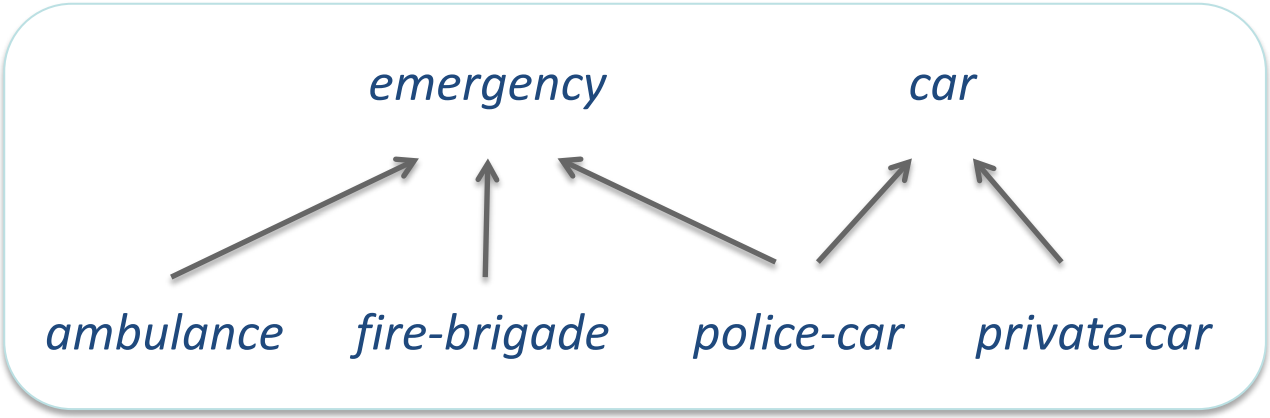
n_2: Give way to **fire brigade**

n_3: Give way to **police cars**

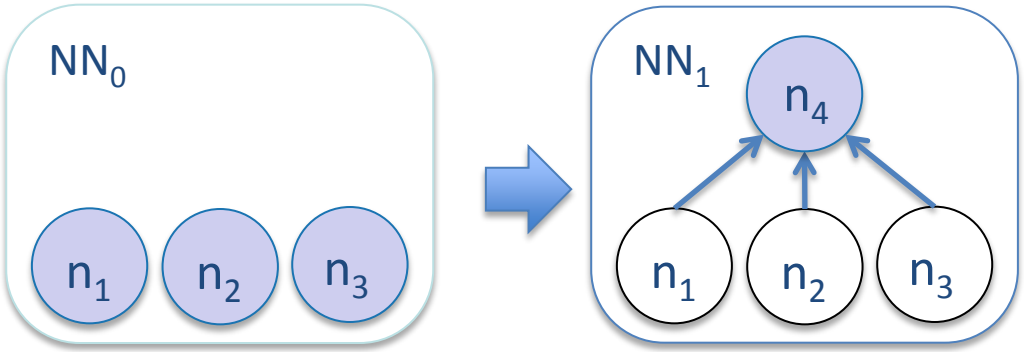
Norm generalisation

Conservative approach

- Term taxonomy



- Norm generalisation



Normative System
$\Omega_0 = \{n_1, n_2, n_3\}$

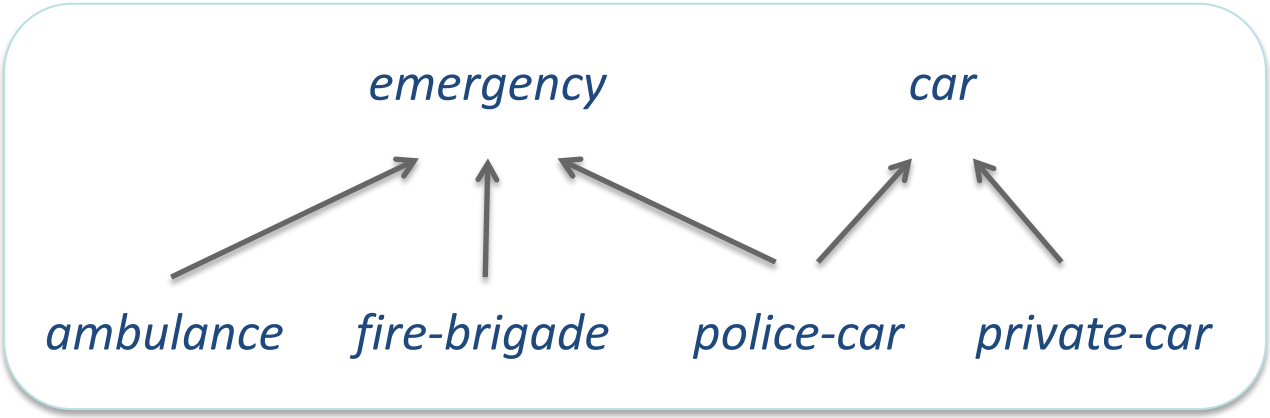
Normative System
$\Omega_1 = \{n_4\}$

n_1: Give way to **ambulances**
n_2: Give way to **fire brigade**
n_3: Give way to **police cars**
n_4: Give way to **emergency** vehicles

Norm generalisation

Conservative approach

- Term taxonomy

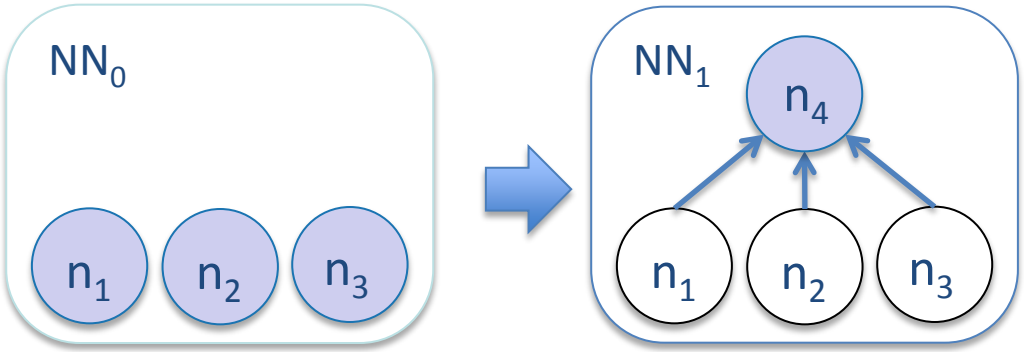


- Norm generalisation

Conservative approach

Employs **full evidence**

to generalise norms.



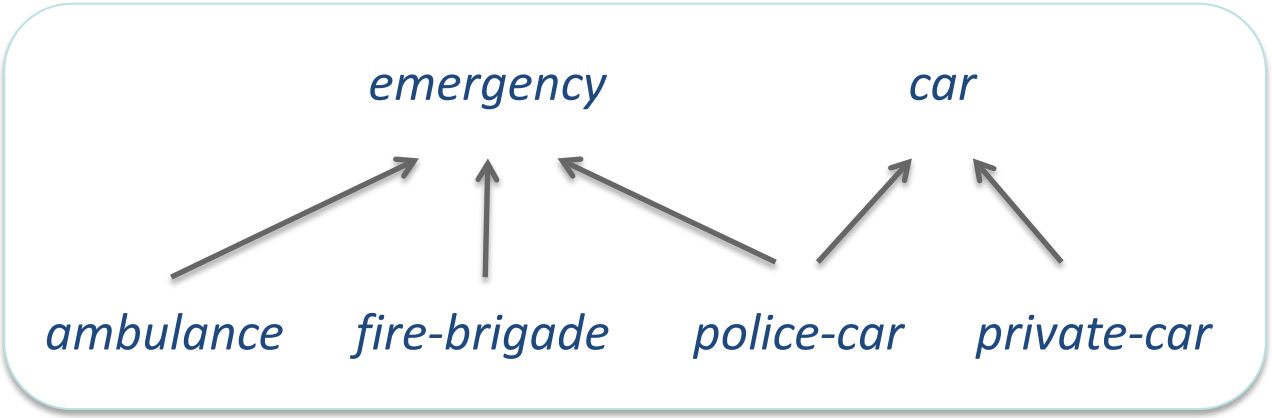
Normative System
$\Omega_0 = \{n_1, n_2, n_3\}$

Normative System
$\Omega_1 = \{n_4\}$

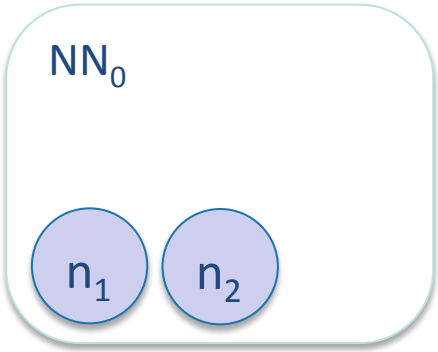
Norm generalisation

Optimistic approach

- Term taxonomy



- Optimistic norm generalisation



Normative System

$\Omega_0 = \{n_1, n_2\}$

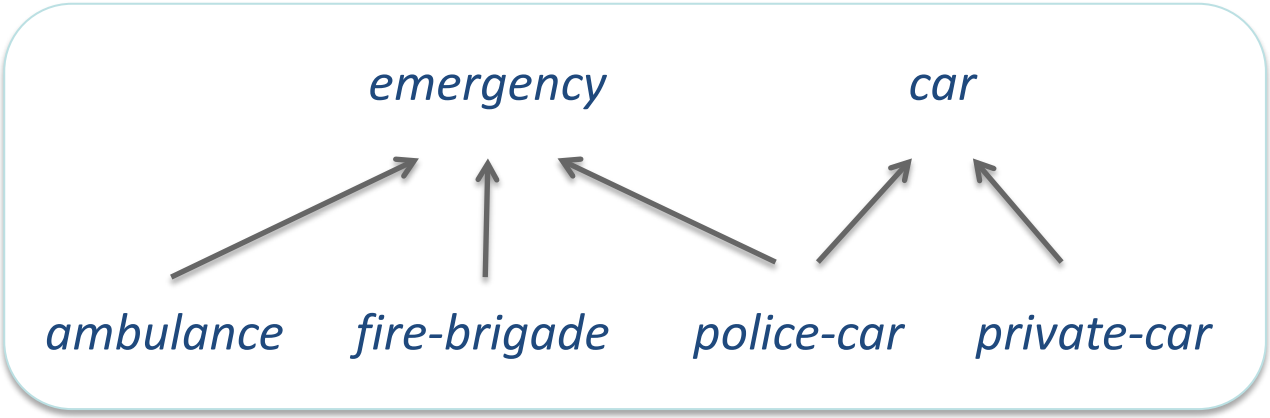
n_1: Give way to **ambulances**

n_2: Give way to **fire brigade**

Norm generalisation

Optimistic approach

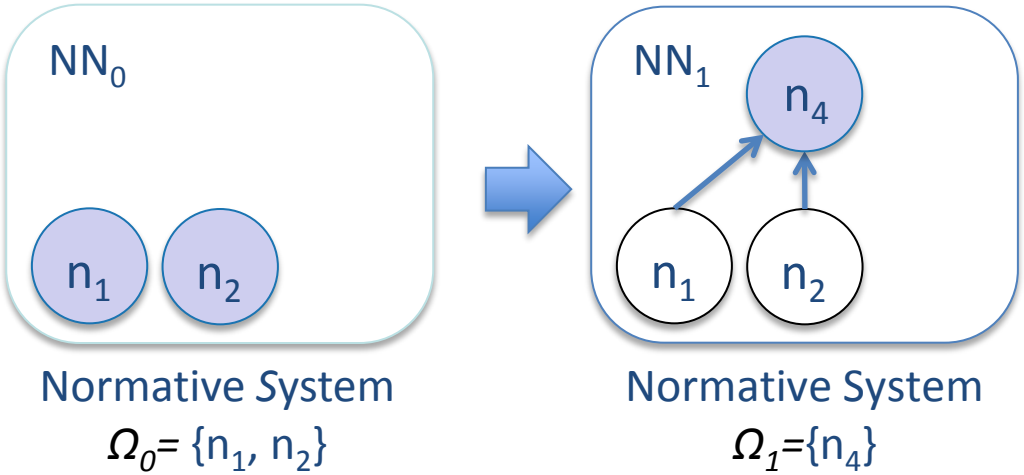
- Term taxonomy



- Optimistic norm generalisation (partial evidence)

Most specific generalisation between two terms

E. Armengol and E. Plaza.
Bottom-up induction of feature terms.
Machine Learning, 41(3):259–294, 2000.



Normative System
$\Omega_0 = \{n_1, n_2\}$

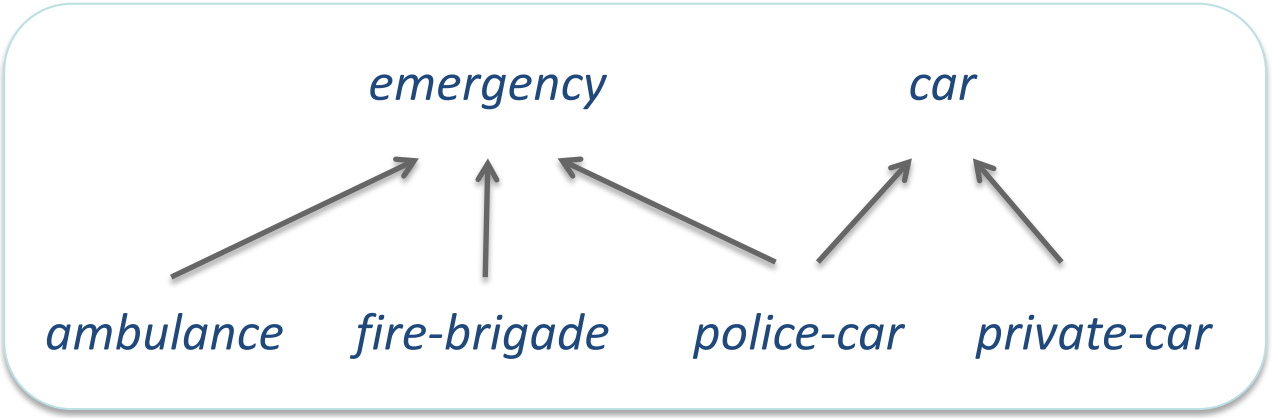
Normative System
$\Omega_1 = \{n_4\}$

n_1: Give way to **ambulances**
n_2: Give way to **fire brigade**
n_4: Give way to **emergency** vehicles

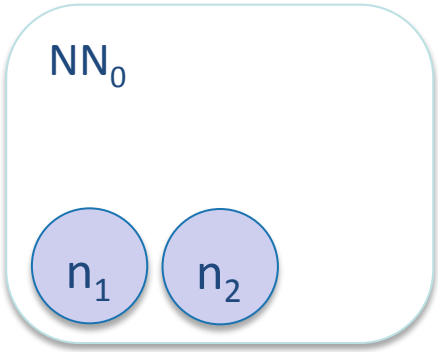
Norm generalisation

Generalisation modes: shallow

- Term taxonomy



- **Shallow** Optimistic norm generalisation



Normative System

$\Omega_0 = \{n_1, n_2\}$

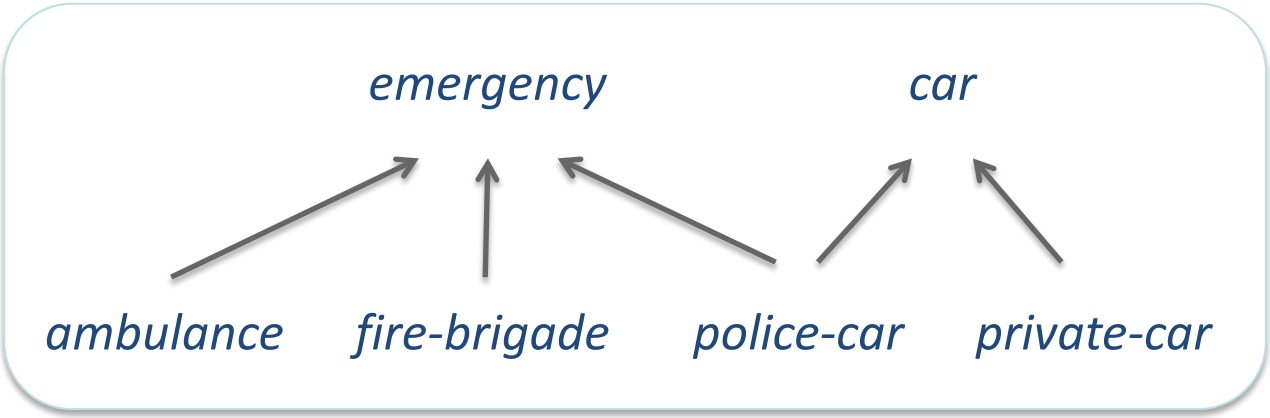
n_1: Give way to **ambulances**

n_2: Give way to **fire brigade**

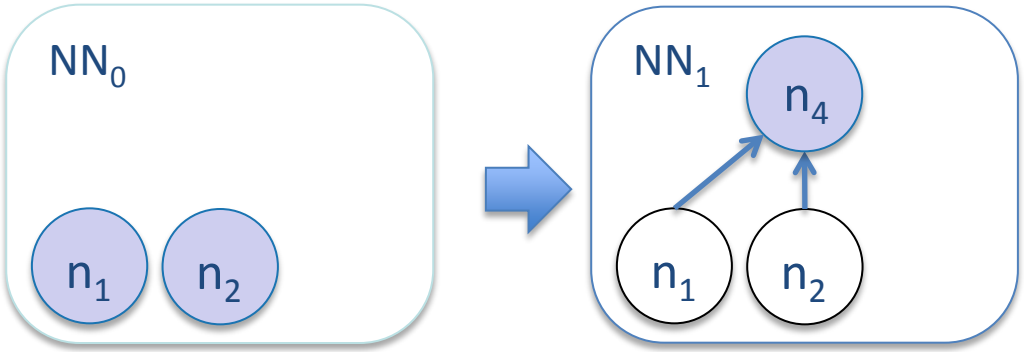
Norm generalisation

Generalisation modes: shallow

- Term taxonomy



- **Shallow** Optimistic norm generalisation
  - **Directly** generalises two active norms (in Ω).



Normative System
$\Omega_0 = \{n_1, n_2\}$

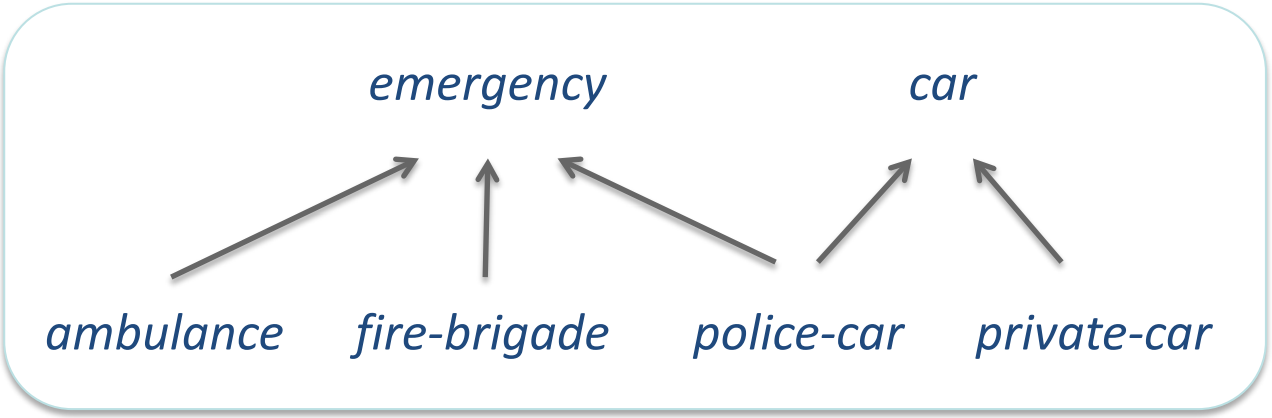
Normative System
$\Omega_1 = \{n_4\}$

n_1: Give way to **ambulances**
n_2: Give way to **fire brigade**
n_4: Give way to **emergency** vehicles

Norm generalisation

Generalisation modes: deep

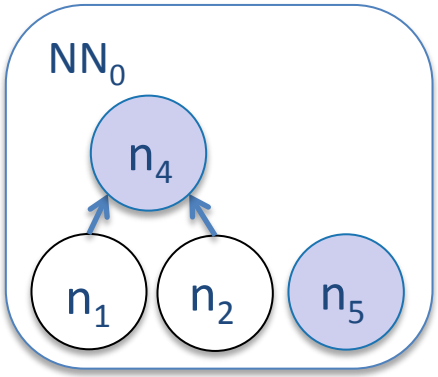
- Term taxonomy



- **Deep** Optimistic norm generalisation

n_1: Give way to **ambulances**
n_2: Give way to **fire brigade**

n_4: Give way to **emergency** vehicles
n_5: Give way to **private cars**

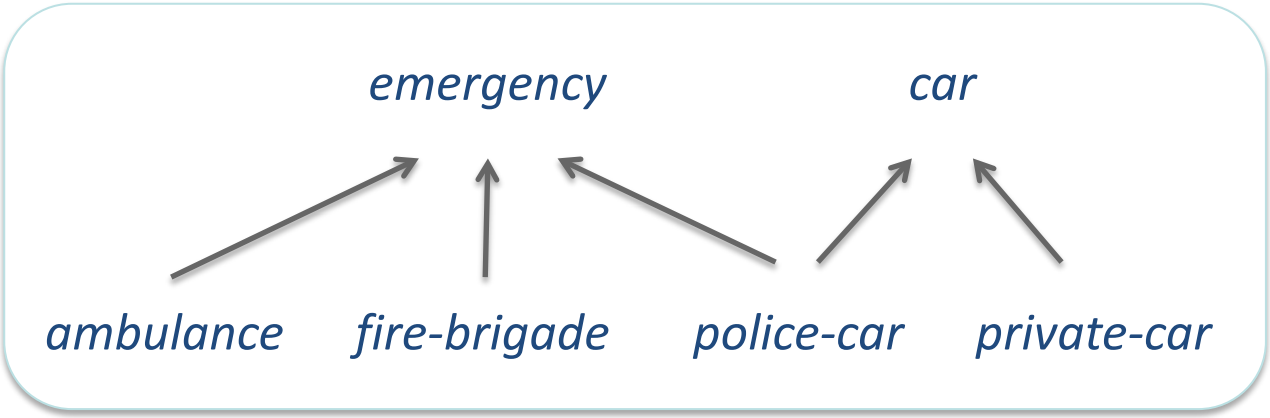


Normative system
$\Omega_0=\{n_4, n_5\}$

Norm generalisation

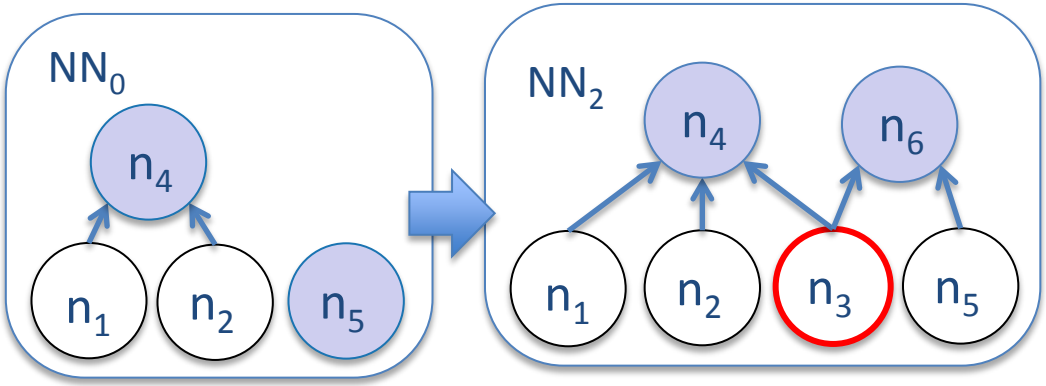
Generalisation modes: deep

- Term taxonomy



- **Deep** Optimistic norm generalisation

n_1: Give way to **ambulances**
n_2: Give way to **fire brigade**
n_3: Give way to **police** cars
n_4: Give way to **emergency** vehicles
n_5: Give way to **private cars**
n_6: Give way to **cars**



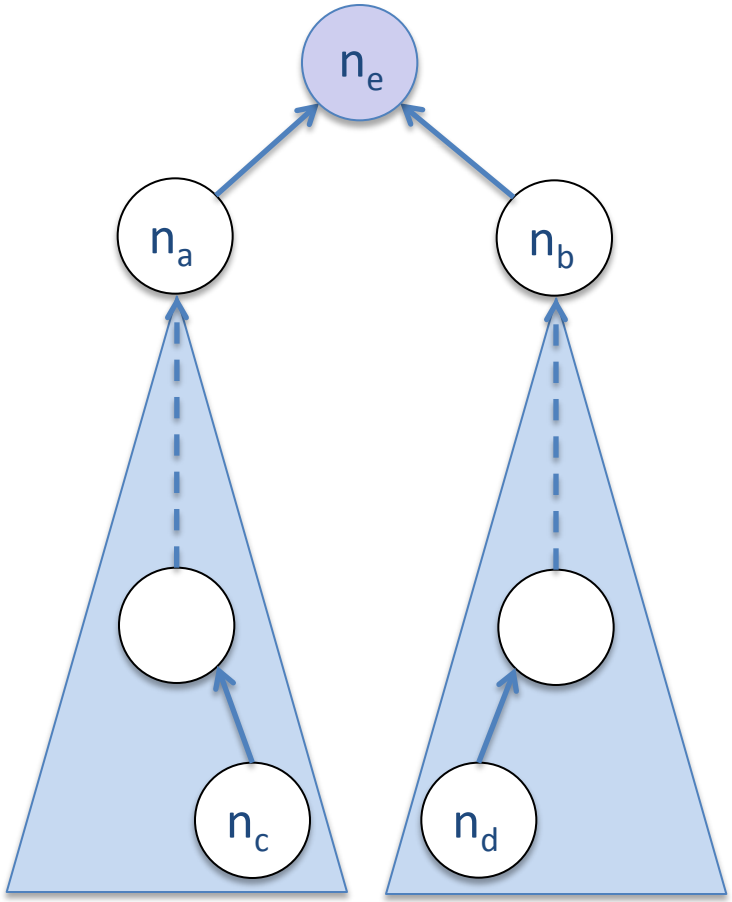
Normative system
$\Omega_0=\{n_4, n_5\}$

Normative system
$\Omega_1=\{n_4, n_6\}$

Norm generalisation

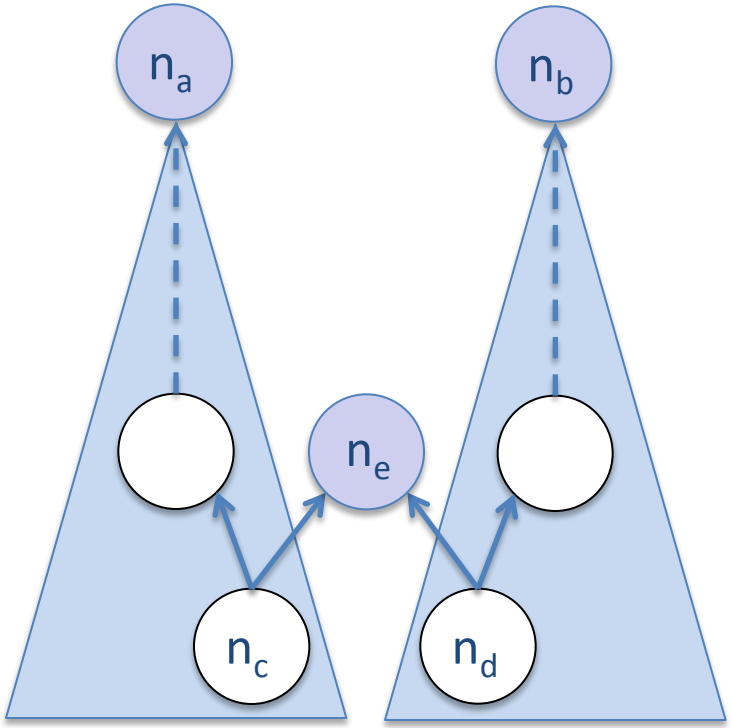
Shallow vs. deep generalisation modes

Shallow generalisation



More **coarse**

Deep generalisation



More **fine-grained**

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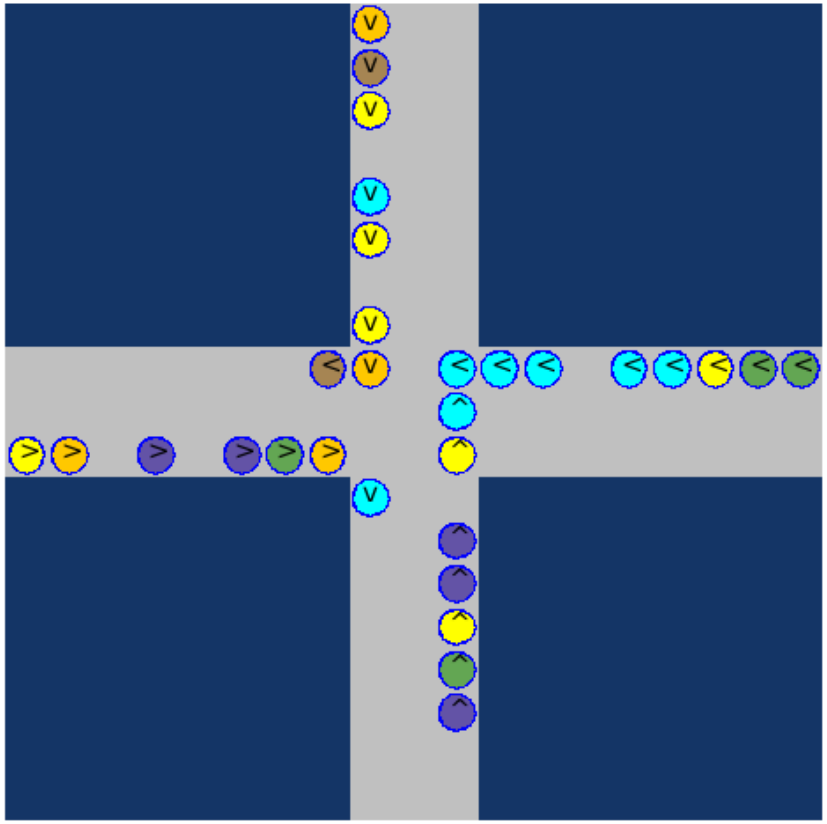
Normative Systems



In this simple scenario we may synthesise many candidate norms:

1. Give way to left.
2. Give way to right.
3. Keep security distance.
4. Stop always.
5. Never stop.
6. …

66 candidate norms → $2^{66} \approx \mathbf{10}^{20}$ candidate Normative *S*ystems.

*What **combination** of candidate norms (NS) achieves MAS goals?*

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Empirical evaluation

1. A **typical execution** of the norm synthesis process.
   - ***Successful synthesis of NS that avoid collisions.***

2. A **robustness analysis** w.r.t. non-compliant behaviour (norm infringements).
   - ***Synthesis of NS even for high norm violation rates.***

3. *Analysis of the **search space***
   - ***Different strategies explore different NS.***

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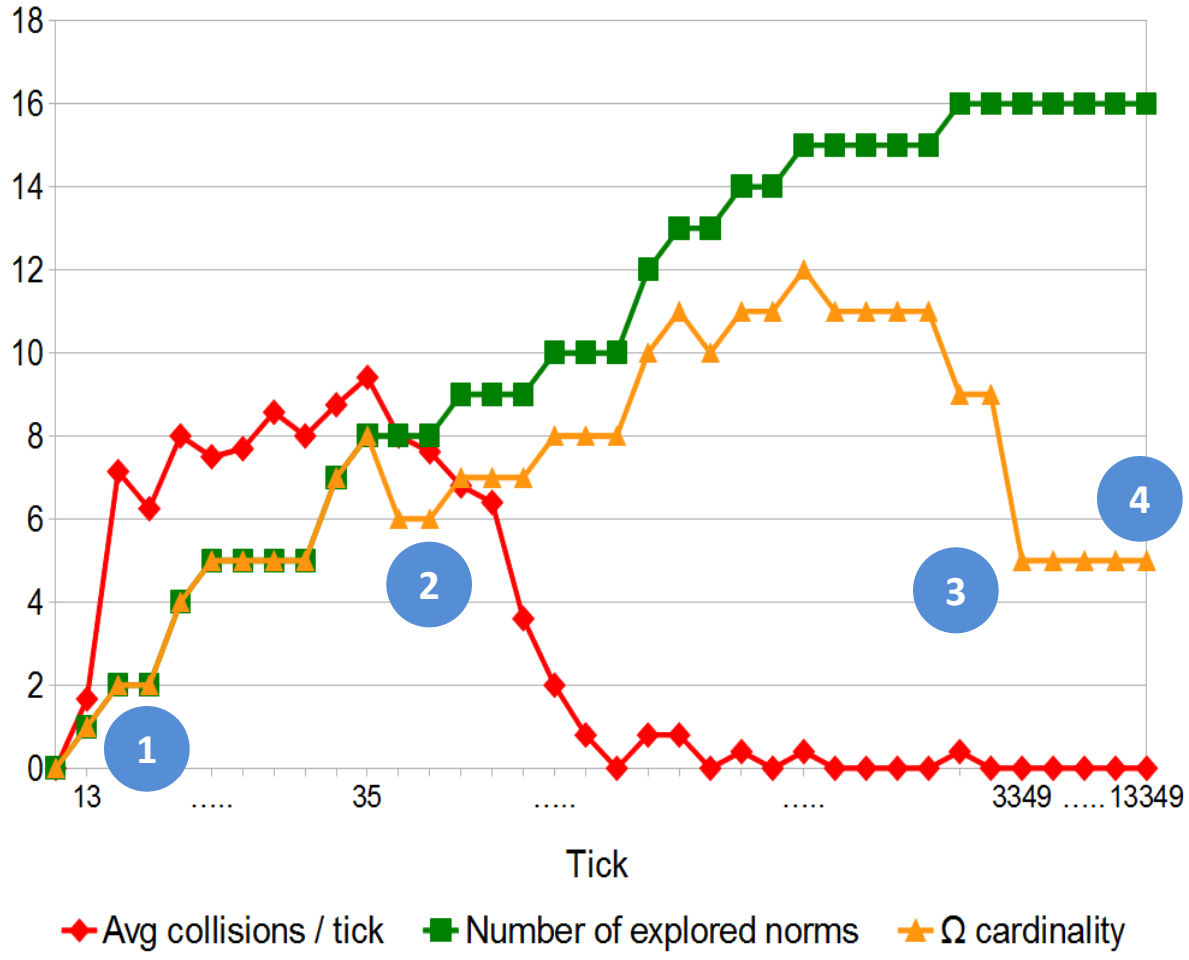
Empirical evaluation

Prototypical execution



1. Tick **13:** first collisions arise and the strategy synthesises first norms.

2. Tick **35:** norm **generalisations** .

3. Tick **3349**: Cardinality of the normative system reduced to 5 norms. Collisions are avoided.

4. Tick **13349**: Simulation stops because of convergence.

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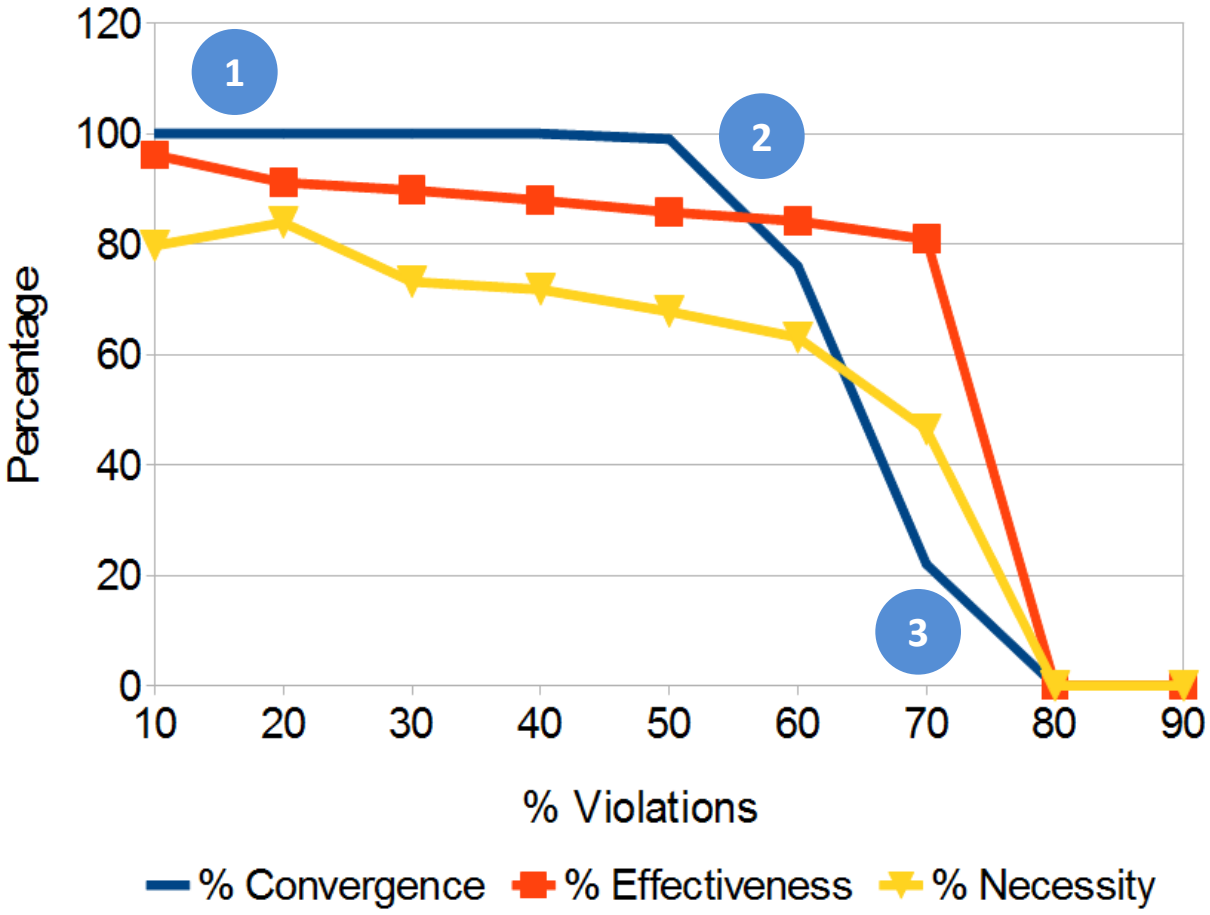
Empirical evaluation

Robustness Analysis



1. **Low violation rates (up to 40%)** converges for 100% of the simulation runs.

2. **High violation rates (40%-60%)** converges between 80% and 98% of the simulation runs.

3. **Very high violation rates (70%-90%)** converges for 20% of the simulation runs despite a 70% violation rate. Norms cannot be synthesised beyond 80% violation rate.

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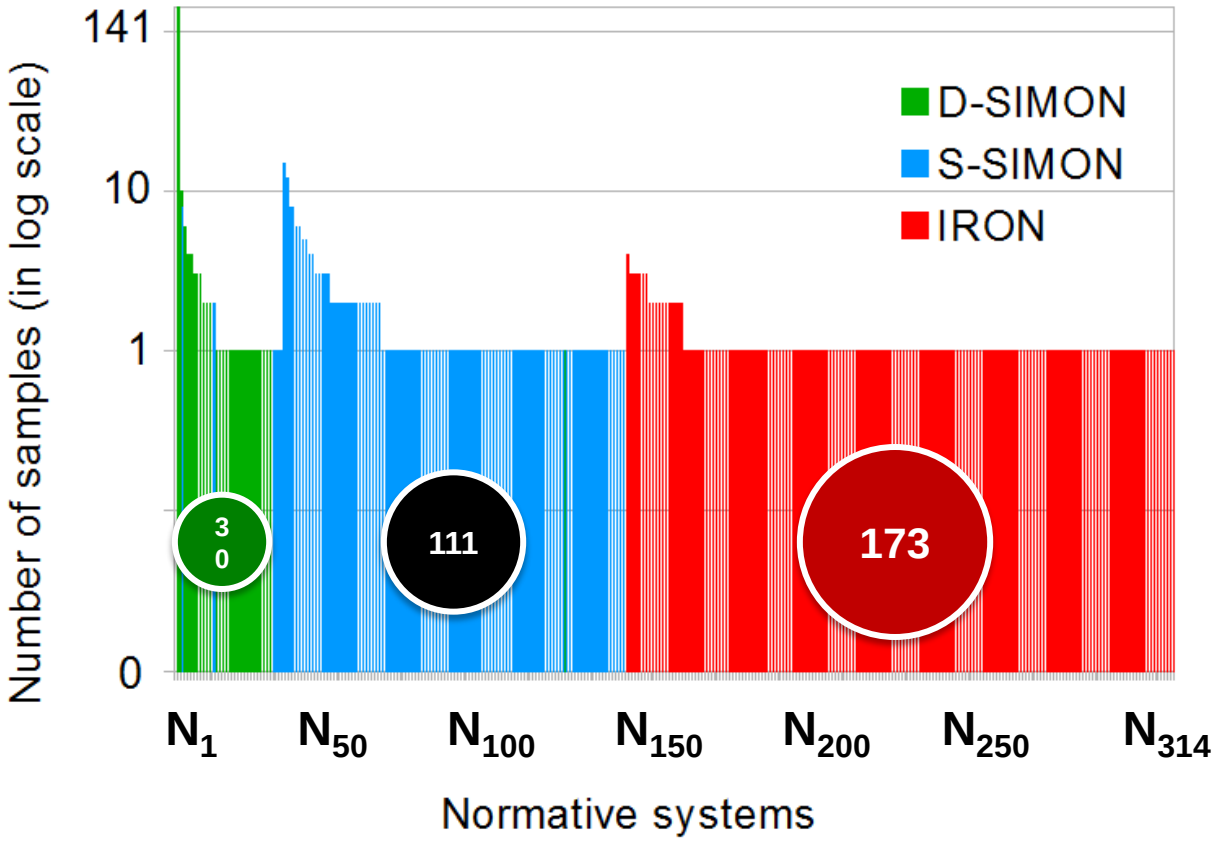
Empirical evaluation

NS Search Space for each norm synthesis strategy



IRON: conservative norm generalisations
SIMON: optimistic norm generalisations

D-SIMON focuses on an search space area with more **compact** NS.

(D-SIMON: requires more computational effort than S-SIMON)

On-line norm generation

Conclusions so far

- We have presented **SIMON**, a novel strategy for the on-line synthesis of conflict-free and compact normative systems that*:*
  - Avoids **conflicts**.
  - Avoids **over regulation**.
  - **Eases** the reasoning of agents.
- Applicable to other domains.

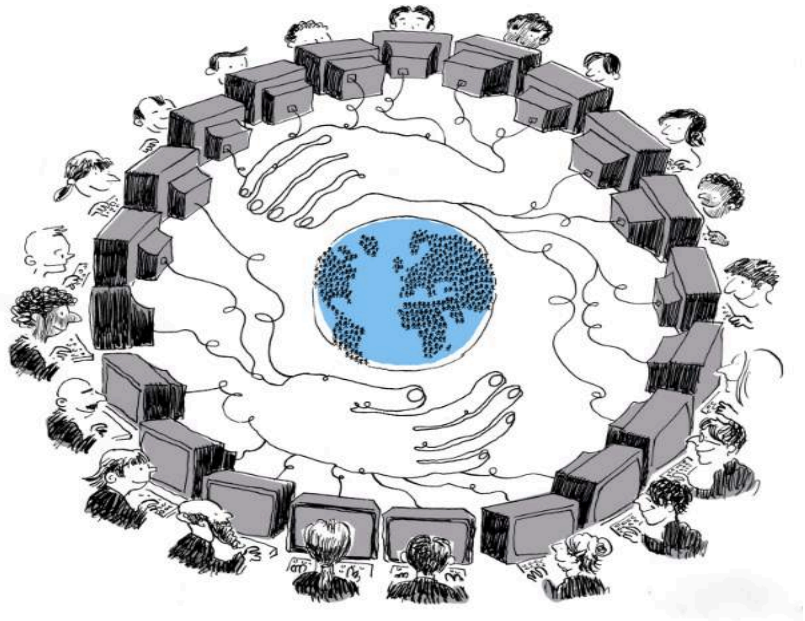
On-line norm generation

Case study 2: Virtual Communities

- Agents model human users interacting within virtual communities
- On-line synthesis of norms to avoid conflicts (i.e. user complaints)

Ex. Norms:

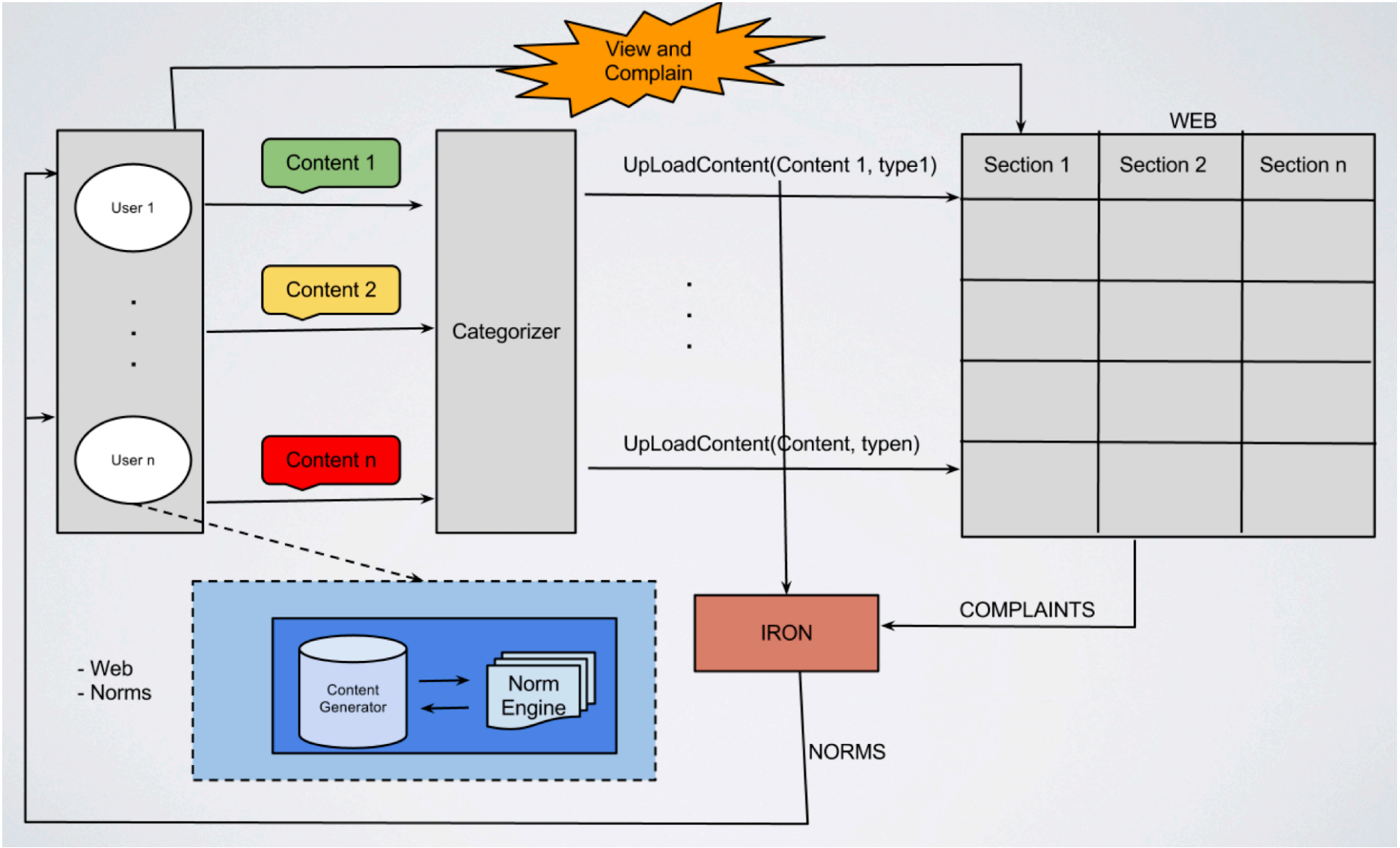
IF user(1) & section(2) & contentType(porn)
THEN prh(upload(content))



MAS = Simulated virtual community

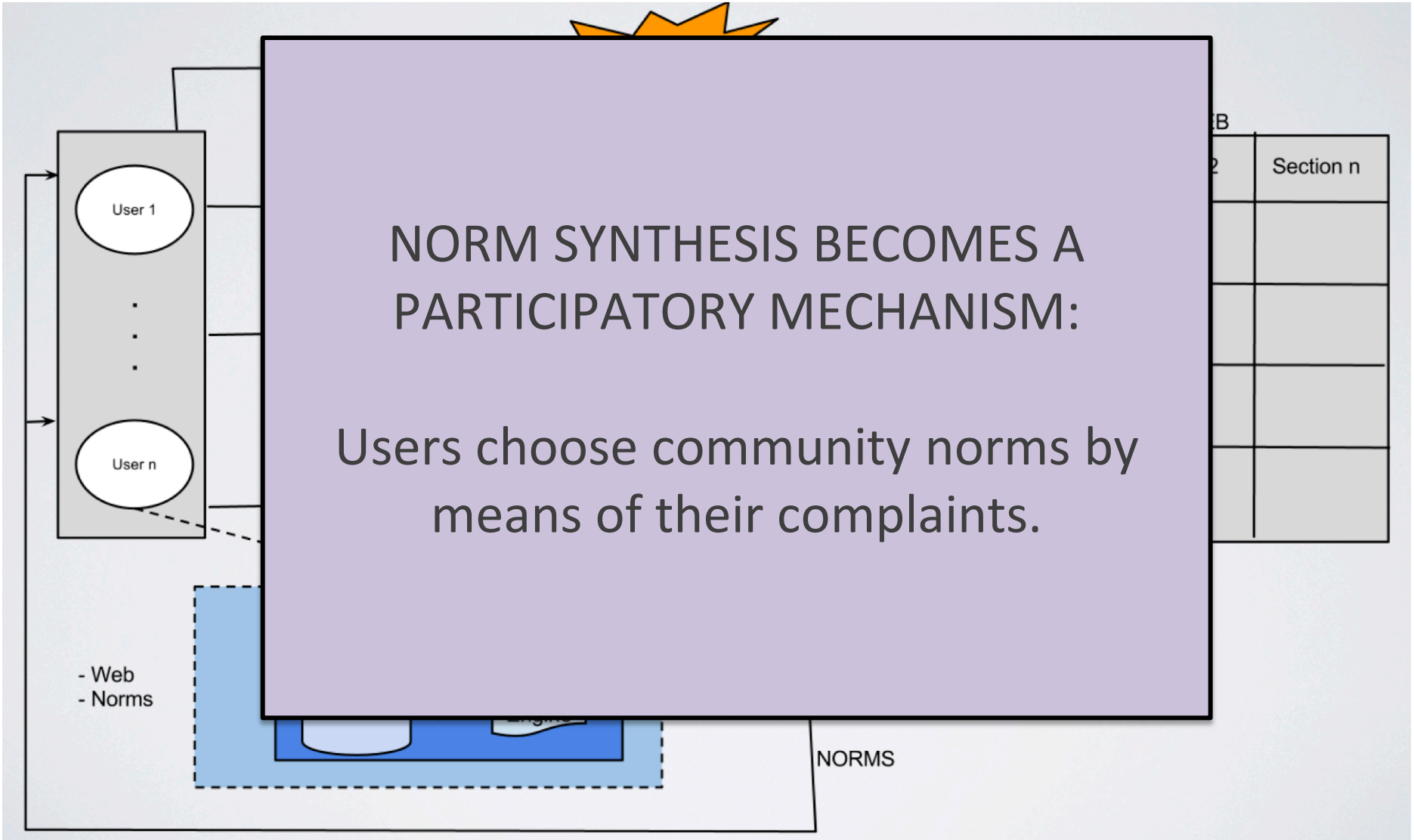
On-line norm generation

Case study 2: Virtual Communities Simulator



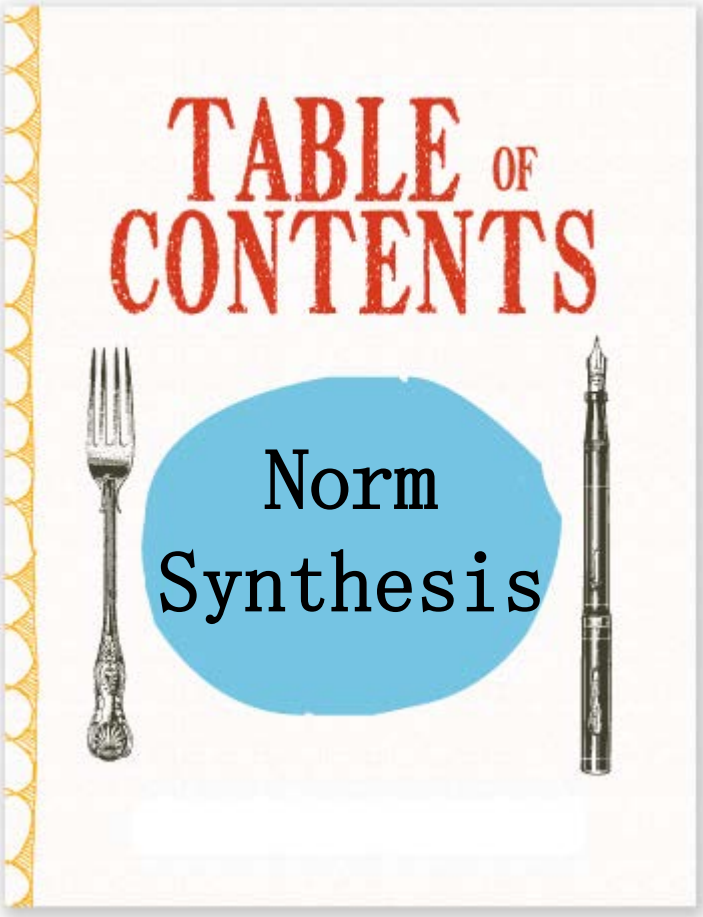
On-line norm generation

Case study 2: Virtual Communities



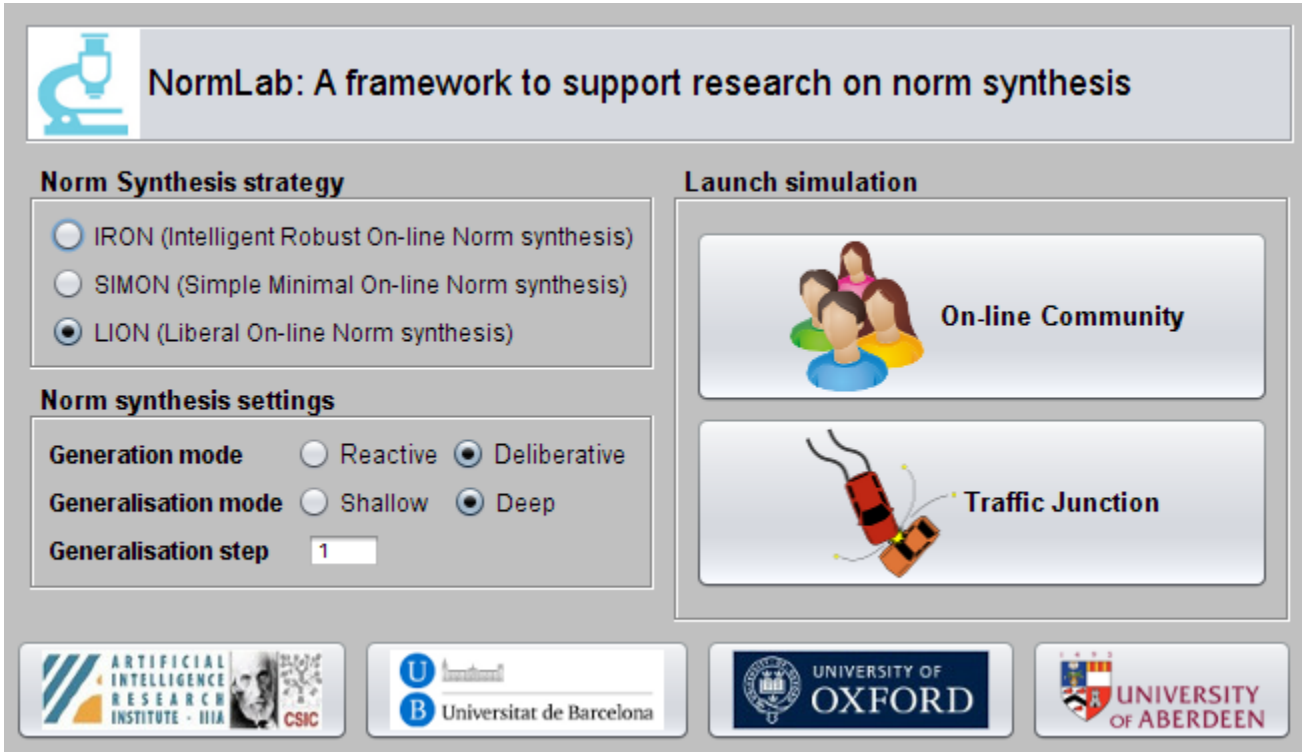
Tutorial Outline

Contents



1. Introdution to Normative MAS
2. **On-line automatic norm synthesis**.
3. Demo and hands-on activity.

NormLab hands-on Tutorial



Javier Morales (IIIA-UB), Maite López-Sánchez(UB), Juan A. Rodríguez-Aguilar (IIIA-CISC), Michael Wooldridge (UO), Wamberto Vasconcelos (UA)

1. NormLab (Introduction)

NormLab is a **framework** to support research on norm synthesis for Multi-Agent Systems.

NormLab allows to:

- **Perform MAS simulations**. It incorporates two different MAS simulators: a traffic simulator, and an on-line community simulator.
- **Perform on-line norm synthesis on MAS simulations.** *NormLab* incorporates different *state-of-the-art* on-line norm synthesis strategies that can be tested on MAS simulations.
- **Develop and test custom norm synthesis strategies**. NormLab allows to develop custom on-line norm synthesis strategies to be tested on the MAS simulations.

NormLab hands-on tutorial Outline

An **introduction** to NormLab

1. (Introduction to NormLab)
2. NormLab architecture.
3. Norm Synthesis Machine.
4. Traffic simulator.

Configuration of the working environment

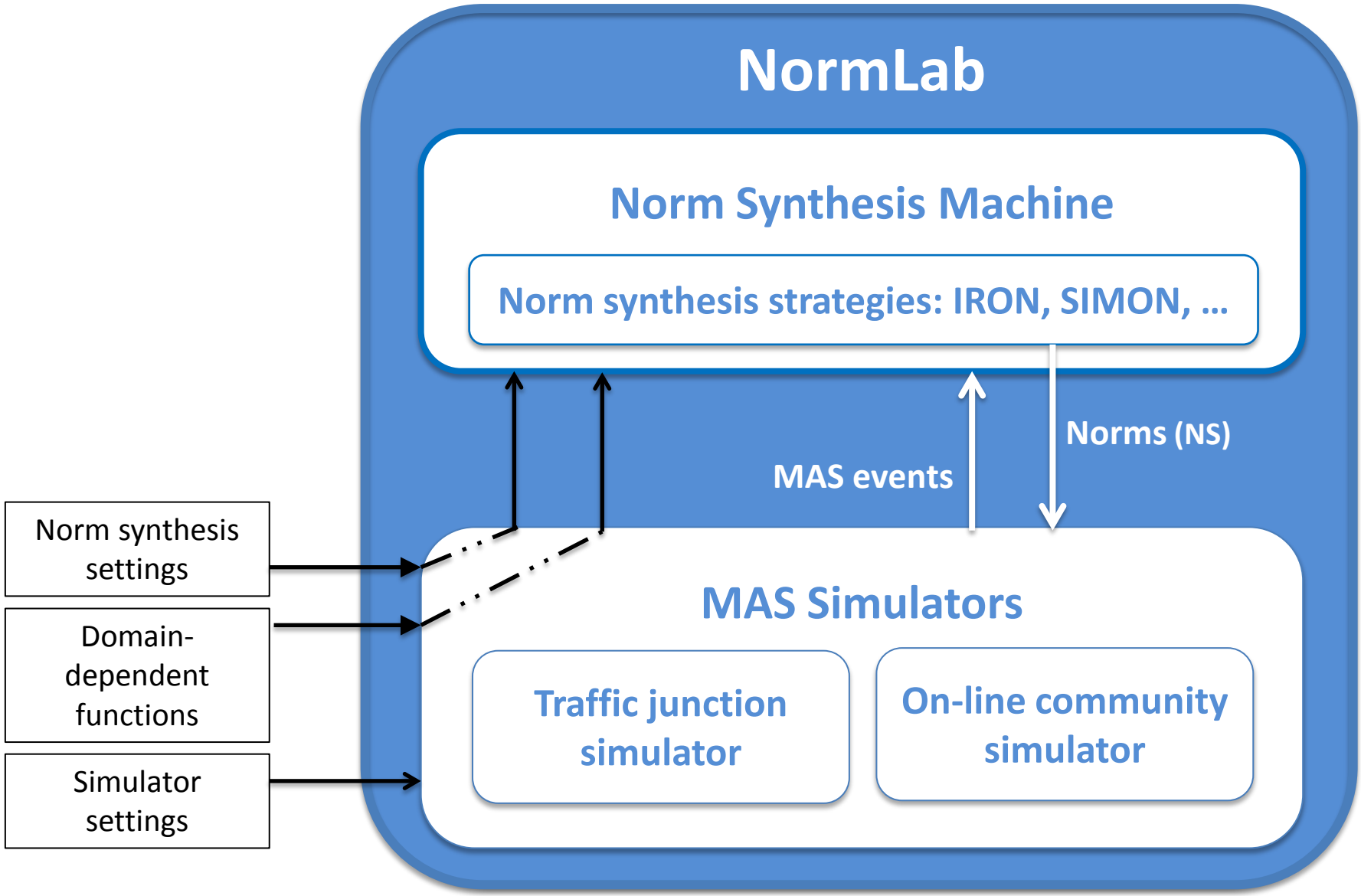
5. NormLab download and installation.

NormLab **execution**:

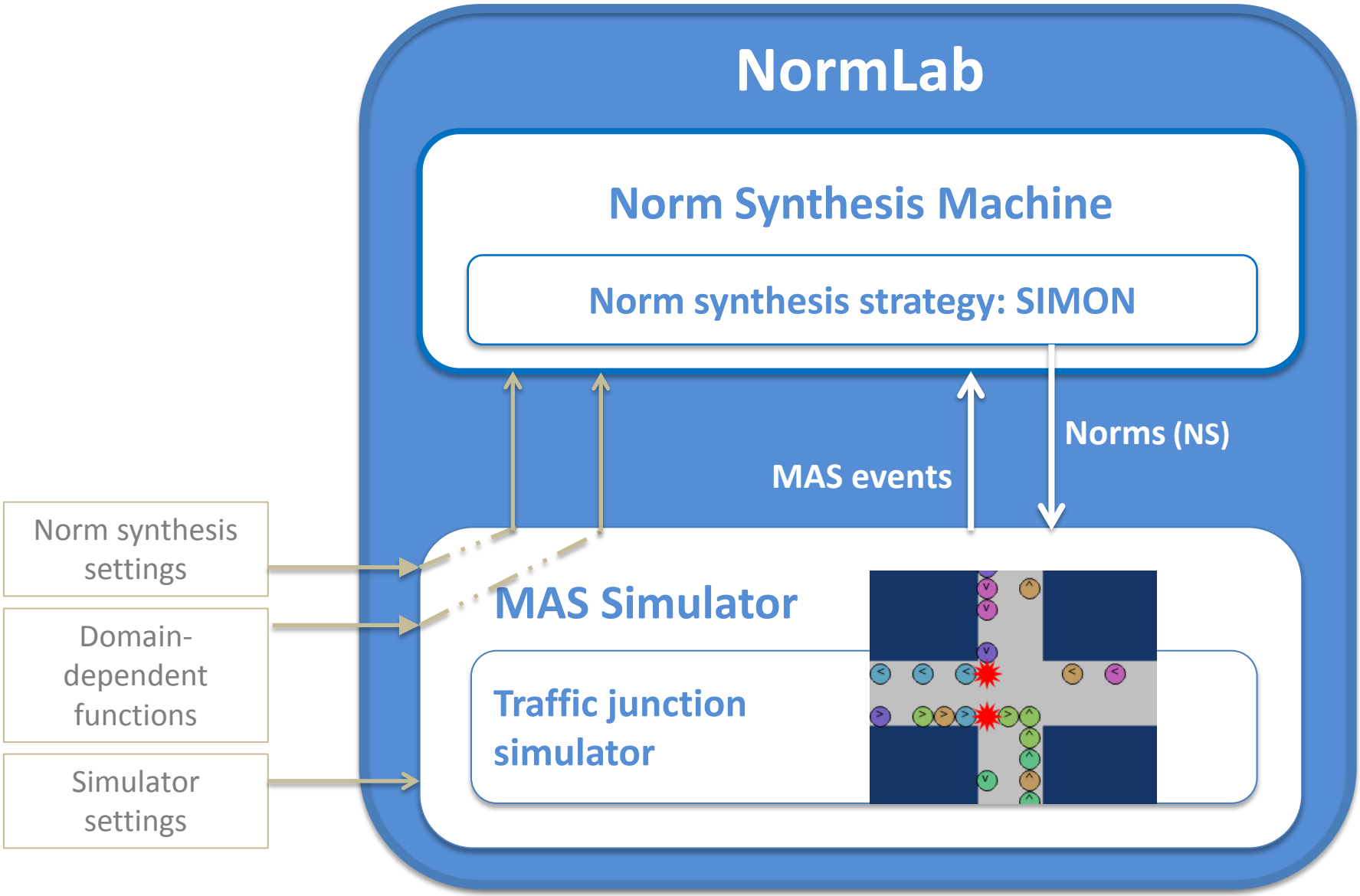
6-8. Execution examples.

9-14. Guided development of different norm synthesis strategies.

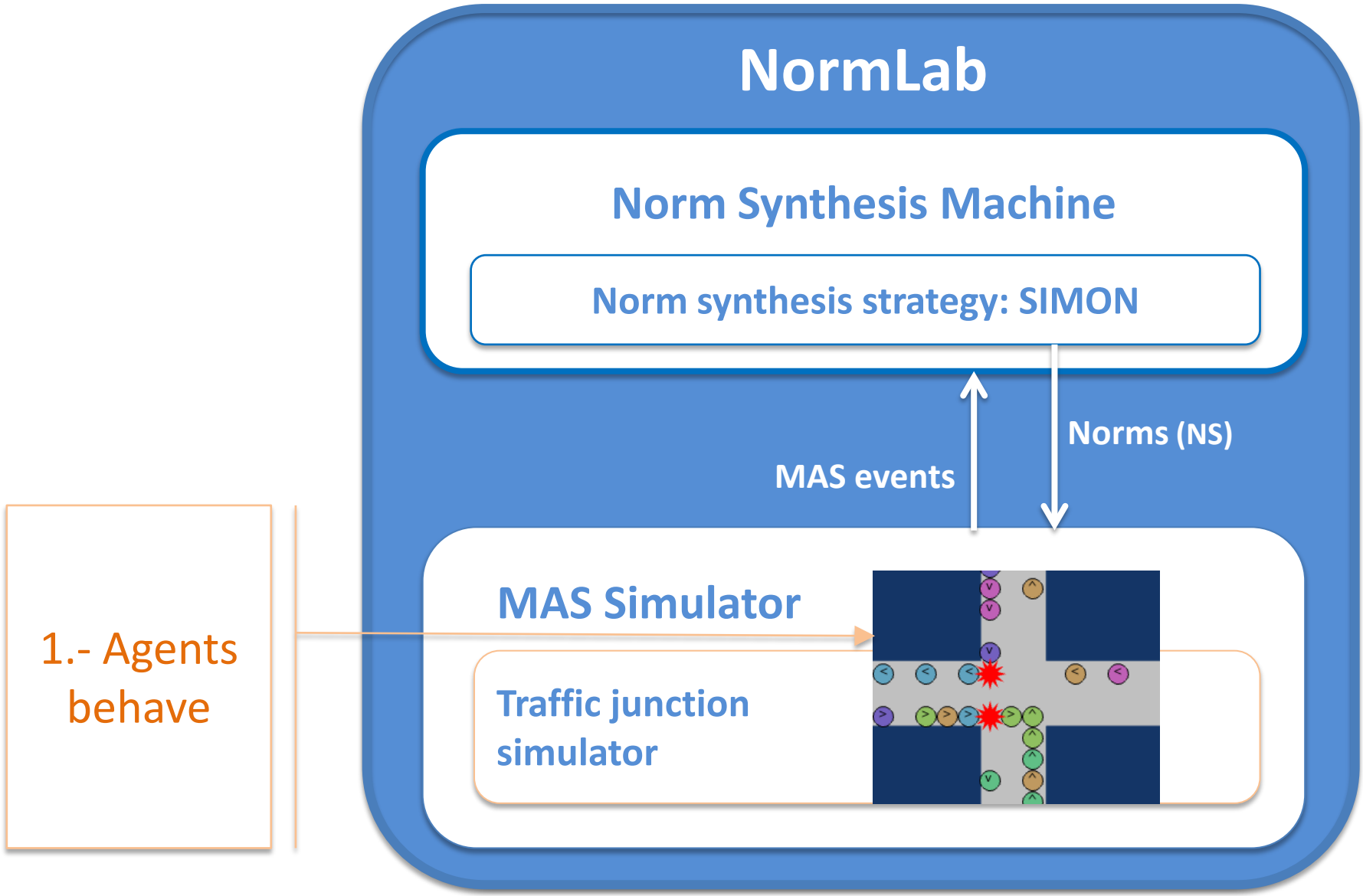
2. NormLab architecture



3. Norm Synthesis Machine



3. Norm Synthesis Machine



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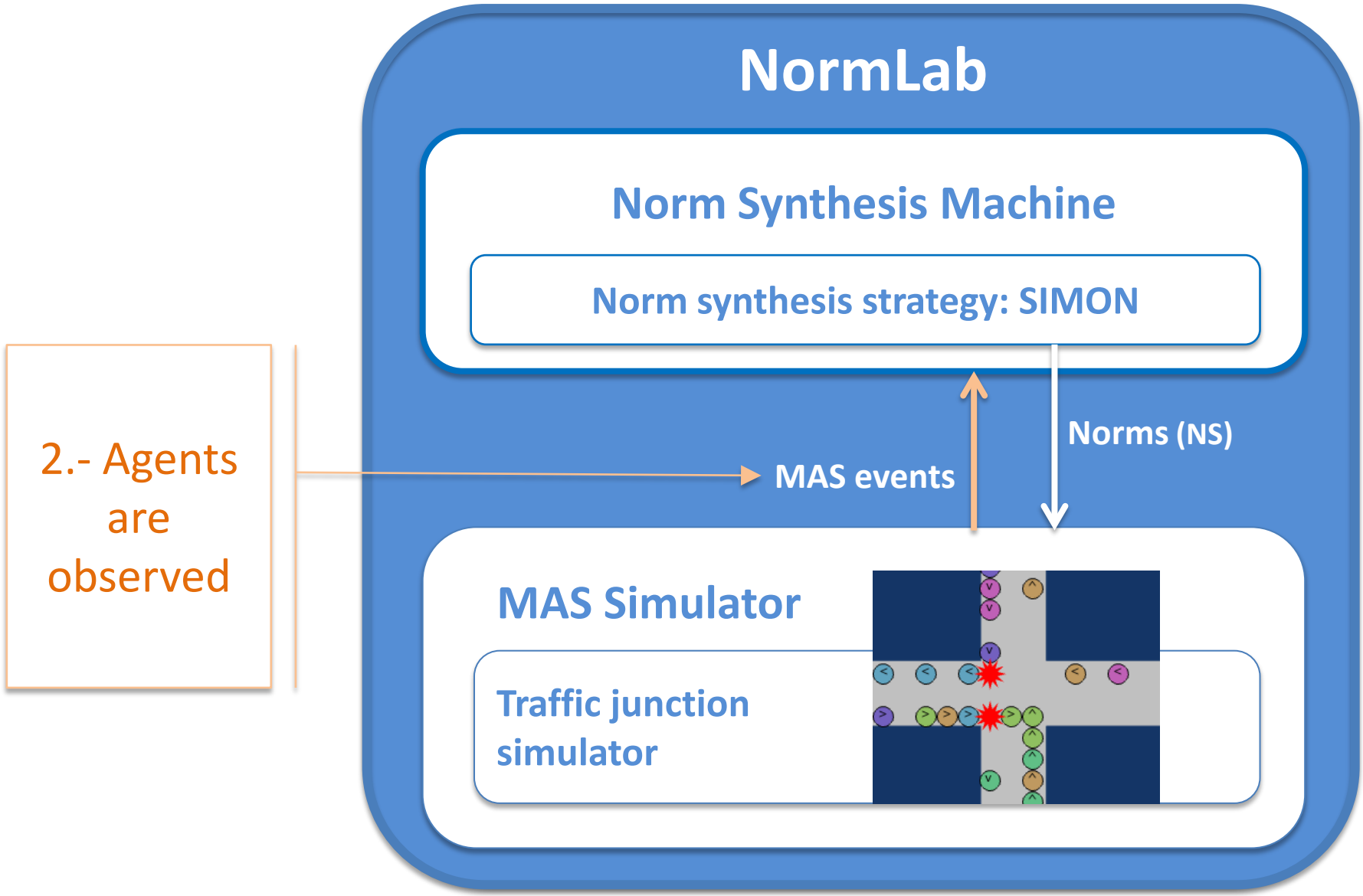
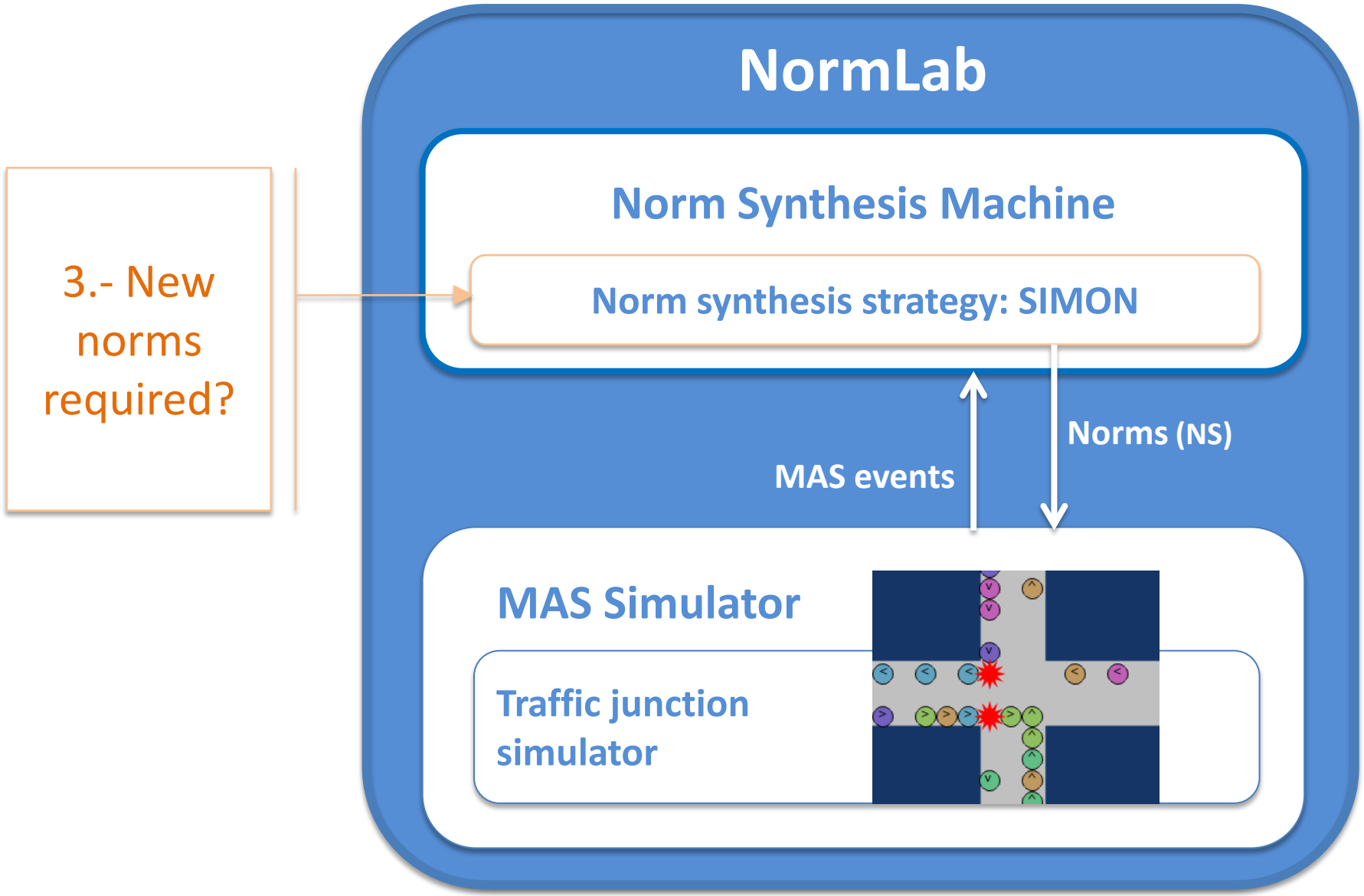
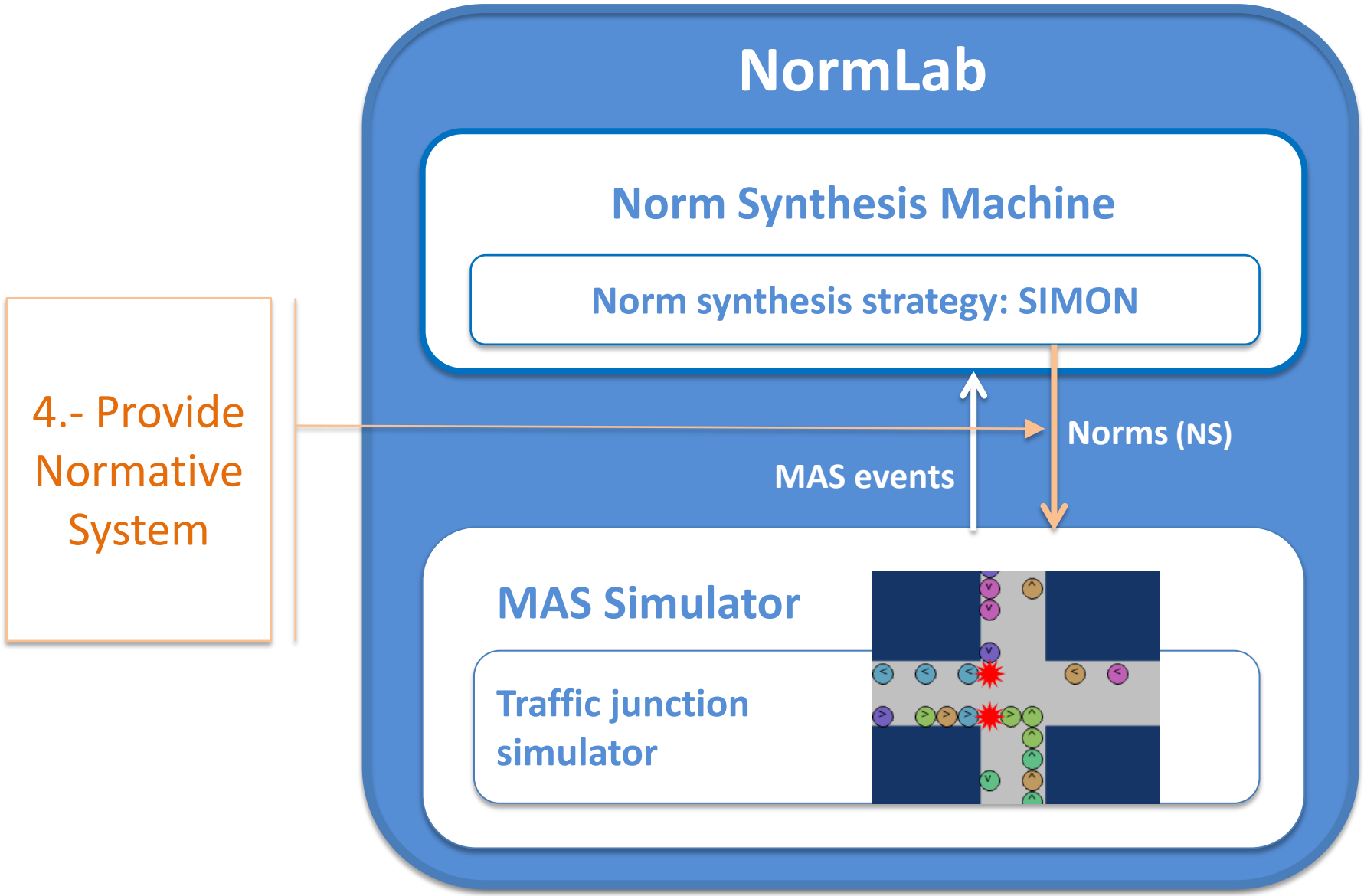


3. Norm Synthesis Machine

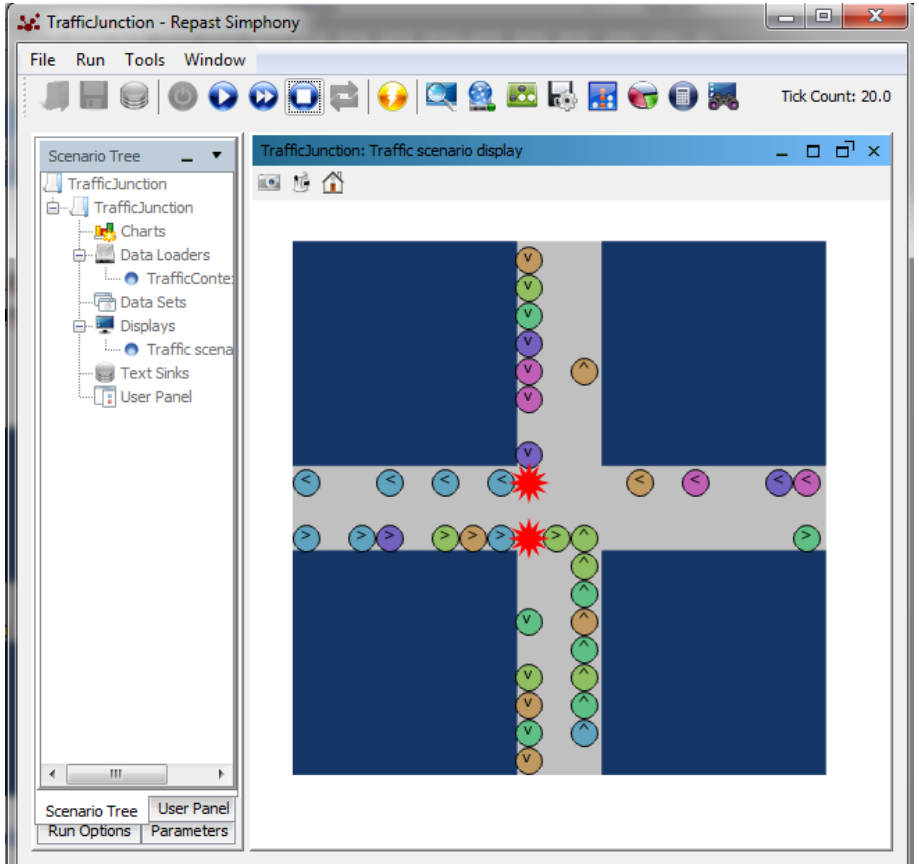


3. Norm Synthesis Machine



4. Traffic simulator

- **Based on Repast Simphony 2.2**
- **Agents** are cars, and **conflicts** are collisions among cars.
- **The goal** is to synthesise normative systems that **avoid collisions** between cars.



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5. NormLab download

NormLab is **multi-platform**. You can use it either in *Windows*, *MacOS* or *Linux*

Requirements

- ***Java JDK 1.6*** or later — http://www.java.com
- ***Eclipse IDE*** (just for Linux users) — http://www.eclipse.org/downloads
- ***Repast Simphony 2.2*** — http://repast.sourceforge.net

Downloads

To use *NormLab* you need to download:

- ***NormSynthesisMachine*****: http://normsynthesis.github.io/NormSynthesisMachine**
  Implements an API that allows to perform norm synthesis for MAS.
- ***NormLabSimulators*****: http://normsynthesis.github.io/NormLabSimulators**
  Code of two MAS simulators: traffic and on-line community.

Download both projects in a **ZIP** or **TAR.GZ** file.

5. NormLab installation

Preparing the working environment

1. Unzip ***NormSynthesisMachine*** and ***NormLabSimulators*** projects to your HOME folder.
   - *For instance… «/Users/Javi/NormLab»*
2. Both projects will be unzipped as *NormSynthesis-«project_name»- «numbers»*. For instance…

   - *NormSynthesis-NormLabSimulators-34d43o*
   - *NormSynthesis-NormSynthesisMachine-1847fje*

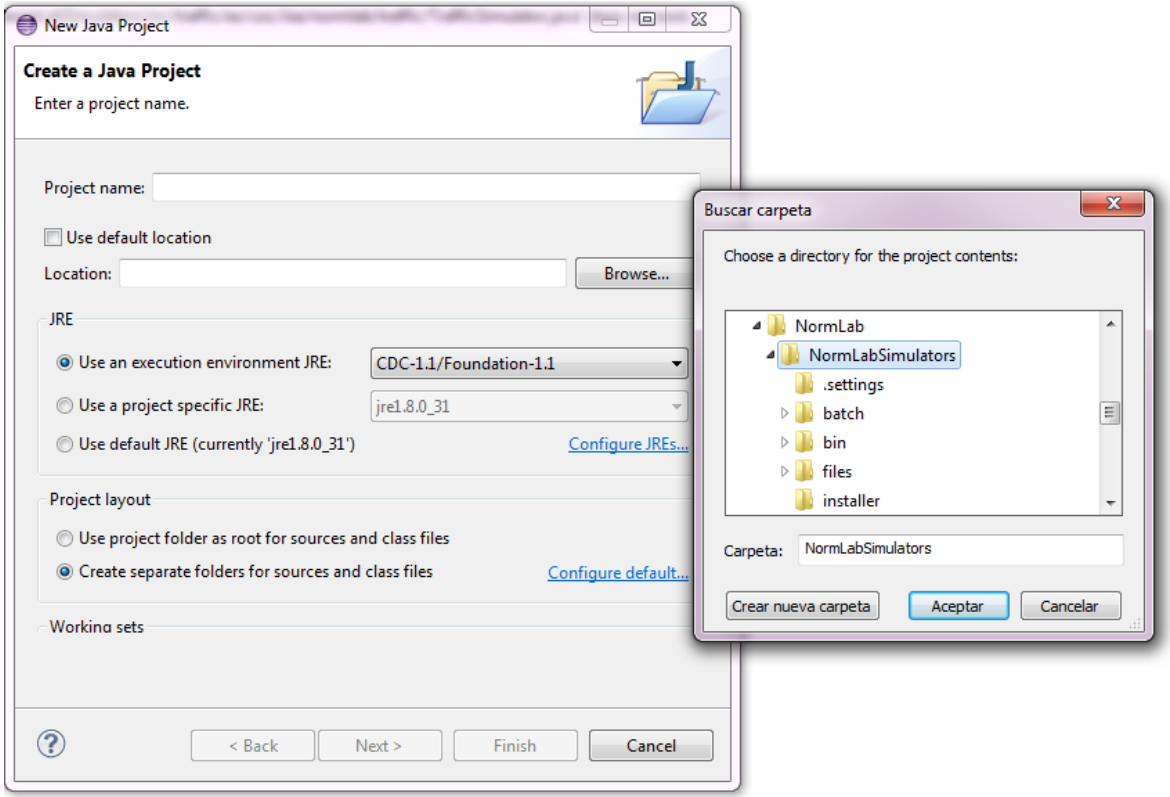
3. Rename both projects, removing the «NormSynthesis» part and the numbers. After renaming them they should look like this:

   - *NormLabSimulators*
   - *NormSynthesisMachine*

5. NormLab installation

Preparing the working environment

1. Open the **Repast Symphony IDE** (in Linux, open ***Eclipse IDE*** with Repast installed on it).
2. Select Java view in Eclipse
3. Import both projects ***NormSynthesisMachine*** and ***NormLabSimulators*** *in* ***Eclipse***.
    1. *File>New>Java Project.*
    2. *Uncheck «Use default location» and click on «Browse».*



5. NormLab project structure

NormLabSimulators project is structured as follows:

src/traffic: The code of the traffic simulator.
(src/onlineComm: The code of the on-line community simulator)
launchers: The launchers that allow to run the two simulators.
repast-settings/TrafficJunction.rs: Basic Repast settings for the traffic junction simulator.
(repast-settings/OnlineCommunities.rs: Basic Repast settings for the on-line community simulator)

NormLab hands-on tutorial Outline

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Tutorial outline

NormLab **execution**:

6-8. Execution examples:

6. **Example** strategy 1: Normlab execution: Returns an **empty** set of norms.
7. **Example** strategy 2: Returns a fixed set of **1 norm**.
8. **Example** strategy 3: Returns a fixed set of **3 norms**.

9-14. Guided development of different norm synthesis strategies:

9. **Development** of example strategy 1: **Empty** set of norms.
10. **Development** of example strategy 2: Fixed set of **1 norm**.
11. **Studying** example 4: A strategy with norm **generation**.
12. **Studying** example 5: A strategy with norm **generation** + **evaluation**.
13. **Studying** SIMON: A strategy with norm **generation** + **evaluation** + **refinement.**

Tutorial outline

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6. NormLab Execution: Example 1

TrafficJunction norm synthesis example 1

We are going to execute the ***TrafficJunction*** simulator with the simplest norm synthesis strategy:

→ *Everytime the strategy is executed, return an **empty** normative system.*

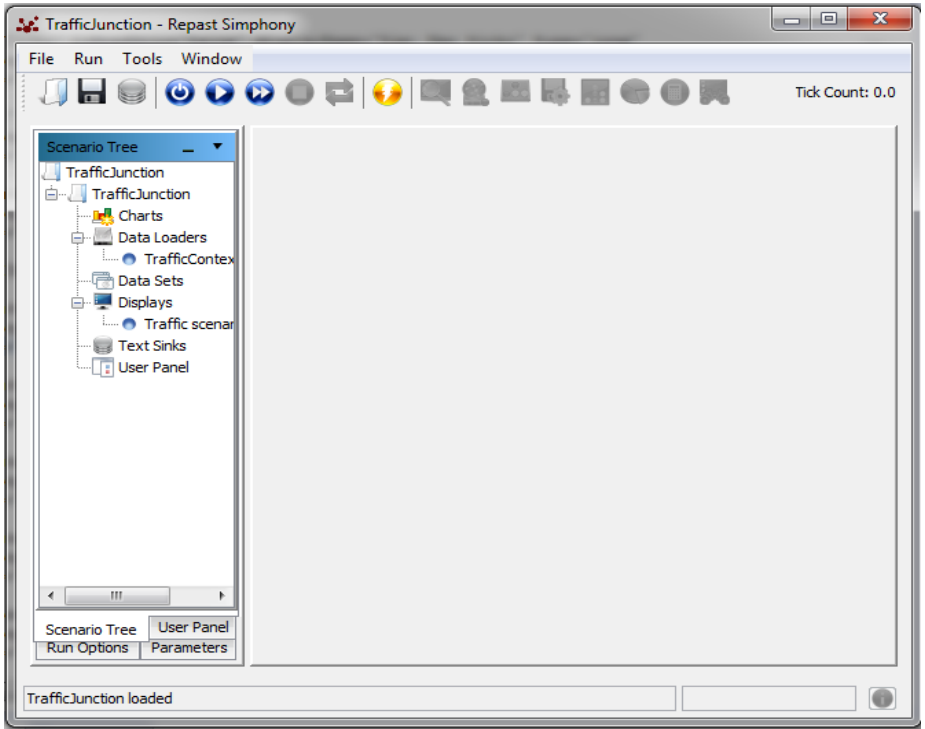
Consequences: No norms are given to the agents → collisions are never avoided.

Note: This execution assumes that file parameters.xml (in directory repast-settings/TrafficJunction.rs within NormLabSimulators project) has parameter «NormSynthesisExample» with field «defaultValue» set to «1»

6. NormLab Execution: Example 1

TrafficJunction norm synthesis example 1

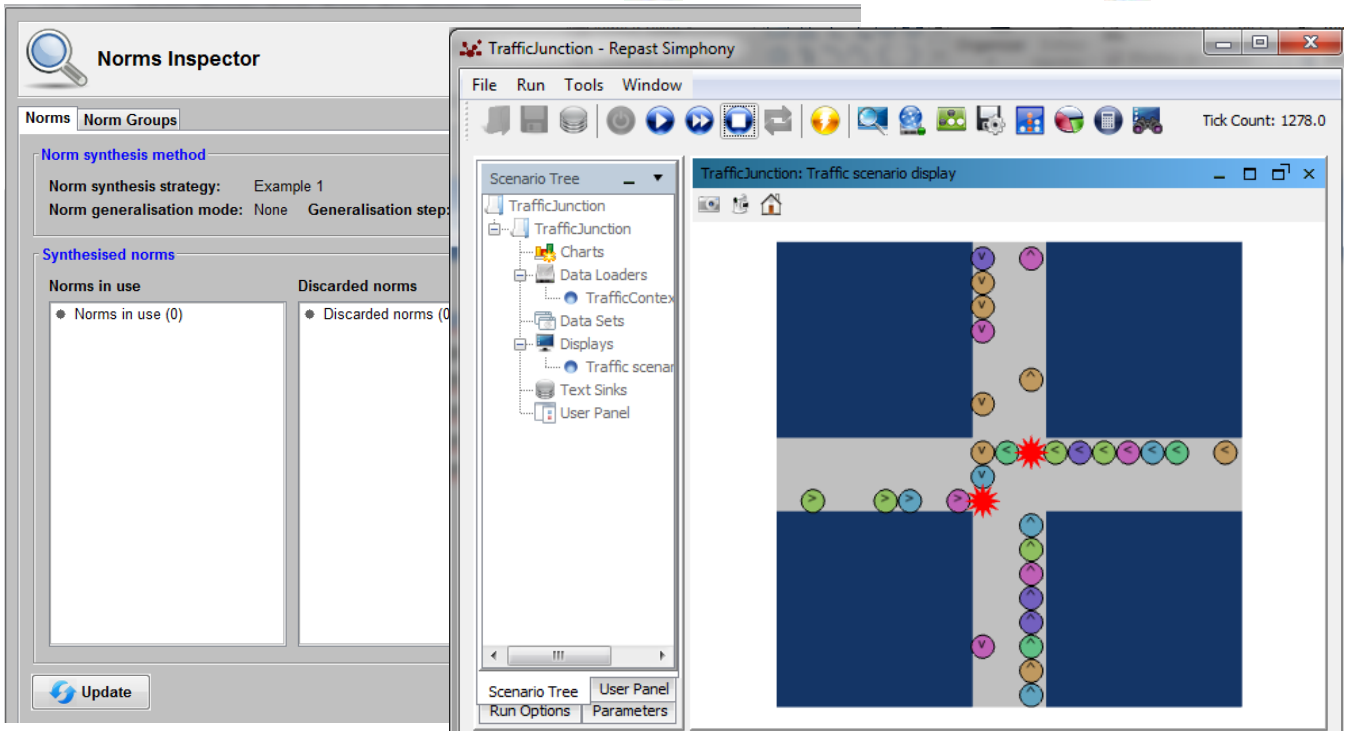
1. In Eclipse, in NormLabSimulators project, go to directory **launchers/**
2. Do right click on the file **TrafficJunctionSimulator.launch**.
3. Click on «Run As» > «TrafficJunctionSimulator».
4. Click on button  to initialise the simulator.



6. NormLab Execution: Example 1

TrafficJunction norm synthesis example 1

1. In Eclipse, in NormLabSimulators project, go to directory **launchers/**
2. Do right click on the file **TrafficJunctionSimulator.launch**.
3. Click on «Run As» > «TrafficJunctionSimulator».
4. Click on button  to initialise the simulator.
5. Click on button  to start the simulator. Cars will appear as coloured balls. Collisions will appear as red stars. Cars will start to drive and they will collide.
6. You can pause the simulation with button  and stop it with button 



Tutorial outline

NormLab **execution**:

6-8. Execution examples

6. **Example** strategy 1: NormLab execution: Returns an **empty** set of norms.
7. **Example** strategy 2: Using norms: Returns a fixed set of **1 norm**.
8. **Example** strategy 3: Returns a fixed set of **3 norms**.

9-14. Guided development of different norm synthesis strategies

9. **Development** of example strategy 1: **Empty** set of norms.
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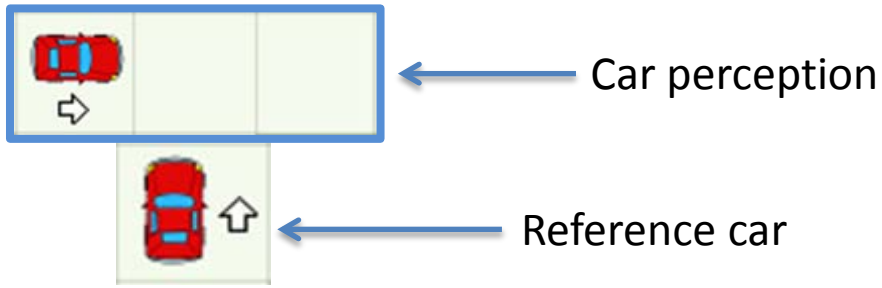
7. Using norms: Example 2

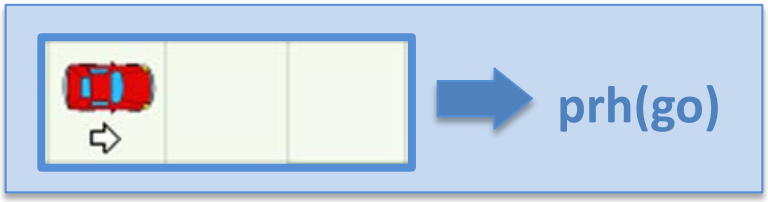
In the traffic simulator, cars' perceptions correspond to the three cells in front of them:



Norms are…

- **IF** … **THEN**… rules.
- Norm precondition: Set of **predicates** with one **term** each.
  - Three predicates **(left, front, right).**
  - Terms **{<, ^, >, v, -, w, *}** represent: cars with {**<**, **^**, **>**, **v**} headings; nothing (-), wall (w); and anything (*)
- Norm postcondition: A **modality**.

Graphical representation



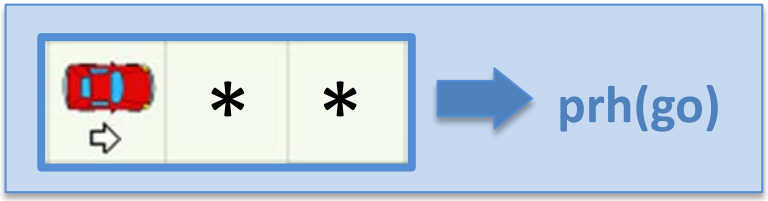
IF left(>) **& front**(-) **& right**(-) **THEN prohibition**(*go*)

7. Using norms: Example 2

TrafficJunction norm synthesis example 2

We will execute the *TrafficJunction* simulator with a norm synthesis strategy that returns a normative system with only **one left-side-priority** norm:

Norm 1



IF left(>) **& front**(*) **& right**(*) **THEN prohibition**(*go*)

It avoids some (but not all) collisions.

7. Using norms: Example 2

TrafficJunction norm synthesis example 2

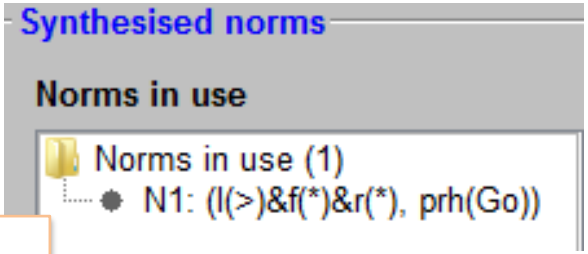
1. In Eclipse, in NormLabSimulators project, go to directory **repast-settings/TrafficJunction.rs**
2. Open file **parameters.xml** by doing right click > *Open with* > *Text Editor.* This file defines the *NormLab* parameters.
3. Search for the parameter «NormSynthesisExample».
4. Set the field «defaultValue» to «2». This will indicate NormLab to launch example 2, which uses a norm synthesis strategy that always returns a normative system with the left-side-priority norm.
5. Save the file.

```
<parameter  name="NormSynthesisExample" isReadOnly="false" displayName="NSM: Norm synthesis example" type="int"
            converter="repast.simphony.parameter.StringConverterFactory$IntConverter"
            defaultValue="2" />
```

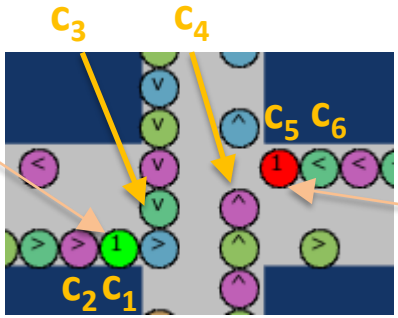
7. Using norms: Example 2

TrafficJunction norm synthesis example 2

6. Do right click on the file **TrafficJunctionSimulator.launch**.
7. Click on «Run As» > «TrafficJunctionSimulator».
8. Run the simulation with button 
9. Update the norm synthesis inspector. Observe how now the normative system contains norm N1, and cars occasionally stop to conform to it.



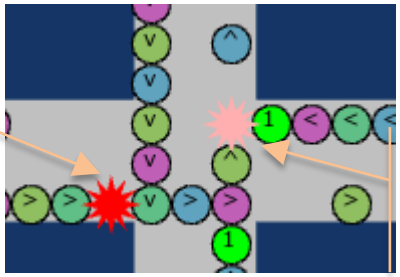
Green cirle: Norm 1 applies and car c_1 stops (c_3 has priority)



Tick i

Red circle: Norm 1 applies but car c_5 does NOT stop

Non regulated collision (between c_1 - c_2)



Tick i +1

Regulated collision (between c_4 - c_5) c_6 complies with N1 (stops)

Tutorial outline

NormLab **execution**:

6-8. Execution examples

6. **Example** strategy 1: NormLab execution: Returns an **empty** set of norms.
7. **Example** strategy 2: Using norms: Returns a fixed set of **1 norm**.
8. **Example** strategy 3: Removing collisions: Returns a fixed set of **3 norms**.

9-14. Guided development of different norm synthesis strategies

9. **Development** of example strategy 1: **Empty** set of norms.
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12. **Studying** example 5: A strategy with norm **generation** + **evaluation**.
13. **Studying** SIMON: A strategy with norm **generation** + **evaluation** + **refinement.**

8. Removing collisions: Example 3

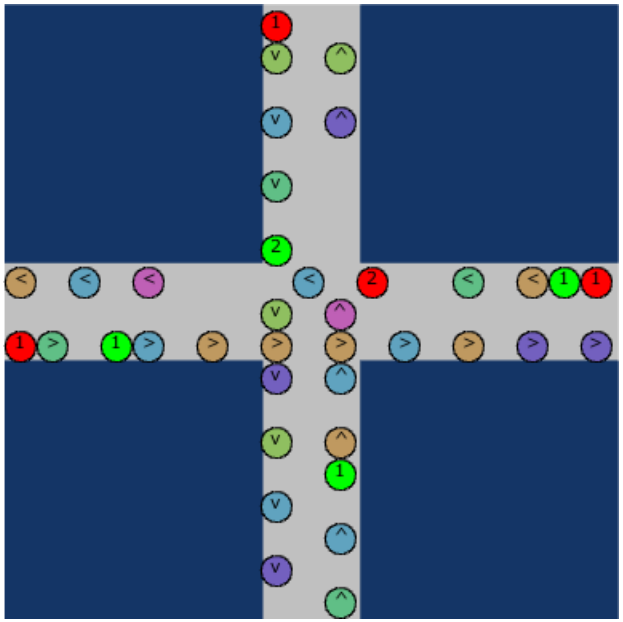
TrafficJunction norm synthesis example 3

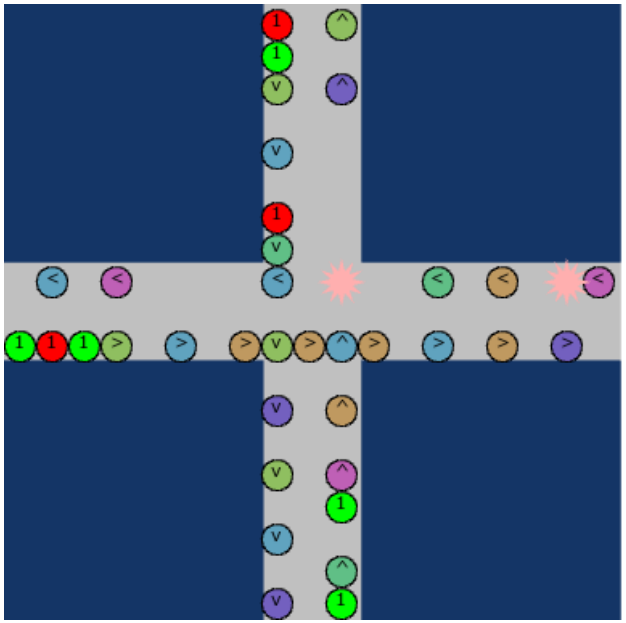
Let's define a norm synthesis strategy that avoids all possible collisions by always returning this Normative System:

N1: IF **left**(*) **&** **front**(^) **&** **right**(*) THEN **prohibition**(*go*)
N2: IF **left**(>) **&** **front**(-) **&** **right**(*) THEN **prohibition**(*go*)
N3: IF **left**(<) **&** **front**(<) **&** **right**(*) THEN **prohibition**(*go*)

Set NormSynthesisExample **defaultValue=«3»** in **parameters.xml** (in NormLabSimulators project, **repast-settings/TrafficJunction.rs**)

Tick i





Tick i+1

Tutorial outline

NormLab **execution**:

6-8. Execution examples

6. **Example** strategy **1**: NormLab execution: Returns an **empty** set of norms.
7. **Example** strategy **2**: Adding norms: Returns a fixed set of **1 norm**.
8. **Example** strategy **3**: Removing collisions: Returns a fixed set of **3 norms**.

9-14. Guided development of different norm synthesis strategies

9. **Development** of example strategy 1: **Empty** set of norms.
10. **Executing** your own strategy
11. **Development** of example strategy 2: **Adding norms** to your strategy (1 norm)
12. **Example 4**: A strategy with norm **generation**.
13. **Example 5**: A strategy with norm **generation** + **evaluation**.
14. **SIMON**: A complete strategy with norm **generation** + **evaluation** + **refinement.**

9. Developing your own strategy

How are all these examples **implemented**? We will now develop our own norm synthesis strategy as the one from example 1, which returns an **empty normative system**.

To do so, we first **parameterise** *NormLab* to use a **custom norm synthesis strategy**:

1. In Eclipse (NormLabSimulators project), go to directory **repast-settings/TrafficJunction.rs**
2. Open file **parameters.xml** by doing right click > *Open with* > *Text Editor.* This file defines the *NormLab* parameters.
3. Search for the parameter «NormSynthesisExample» and set the field **defaultValue=«0»**. This will indicate NormLab that we do not want to load a pre-designed example.
4. Search for the parameter «NormSynthesisStrategy» and set the field **defaultValue=«0».** This will indicate *NormLab* that we will provide a custom norm synthesis strategy.
5. Save the file

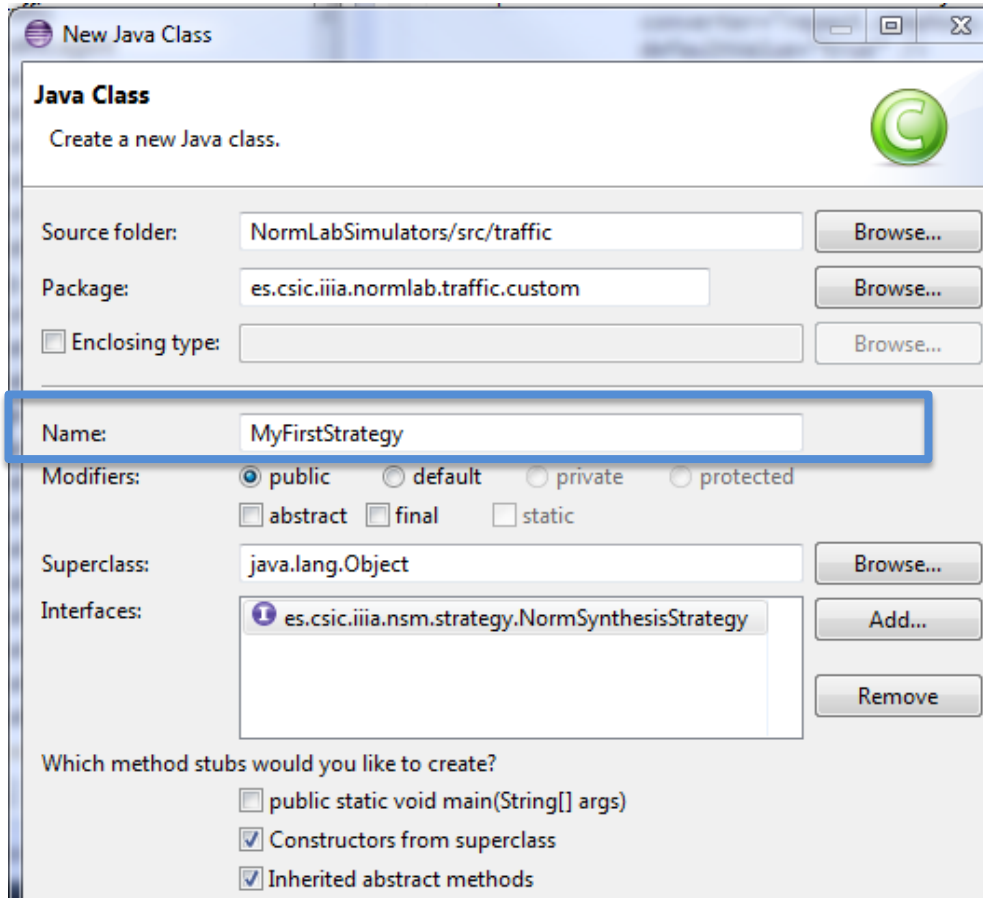
```
<parameter
 name="NormSynthesisExample" isReadOnly="false" displayName="NSM: Norm synthesis example" type="int"
 converter="repast.simphony.parameter.StringConverterFactory$IntConverter"
 defaultValue="0" />
<parameter
 name="NormSynthesisStrategy" isReadOnly="false"
displayName="NSM: Norm synthesis strategy (CUSTOM/IRON/SIMON/XSIMON)" type="int"
converter="repast.simphony.parameter.StringConverterFactory$IntConverter"
defaultValue="0" />
```

9. Developing your own strategy

Now, **create your own norm synthesis strategy** *MyFirstStrategy.java:*

- In NormLabSimulators project, go to package **es.csic.iiia.normlab.traffic.custom** in src/traffic **.**
- There, right-click **New > Class** to create a new Java class *MyFirstStrategy.java* that implements NormSynthesisStragegy interface by:

1.- Naming it MyFirstStrategy



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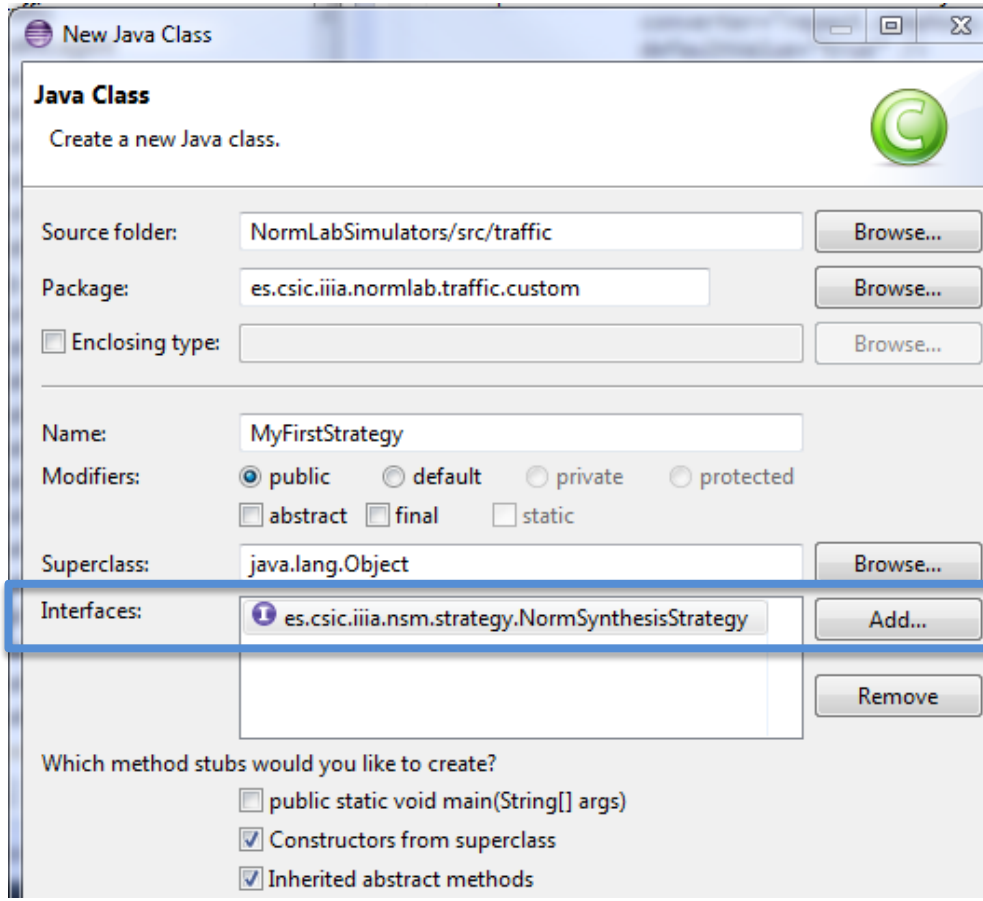
1.- Naming it MyFirstStrategy

2.- Adding interface **es.csic.iiia.nsm.strategy.NormSynthesisStrategy**



9. Developing your own strategy

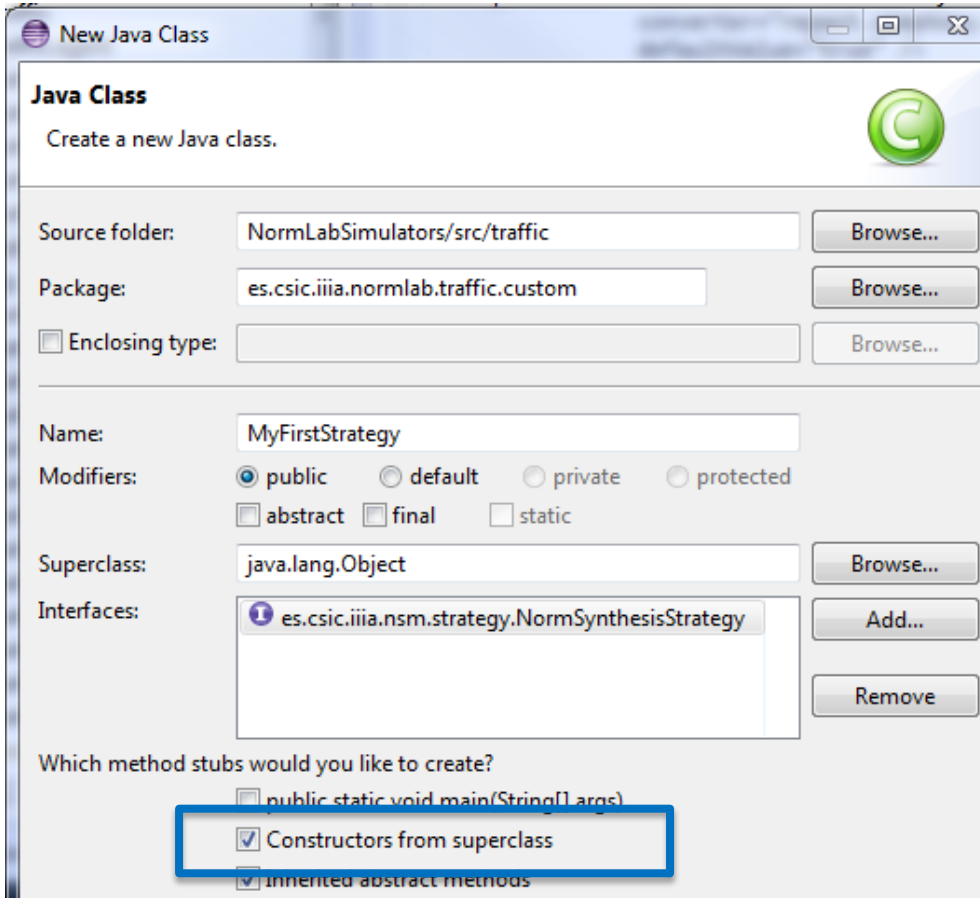
Now, **create your own norm synthesis strategy** *MyFirstStrategy.java:*

- In NormLabSimulators project, go to package **es.csic.iiia.normlab.traffic.custom** in src/traffic **.**
- There, right-click **New > Class** to create a new Java class *MyFirstStrategy.java* that implements NormSynthesisStragegy interface by:

1.- Naming it MyFirstStrategy

2.- Adding interface
es.csic.iiia.nsm.strategy.NormSynthesisStrategy

3.- Cheking the constructor creation



9. Developing your own strategy

Now, **create your own norm synthesis strategy** *MyFirstStrategy.java:*

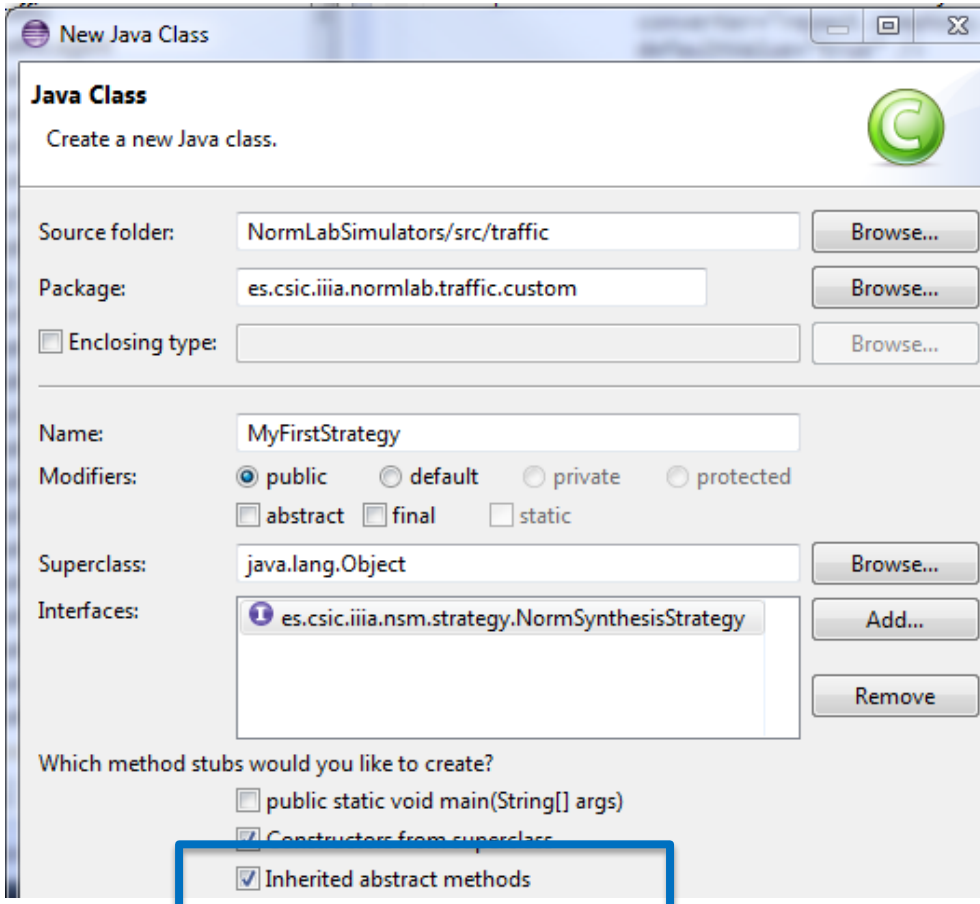
- In NormLabSimulators project, go to package **es.csic.iiia.normlab.traffic.custom** in src/traffic **.**
- There, right-click **New > Class** to create a new Java class *MyFirstStrategy.java* that implements NormSynthesisStragegy interface by:

1.- Naming it MyFirstStrategy

2.- Adding interface **es.csic.iiia.nsm.strategy.NormSynthesisStrategy**

3.- Cheking the constructor creation

4.- Creating inherited abstract method **execute()** (check "Inherited abstract methods")




```java
package es.csic.iiia.normlab.traffic.custom;
import es.csic.iiia.nsm.norm.NormativeSystem;
import es.csic.iiia.nsm.strategy.NormSynthesisStrategy;

public class MyFirstStrategy implements NormSynthesisStrategy {

  public MyFirstStrategy() {
    // TODO Auto-generated constructor stub
  }

  @Override
  public NormativeSystem execute() {
    // TODO Auto-generated method stub
    return null;
  }
}
```

9. Developing your own strategy

And **implement** the **norm synthesis strategy** class:

1. In the class, add a Normative Network attribute :
   private NormativeNetwork normativeNetwork;

The Norm Synthesis Machine contains the **Normative Network** which includes the Normative System:

- Normative Network: contains all synthesised norms.
- Normative System: set of (active) norms given to the agents.

```
package es.csic.iiia.normlab.traffic.custom;
import es.csic.iiia.nsm.net.norm.NormativeNetwork;
import es.csic.iiia.nsm.norm.NormativeSystem;
import es.csic.iiia.nsm.strategy.NormSynthesisStrategy;

public class MyFirstStrategy implements NormSynthesisStrategy {

  /* Normative Network: a data structure to keep synthesised norms*/
  private NormativeNetwork nomativeNetwork;

  /** Constructor of the strategy
   * @param nsm*/
  public MyFirstStrategy(es.csic.iiia.nsm.NormSynthesisMachine nsm) {
    /* Get Normative Network*/
    this.nomativeNetwork=nsm.getNormativeNetwork();
  }

  @Override
  public NormativeSystem execute() {
    // TODO Auto-generated method stub
    return null;
  }
}
```

9. Developing your own strategy

And **implement** the **norm synthesis strategy** class:

1. In the class, add a Normative Network attribute :
   private NormativeNetwork normativeNetwork;
2. In the constructor, add the parameter ***es.csic.iiia.nsm.NormSynthesisMachine nsm*** and use it to initialize (to empty) the Normative Network attribute:
   this.normativeNetwork = nsm.getNormativeNetwork();

The Norm Synthesis Machine contains the **Normative Network** which includes the Normative System:

- Normative Network: contains all synthesised norms.
- Normative System: set of (active) norms given to the agents.

```
package es.csic.iiia.normlab.traffic.custom;
import es.csic.iiia.nsm.net.norm.NormativeNetwork;
import es.csic.iiia.nsm.norm.NormativeSystem;
import es.csic.iiia.nsm.strategy.NormSynthesisStrategy;

public class MyFirstStrategy implements NormSynthesisStrategy {

  /* Normative Network: a data structure to keep synthesised norms*/
  private NormativeNetwork nomativeNetwork;

  /** Constructor of the strategy
   * @param nsm*/
  public MyFirstStrategy(es.csic.iiia.nsm.NormSynthesisMachine nsm) {
    /* Get Normative Network*/
    this.nomativeNetwork=nsm.getNormativeNetwork();
  }

  @Override
  public NormativeSystem execute() {
    // TODO Auto-generated method stub
    return null;
  }
}
```

9. Developing your own strategy

And **implement** the **norm synthesis strategy** class:

1. In the class, add a Normative Network attribute :
   private NormativeNetwork normativeNetwork;
2. In the constructor, add the parameter ***es.csic.iiia.nsm.NormSynthesisMachine nsm*** and use it to initialize (to empty) the Normative Network attribute:
   this.normativeNetwork = nsm.getNormativeNetwork();

The Norm Synthesis Machine contains the **Normative Network** which includes the Normative System:

- Normative Network: contains all synthesised norms.
- Normative System: set of (active) norms given to the agents.

3. Strategy execution: return the empty **Normative System** in method **execute()**:

return this.normativeNetwork.getNormativeSystem();

```
package es.csic.iiia.normlab.traffic.custom;
import es.csic.iiia.nsm.net.norm.NormativeNetwork;
import es.csic.iiia.nsm.norm.NormativeSystem;
import es.csic.iiia.nsm.strategy.NormSynthesisStrategy;

public class MyFirstStrategy implements NormSynthesisStrategy {

  /* Normative Network: a data structure to keep synthesised norms*/
  private NormativeNetwork nomativeNetwork;

  /** Constructor of the strategy
   * @param nsm*/
  public MyFirstStrategy(es.csic.iiia.nsm.NormSynthesisMachine nsm) {
    /* Get Normative Network*/
    this.nomativeNetwork=nsm.getNormativeNetwork();
  }

  /* Execute the strategy*/
  @Override
  public NormativeSystem execute() {
    return this.nomativeNetwork.getNormativeSystem();
  }
}
```

9. Developing your own strategy

Congratulations! You have created your first norm synthesis strategy, which returns an empty normative system. Your code should now look like this:

```
package es.csic.iiia.normlab.traffic.custom;

import es.csic.iiia.nsm.net.norm.NormativeNetwork;
import es.csic.iiia.nsm.norm.NormativeSystem;

/**
 *
 */
public class MyFirstStrategy implements es.csic.iiia.nsm.strategy.NormSynthesisStrategy {

  /* The normative network, a data structure to keep track of norms */
  private NormativeNetwork normativeNetwork;

  /**
   * Constructor of the strategy
   *
   * @param nsm
   */
  public MyFirstStrategy(es.csic.iiia.nsm.NormSynthesisMachine nsm) {

    /* Get normative network */
    this.normativeNetwork = nsm.getNormativeNetwork();
  }

  /**
   * Executes your strategy
   */
  @Override
  public NormativeSystem execute() {
    return normativeNetwork.getNormativeSystem();
  }
}
```

Tutorial outline

NormLab **execution**:

6-8. Execution examples

6. **Example** strategy **1**: NormLab execution: Returns an **empty** set of norms.
7. **Example** strategy **2**: Adding norms: Returns a fixed set of **1 norm**.
8. **Example** strategy **3**: Removing collisions: Returns a fixed set of **3 norms**.

9-14. Guided development of different norm synthesis strategies

9. **Development** of example strategy 1: **Empty** set of norms.
10. **Invoking** your strategy
11. **Development** of example strategy 2: **Adding norms** to your strategy (1 norm)
12. **Example 4**: A strategy with norm **generation**.
13. **Example 5**: A strategy with norm **generation** + **evaluation**.
14. **SIMON**: A complete strategy with norm **generation** + **evaluation** + **refinement.**

10. Invoking your strategy

But, how does *NormLab* invoke our new norm synthesis strategy?
The Traffic Simulator includes (in package **es.csic.iiia.normlab.traffic.agent**) an agent **DefaultTrafficNormSynthesisAgent** whose:

A. **Constructor** creates the **Norm Synthesis Machine** and configures it to use **our strategy**
B. **step()** method invokes our strategy at every simulation **tick**.

```
public DefaultTrafficNormSynthesisAgent(List<TrafficCamera> cameras,
    PredicatesDomains predDomains, DomainFunctions dmFunctions,
    NormSynthesisSettings nsSettings, long randomSeed) {
```

A

```
public void step() throws IncorrectSetupException {
  this.addedNorms.clear();
  this.removedNorms.clear();

  /* Execute strategy and obtain new normative system */
  NormativeSystem newNormativeSystem = nsm.executeStrategy();
```

B

10. Invoking your strategy (A)

Specifically, the constructor **(A) DefaultTrafficNormSynthesisAgent()** is in charge of:

1. Creating the norm synthesis machine.
2. Adding a set of sensors to the norm synthesis machine in order to perceive the scenario.
3. Setting the norm synthesis strategy.

```
public DefaultTrafficNormSynthesisAgent(List<TrafficCamera> cameras,
    PredicatesDomains predDomains, DomainFunctions dmFunctions,
    NormSynthesisSettings nsSettings, long randomSeed) {

  this.nsSettings = nsSettings;

  this.normativeSystem = new NormativeSystem();
  this.addedNorms = new ArrayList<Norm>();
  this.removedNorms = new ArrayList<Norm>();

  /* 1. Create norm synthesis machine */
  this.nsm = new NormSynthesisMachine(nsSettings, predDomains,
      dmFunctions, !RunEnvironment.getInstance().isBatch(), randomSeed);

  /* 2. Add sensors to the monitor of the norm synthesis machine */
  for(TrafficCamera camera : cameras) {
    this.nsm.addSensor(camera);
  }

  /* 3. Set the norm synthesis strategy */
  this.setNormSynthesisStrategy();
}
```

1
2
3
A

10. Invoking your strategy (A.1)

The invocation to the constructor of the NormSynthesisMachine (**A.1**) requires :

i. **NormSynthesisSettings**: The settings for the norm synthesis machine.
ii. **PredicatesDomains**: Agents' language: predicates and terms describing the scenario from the agents' local point of view.
iii. **DomainFunctions**: Some domain-dependent functions that the Norm Synthesis Machine requires to synthesise norms (e.g., conflict detection, norm applicability).

```
public DefaultTrafficNormSynthesisAgent(List<TrafficCamera> cameras,
    PredicatesDomains predDomains, DomainFunctions dmFunctions,
    NormSynthesisSettings nsSettings, long randomSeed) {

  this.nsSettings = nsSettings;

  this.normativeSystem = new NormativeSystem();
  this.addedNorms = new ArrayList<Norm>();
  this.removedNorms = new ArrayList<Norm>();

  /* 1. Create norm synthesis machine */
  this.nsm = new NormSynthesisMachine(nsSettings, predDomains,
      dmFunctions, !RunEnvironment.getInstance().isBatch(), randomSeed);

  /* 2. Add sensors to the monitor of the norm synthesis machine */
  for(TrafficCamera camera : cameras) {
    this.nsm.addSensor(camera);
  }

  /* 3. Set the norm synthesis strategy */
  this.setNormSynthesisStrategy();
}
```

i ii iii 1 A

10. Invoking your strategy (A.1.i)

NormSynthesisSettings (A.1.i) : An interface to be implemented (located in package **es.csic.iiia.nsm.config** in **NormSynthesisMachine** project)

- **getNormSynthesisStrategy()**: Returns the norm synthesis strategy to use.
- getSystemGoals(): A list of system goals. In traffic, the only goal is "to avoid collisions".
- isNormGenerationReactiveToConflicts(): True if NSM tries to add a new norm upon the detection of each non-regulated conflict. False if it creates the nom but does not add it to the Normative System immediately.
- getNormsDefaultUtility(): Norms' default utility (0.5 by default).
- getNormEvaluationLearningRate(): The α rate in IRON and SIMON to evaluate norms (0.1 recom.).
- getNormsPerformanceRangesSize(): The size of the window to compute norms' performance ranges.
- getNormGeneralisationMode(): SIMON's norm generalisation mode (Shallow/Deep).
- public int getNormGeneralisationStep(): SIMON's norm generalisation step: number of norm predicates that can be simultaneously generalised.
- getGeneralisationBoundary(Dimension dim, Goal goal): Minimum value of effectiveness/necessity that a norm's performance must reach to be generalised. It corresponds to the threshold α_{gen} in [1].
- getSpecialisationBoundary(Dimension dim, Goal goal): Value of Effectiveness/necessity under which a norm can be specialised. It corresponds to the threshold α_{spec} described in [1].
- getSpecialisationBoundaryEpsilon(Dimension dim, Goal goal): LION's epsilon to create, together with the specialisation boundaries, a norm deactivation band.
- getNumTicksOfStabilityForConvergence(): Number of simulation ticks without conflicts nor changes in the normative system to converge.

An **implementation** of these settings for the traffic simulator is located in (NormLabSimulators project, src/traffic) package **es.csic.iiia.normlab.traffic.normsynthesis,** in class *TrafficNormSynthesisSettings*

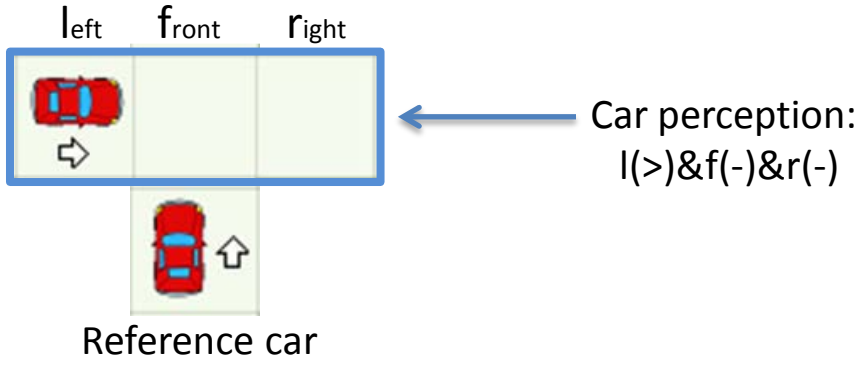
[1] Minimality and Simplicity in the On-line Automated Synthesis of Normative Systems. Javier Morales; Maite López-Sánchez; Juan A. Rodríguez-Aguilar; Michael Wooldridge; Wamberto W. Vasconcelos. AAMAS '14:, p.109-116 (2014)

10. Invoking your strategy (A.1.ii)

PredicatesDomains (A.1.ii) : Contains the predicates and terms that the agents employ to describe the MAS from their local point of view. Located in package **es.csic.iiia.nsm.agent.language** (NormSynthesisMachine project, src/)**.**

The traffic simulator creates predicates and their domains in class **TrafficSimulator** (NormLabSimulators project, src/traffic) from package **es.csic.iiia.normlab.traffic**, method **createPredicatesDomains().**

- Three different predicates **(l, f, r)** that represent the left, front and right positions in front of a car.
- Seven different terms {**<, ^, >, v, -, *, w**} representing: cars with different headings **{<, ^, >, v}**, nothing (-), anything (*), and wall (**w**).



10. Invoking your strategy (A.1.ii)

PredicatesDomains (A.1.ii) : class TrafficSimulator, method createPredicatesDomains():

```
private void createPredicatesDomains() {

  /* Predicate "left" domain */
  TaxonomyOfTerms leftPredTaxonomy = new TaxonomyOfTerms("l");
  leftPredTaxonomy.addTerm("*");
  leftPredTaxonomy.addTerm("<");
  leftPredTaxonomy.addTerm(">");
  leftPredTaxonomy.addTerm("-");
  leftPredTaxonomy.addRelationship("<", "*");
  leftPredTaxonomy.addRelationship(">", "*");
  leftPredTaxonomy.addRelationship("-", "*");

  /* Predicate "front" domain*/
  TaxonomyOfTerms frontPredTaxonomy = new TaxonomyOfTerms("f", leftPredTaxonomy);
  frontPredTaxonomy.addTerm("^");
  frontPredTaxonomy.addRelationship("^", "*");

  /* Predicate "right" domain*/
  TaxonomyOfTerms rightPredTaxonomy = new TaxonomyOfTerms("r", leftPredTaxonomy);
  rightPredTaxonomy.addTerm("w");
  rightPredTaxonomy.addRelationship("w", "*");

  this.predDomains = new PredicatesDomains();
  this.predDomains.addPredicateDomain("l", leftPredTaxonomy);
  this.predDomains.addPredicateDomain("f", frontPredTaxonomy);
  this.predDomains.addPredicateDomain("r", rightPredTaxonomy);
}
```

10. Invoking your strategy (A.1.iii)

DomainFunctions (A.1.iii) : An interface to be implemented. Located in package **es.csic.iiia.nsm.config** (NormSynthesisMachine project, src/).

- **isConsistent(**SetOfPredicatesWithTerms agentContext**):** Returns true if a set of predicates with terms is consistent with the domain scenario. E.g.: (left(>),front(-),right(-)) is consistent (possible) but (left(>),front(<),right(-)) is not consistent, since two cars can not drive in opposite directions in the same lane.
- **agentContextFunction(**long agentId, View view**):** Returns the local perception of a given agent (i.e., its context) from the observation (view) of the state of the simulated scenario.
- **agentActionFunction(**long agentId,ViewTransition viewTransition**):** Returns a list of actions performed by an agent in the transition from a state $\mathbf{s_t}$ to a state $\mathbf{s_{t-1}}$
- **getConflicts(**Goal goal,ViewTransition viewTransition**):** Receives a transition between two states, a system goal (e.g., to avoid collisions) and returns the conflicts that have arisen in that transition with respect to the system goal (e.g., returns the collisions).
- **hasConflict(**View view, long agentId, Goal goal**):** Returns true if a given agent is in conflict in a given system state (i.e., View).

An implementation of the domain functions for the traffic simulator is located on (NormLabSimulators project, src/traffic) **es.csic.iiia.normlab.traffic.normsynthesis**, *TrafficDomainFunctions* class.

10. Invoking your strategy (recap)

The Traffic Simulator includes **DefaultTrafficNormSynthesisAgent** agent whose:

A. Constructor

1. Creates the Norm Synthesis Machine (NSM).
2. Adds a set of sensors to SNM to perceive the scenario.
3. Sets the norm synthesis strategy in the NSM.

B. step() method invokes our strategy at every simulation **tick**.

```
public DefaultTrafficNormSynthesisAgent( ···) {
  ...
  /* 1. Create norm synthesis machine */
  this.nsm = new NormSynthesisMachine(nsSettings, predDomains,
      dmFunctions, !RunEnvironment.getInstance().isBatch(), randomSeed);

  /* 2. Add sensors to the monitor of the norm synthesis machine */
  for(TrafficCamera camera : cameras) {
    this.nsm.addSensor(camera);
  }

  /* 3. Set the norm synthesis strategy */
  this.setNormSynthesisStrategy();
}
```

1 2 3 A

```
public void step() throws IncorrectSetupException {
  this.addedNorms.clear();
  this.removedNorms.clear();

  /* Execute strategy and obtain new normative system */
  NormativeSystem newNormativeSystem = nsm.executeStrategy();
```

B

10. Invoking your strategy (A.3, B)

The Traffic Simulator includes **DefaultTrafficNormSynthesisAgent** agent whose:

A. Constructor

1. Creates the Norm Synthesis Machine (NSM).
2. Adds a set of sensors to SNM to perceive the scenario.
3. Sets the norm synthesis strategy in the NSM: Method SetNormSynthesisStrategy() invokes method **createCustomNormSynthesisStrategy()**
   (located in the same class *DefaultTrafficNormSynthesisAgent*):
   - **Implement** this method by creating and returning your norm synthesis strategy:

```
/**
 * Sets a custom norm synthesis strategy
 */
protected NormSynthesisStrategy createCustomNormSynthesisStrategy() {
  return new MyFirstStrategy(nsm);
}
}
```

B. step() method invokes our strategy at every simulation **tick**.

- Execute the simulation as you did for examples 1, 2 and 3 (NormLabSimulators project, launchers/: TrafficJunctionSimulator.launch > Run As …)

Congratulations! You are using your own strategy!

Tutorial outline

NormLab **execution**:

6-8. Execution examples

6. **Example** strategy **1**: NormLab execution: Returns an **empty** set of norms.
7. **Example** strategy **2**: Adding norms: Returns a fixed set of **1 norm**.
8. **Example** strategy **3**: Removing collisions: Returns a fixed set of **3 norms**.

9-14. Guided development of different norm synthesis strategies

9. **Development** of example strategy 1: **Empty** set of norms.
10. **Executing** your own strategy
11. **Development** of example strategy 2: **Adding norms** to your strategy (1 norm)
12. **Example 4**: A strategy with norm **generation**.
13. **Example 5**: A strategy with norm **generation** + **evaluation**.
14. **SIMON**: A complete strategy with norm **generation** + **evaluation** + **refinement.**

11. Adding norms to your strategy

Let's now **add some norms**. We will add the left-side-priority norm from **example 2**.

1. **Crate** a new norm synthesis strategy *MySecondStrategy.java* by **Copying** (cut&paste+rename) your first strategy *MyFirstStrategy.java*
   Your code should look like this:

```
/**
 * My second strategy
 */
public class MySecondStrategy implements es.csic.iiia.nsm.strategy.NormSynthesisStrategy {

  /* The normative network, a data structure to keep track of norms */
  private NormativeNetwork normativeNetwork;

  /**
   * Constructor of the strategy
   *
   * @param nsm the norm synthesis machine
   */
  public MySecondStrategy(es.csic.iiia.nsm.NormSynthesisMachine nsm) {
    this.normativeNetwork = nsm.getNormativeNetwork();
  }

  @Override
  public NormativeSystem execute() {
    return normativeNetwork.getNormativeSystem();
  }
}
```

11. Adding norms to your strategy

2. Implement a method **createNormativeSystem()** in *MySecondStrategy.java* to create norms with:

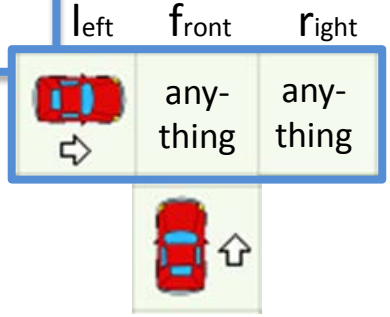
- Preconditions: a set of predicate-term pairs and
- Postconditions: a modality (prohibition/obligation) over an action

i. Create a new norm precondition: **IF l(>) & f(*) & r(*)**

```
private void createNormativeSystem() {
  /* Create norm preconditions */
  SetOfPredicatesWithTerms n1Precondition = new SetOfPredicatesWithTerms();
  n1Precondition.add("l", ">");
  n1Precondition.add("f", "*");
  n1Precondition.add("r", "*");

  /* Create norms */
  Norm n1 = new Norm(n1Precondition,
      NormModality.Prohibition, CarAction.Go);

  /* Add the norms to the normative network and activate them */
  this.normativeNetwork.add(n1);
  normativeNetwork.setState(n1, NetworkNodeState.ACTIVE);
}
```



11. Adding norms to your strategy

2. Implement a method **createNormativeSystem()** in *MySecondStrategy.java* to create norms with:

- Preconditions: a set of predicate-term pairs and
- Postconditions: a modality (prohibition/obligation) over an action

i. Create a new norm precondition: **IF l(>) & f(*) & r(*)**

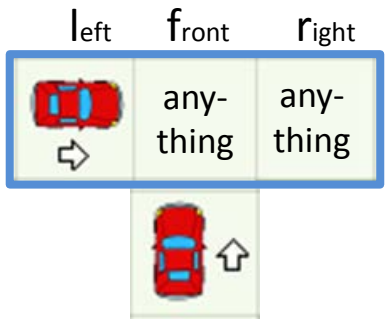
ii. Create a **new norm n1** with this precondition and as postcondition: **THEN Prohition(Go)**

```
private void createNormativeSystem() {

  /* Create norm preconditions */
  SetOfPredicatesWithTerms n1Precondition = new SetOfPredicatesWithTerms();
  n1Precondition.add("l", ">");
  n1Precondition.add("f", "*");
  n1Precondition.add("r", "*");

  /* Create norms */
  Norm n1 = new Norm(n1Precondition,
      NormModality.Prohibition, CarAction.Go);

  /* Add the norms to the normative network and activate them */
  this.normativeNetwork.add(n1);
  normativeNetwork.setState(n1, NetworkNodeState.ACTIVE);
}
```



11. Adding norms to your strategy

2. Implement a method **createNormativeSystem()** in *MySecondStrategy.java* to create norms with:

- Preconditions: a set of predicate-term pairs and
- Postconditions: a modality (prohibition/obligation) over an action

i. Create a new norm precondition: **IF l(>) & f(*) & r(*)**

ii. Create a **new norm n1** with this precondition and as postcondition: **THEN Prohition(Go)**

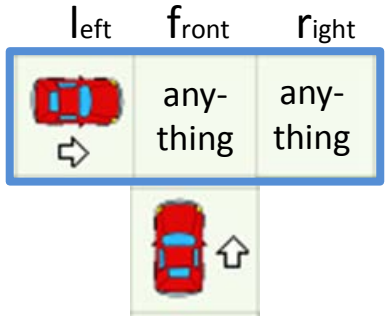
iii. Add norm n1 to the Normative Network and activate it so it becomes part of the Normative System

```
private void createNormativeSystem() {

  /* Create norm preconditions */
  SetOfPredicatesWithTerms n1Precondition = new SetOfPredicatesWithTerms();
  n1Precondition.add("l", ">");
  n1Precondition.add("f", "*");
  n1Precondition.add("r", "*");

  /* Create norms */
  Norm n1 = new Norm(n1Precondition,
      NormModality.Prohibition, CarAction.Go);

  /* Add the norms to the normative network and activate them */
  this.normativeNetwork.add(n1);
  normativeNetwork.setState(n1, NetworkNodeState.ACTIVE);
}
```



11. Adding norms to your strategy

3. Invoke method **createNormativeSystem()** at the end of *MySecondStrategy* constructor

```
public class MySecondStrategy implements es.csic.iiia.nsm.strategy.NormSynthesisStrategy {

  /* The normative network, a data structure to keep track of norms */
  private NormativeNetwork normativeNetwork;

  /**
   * Constructor of the strategy
   *
   * @param nsm the norm synthesis machine
   */
  public MySecondStrategy(es.csic.iiia.nsm.NormSynthesisMachine nsm) {
    this.normativeNetwork = nsm.getNormativeNetwork();

    this.createNormativeSystem(); // Create a default normative system
  }

  @Override
  public NormativeSystem execute() {
    return normativeNetwork.getNormativeSystem();
  }

  /**
   * Creates a normative system to give way to the cars on the left
   */
  private void createNormativeSystem() {
    /* Create norm preconditions */
    SetOfPredicatesWithTerms n1Precondition = new SetOfPredicatesWithTerms();
    n1Precondition.add("l", ">");
    n1Precondition.add("f", "*");
    n1Precondition.add("r", "*");

    /* Create norms */
    Norm n1 = new Norm(n1Precondition, NormModality.Prohibition, CarAction.Go);

    /* Add the norms to the normative network and activate them */
    this.normativeNetwork.add(n1);
    normativeNetwork.setState(n1, NetworkNodeState.ACTIVE);
  }
}
```

At each tick, the strategy will return the norms that are active in the normative network (i.e., the normative system).

11. Adding norms to your strategy

4. Change method **createCustomNormSynthesisStrategy()** from *DefaultTrafficNormSynthesisAgent* (in package **es.csic.iiia.normlab.traffic.agent**, NormLabSimulators project, src/traffic) to use your new strategy.

```
/**
 * Sets a custom norm synthesis strategy
 */
protected NormSynthesisStrategy createCustomNormSynthesisStrategy() {
  return new MySecondStrategy(nsm);
}
```

   - Recall that the traffic norm synthesis agent in the traffic simulator creates the norm synthesis machine and executes the strategy at every simulation tick.

5. Execute the Traffic Simulator (NormLabSimulators project, launchers/: TrafficJunctionSimulator.launch > Run As …) to observe that this second strategy works as example 2.
   - The normative system contains a single norm N1.

Tutorial outline

NormLab **execution**:

6-8. Execution examples

6. **Example** strategy **1**: NormLab execution: Returns an **empty** set of norms.
7. **Example** strategy **2**: Adding norms: Returns a fixed set of **1 norm**.
8. **Example** strategy **3**: Removing collisions: Returns a fixed set of **3 norms**.

9-14. Guided development of different norm synthesis strategies

9. **Development** of example strategy 1: **Empty** set of norms.
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12. **Example 4**: A strategy with automatic norm **generation**.
13. **Example 5**: A strategy with norm **generation** + **evaluation**.
14. **SIMON**: A complete strategy with norm **generation** + **evaluation** + **refinement.**

12. Your strategy with automatic norm generation

How can we automatically generate norms on-line?

Example 4 (***TrafficNSExample4_NSStrategy*** in package **es.csic.iiia.normlab.traffic.examples.ex4,** NormLabSimulators project) uses **operators** (methods defined in *TrafficNSExample4_NSOperators*) to **create**, **add** and **activate** norms the Normative Network:

- **Activate (norm):** sets the state of norm to «Active»

- **Add (norm):** adds norm into the Normative Network and activates it.

- **Create (Conflict, Goal):**
  - Applies Case-Based Reasoning (CBR) to create a norm aimed at avoiding future conflicts.
  - If the norm does not exist in the Normative Network, then it adds (and activates) it. Otherwise, if the norm is not active (nor represented)in the NN , then it activates it.

12. Your strategy with automatic norm generation

TrafficNSExample4_NSStrategy uses operators to synthesize norms :

Everytime the strategy is executed, it:

1. Generates norms

2. Returns the Normative System.

```
/**
 * Executes IRON's strategy
 * @return the normative system resulting from the norm synthesis cycle
 */
public NormativeSystem execute() {
  this.normAdditions.clear();
  this.normDeactivations.clear();
  this.createdNorms.clear();
  this.activatedNorms.clear();

  /*-------------------
   *  Norm generation
   *-------------------*/

  this.normGeneration();

  /* Return the current normative system */
  return normativeNetwork.getNormativeSystem();
}

/**
 * Executes the norm generation phase
 */
private void normGeneration() {

  /* Obtain monitor perceptions */
  obtainPerceptions(viewTransitions);

  /* Conflict detection */
  conflicts = conflictDetection(viewTransitions);

  /* Norm generation */
  for(Goal goal : conflicts.keySet()) {
    for(Conflict conflict : conflicts.get(goal)) {
      operators.create(conflict, goal);
    }
  }
}
```

12. Your strategy with automatic norm generation

TrafficNSExample4_NSStrategy uses operators to synthesize norms :

Everytime the strategy is executed, it:

1. Generates norms
    1. Perceives the scenario
2. Returns the Normative System.

```
/**
 * Executes IRON's strategy
 * @return the normative system resulting from the norm synthesis cycle
 */
public NormativeSystem execute() {
  this.normAdditions.clear();
  this.normDeactivations.clear();
  this.createdNorms.clear();
  this.activatedNorms.clear();

  /*-------------------
   *  Norm generation
   *-------------------*/

  this.normGeneration();

  /* Return the current normative system */
  return normativeNetwork.getNormativeSystem();
}
```

```
/**
 * Executes the norm generation phase
 */
private void normGeneration() {

  /* Obtain monitor perceptions */
  obtainPerceptions(viewTransitions);

  /* Conflict detection */
  conflicts = conflictDetection(viewTransitions);

  /* Norm generation */
  for(Goal goal : conflicts.keySet()) {
    for(Conflict conflict : conflicts.get(goal)) {
      operators.create(conflict, goal);
    }
  }
}
```

ViewTransition: description of partial scenario transition from time t-1 to time t (current tick)

12. Your strategy with automatic norm generation

TrafficNSExample4_NSStrategy uses operators to synthesize norms :

Everytime the strategy is executed, it:

1. Generates norms
    1. Perceives the scenario
    2. Detects non regulated conflicts

2. Returns the Normative System.

Conflict detection through getConflicts() domain function
Each conflict has a ViewTransition with a conflict at tick t and an involved (responsible) agent.

```
/**
 * Executes IRON's strategy
 * @return the normative system resulting from the norm synthesis cycle
 */
public NormativeSystem execute() {
  this.normAdditions.clear();
  this.normDeactivations.clear();
  this.createdNorms.clear();
  this.activatedNorms.clear();

  /*-------------------
   *  Norm generation
   *-------------------*/

  this.normGeneration();

  /* Return the current normative system */
  return normativeNetwork.getNormativeSystem();
}

/**
 * Executes the norm generation phase
 */
private void normGeneration() {

  /* Obtain monitor perceptions */
  obtainPerceptions(viewTransitions);

  /* Conflict detection */
  conflicts = conflictDetection(viewTransitions);

  /* Norm generation */
  for(Goal goal : conflicts.keySet()) {
    for(Conflict conflict : conflicts.get(goal)) {
      operators.create(conflict, goal);
    }
  }
}
```

12. Your strategy with automatic norm generation

TrafficNSExample4_NSStrategy uses operators to synthesize norms :

Everytime the strategy is executed, it:

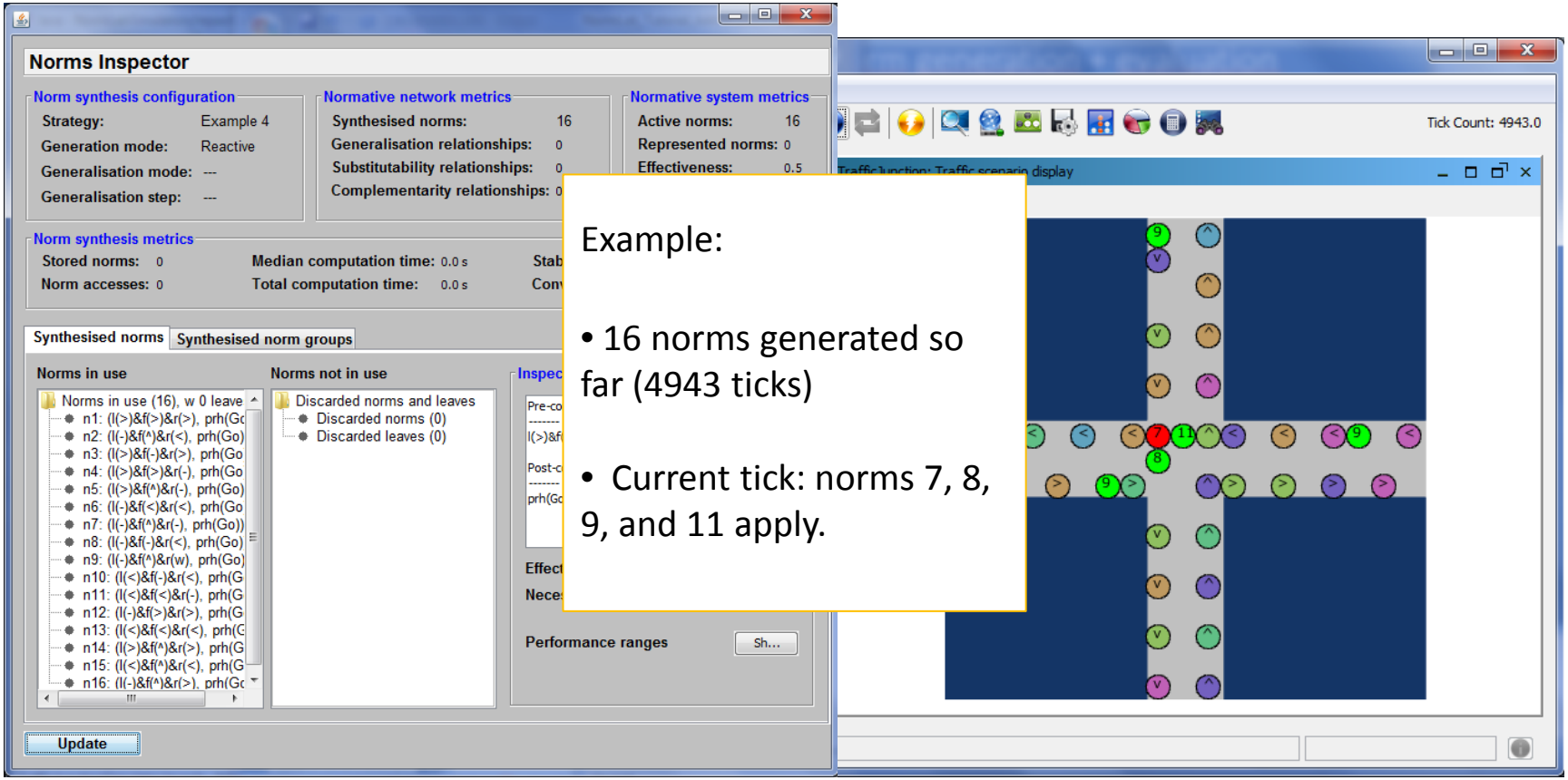
1. Generates norms
    1. Perceives the scenario
    2. Detects non regulated conflicts
    3. **Creates** norms for each conflict.
2. Returns the Normative System.

```
/**
 * Executes IRON's strategy
 * @return the normative system resulting from the norm synthesis cycle
 */
public NormativeSystem execute() {
  this.normAdditions.clear();
  this.normDeactivations.clear();
  this.createdNorms.clear();
  this.activatedNorms.clear();

  /*-------------------
   *  Norm generation
   *-------------------*/

  this.normGeneration();

  /* Return the current normative system */
  return normativeNetwork.getNormativeSystem();
}

/**
 * Executes the norm generation phase
 */
private void normGeneration() {

  /* Obtain monitor perceptions */
  obtainPerceptions(viewTransitions);

  /* Conflict detection */
  conflicts = conflictDetection(viewTransitions);

  /* Norm generation */
  for(Goal goal : conflicts.keySet()) {
    for(Conflict conflict : conflicts.get(goal)) {
      operators.create(conflict, goal);
    }
  }
}
```

12. Your strategy with automatic norm generation

Execute the strategy:

1. Set NormSynthesisExample **defaultValue=«4»** in **parameters.xml** (in NormLabSimulators project, **repast-settings/TrafficJunction.rs**) and save the file.
2. Execute the simulator
   - NormLabSimulators project, launchers/: TrafficJunctionSimulator.launch > Run As …
3. Observe how, as long as cars collide, it generates norms to avoid these collisions
   - Norms are never evaluated (select a norm and click on button *Show* performance ranges).



Tutorial outline

NormLab **execution**:

6-8. Execution examples

6. **Example** strategy **1**: NormLab execution: Returns an **empty** set of norms.
7. **Example** strategy **2**: Adding norms: Returns a fixed set of **1 norm**.
8. **Example** strategy **3**: Removing collisions: Returns a fixed set of **3 norms**.

9-14. Guided development of different norm synthesis strategies

9. **Development** of example strategy 1: **Empty** set of norms.
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13. Automatic norm generation + evaluation

Are generated norms good enough?

Let's see example 5: ***TrafficNSExample5_NSStrategy*** (in NormLabSimulators project, src/traffic **es.csic.iiia.normlab.traffic.examples.ex5** package) :

Whenever the strategy is **executed:**

- It generates norms (as example 4)
- It **evaluates norms:** how?

```
public NormativeSystem execute() {
    this.normAdditions.clear();
    this.normDeactivations.clear();
    this.createdNorms.clear();
    this.activatedNorms.clear();

    this.normGeneration();

    this.normEvaluation();

    /* Return the current normative system */
    return normativeNetwork.getNormativeSystem();
}
```

13. Automatic norm generation + evaluation

Norm Evaluation (*TrafficNSExample5_NSStrategy*) :

```
private void normEvaluation() {

  /* Compute norm applicability */
  this.normApplicability = this.normApplicability(viewTransitions);

  /* Detect norm applicability and compliance */
  this.normCompliance(this.normApplicability);

  /* Update utilities and performances */
  this.updateUtilitiesAndPerformances(this.normCompliance);
}
```

1. **Retrieve** the norms that applied to each agent in the simulation at time t-1:

```
protected Map<ViewTransition, NormsApplicableInView> normApplicability(
    List<ViewTransition> vTransitions)  {

  /* Clear norm applicability from previous tick */
  this.normApplicability.clear();

  /* Get applicable norms of each viewTransition (of each sensor) */
  for(ViewTransition vTrans : vTransitions) {
    NormsApplicableInView normApplicability;
    normApplicability = this.normReasoner.getNormsApplicable(vTrans);
    this.normApplicability.put(vTrans, normApplicability);
  }
  return this.normApplicability;
}
```

For each viewTransition, normReasoner computes the norms that apply to each agent by using DomainFunctions

13. Automatic norm generation + evaluation

Norm Evaluation (*TrafficNSExample5_NSStrategy*):

```
private void normEvaluation() {

  /* Compute norm applicability */
  this.normApplicability = this.normApplicability(viewTransitions);

  /* Detect norm applicability and compliance */
  this.normCompliance(this.normApplicability);

  /* Update utilities and performances */
  this.updateUtilitiesAndPerformances(this.normCompliance);
}
```

2. **Norm compliance**: Did agents **complied** with their applicable norms? Did that lead to conflicts?

```
protected void normCompliance(Map<ViewTransition,
    NormsApplicableInView> normApplicability) {

  /* Check norm compliance in the view in terms of each system goal */
  for(Goal goal : this.nsmSettings.getSystemGoals()) {

    /* Clear norm compliance of previous tick */
    this.normCompliance.get(goal).clear();

    /* Evaluate norm compliance and conflicts in each
     * view transition with respect to each system goal */
    for(ViewTransition vTrans : normApplicability.keySet()) {
      NormsApplicableInView vNormAppl = normApplicability.get(vTrans);

      /* If there is no applicable norm in the view, continue */
      if(vNormAppl.isEmpty()) {
        continue;
      }
      NormComplianceOutcomes nCompliance = this.normReasoner.
          checkNormComplianceAndOutcomes(vNormAppl, goal);

      this.normCompliance.get(goal).put(vTrans, nCompliance);
    }
  }
}
```

normReasoner.
checkNormComplianceAndOutcomes

13. Automatic norm generation + evaluation

Norm Evaluation (*TrafficNSExample5_NSStrategy*):

```
private void normEvaluation() {

  /* Compute norm applicability */
  this.normApplicability = this.normApplicability(viewTransitions);

  /* Detect norm applicability and compliance */
  this.normCompliance(this.normApplicability);

  /* Update utilities and performances */
  this.updateUtilitiesAndPerformances(this.normCompliance);
}
```

3. **Update norms' utilities** based on norm compliance

```
protected void  updateUtilitiesAndPerformances(
    Map<Goal, Map<ViewTransition,NormComplianceOutcomes>> normCompliance) {

  for(Goal goal : this.nsmSettings.getSystemGoals()) {
    for(ViewTransition vTrans : normCompliance.get(goal).keySet()) {
      for(Dimension dim : this.nsm.getNormEvaluationDimensions()) {
        this.utilityFunction.evaluate(dim, goal,
            normCompliance.get(goal).get(vTrans), normativeNetwork);
      }
    }
  }
}
```

evaluate(…) method in
TrafficNSExample5_NSUtilityFunction
(in NormLabSimulators project, src/traffic
es.csic.iiia.normlab.traffic.examples.ex5 package)

13. Automatic norm generation + evaluation

Norm Evaluation (*TrafficNSExample5_NSStrategy*):

```
private void normEvaluation() {

  /* Compute norm applicability */
  this.normApplicability = this.normApplicability(viewTransitions);

  /* Detect norm applicability and compliance */
  this.normCompliance(this.normApplicability);

  /* Update utilities and performances */
  this.updateUtilitiesAndPerformances(this.normCompliance);
}
```

3. **Update norms' utilities** based on norm compliance

```
protected void  updateUtilitiesAndPerformances(
    Map<Goal, Map<ViewTransition,NormComplianceOutcomes>> normCompliance) {

  for(Goal goal : this.nsmSettings.getSystemGoals()) {
    for(ViewTransition vTrans : normCompliance.get(goal).keySet()) {
      for(Dimension dim : this.nsm.getNormEvaluationDimensions()) {
        this.utilityFunction.evaluate(dim, goal,
            normCompliance.get(goal).get(vTrans), normativeNetwork);
      }
    }
  }
}
```

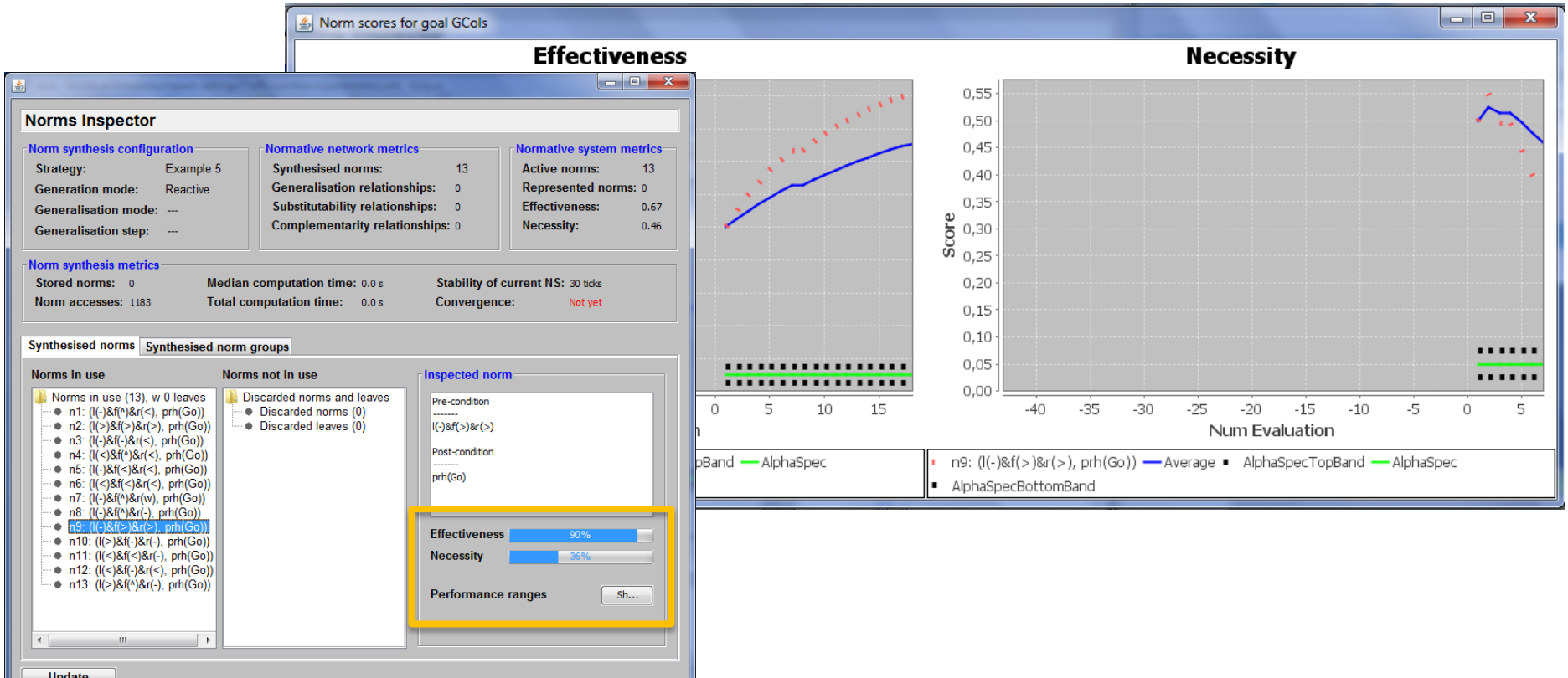
Evaluates each norm in terms of system goals: Is it useful to **avoid conflicts**?
(e.g. traffic: avoids car collisions?). Two dimensions:

- **Effectiveness**: when complied, is it effective to avoid conflicts?
  - If complied + no conflicts → ***Effective***
  - If complied + conflicts → ***Ineffective***
- **Necessity**: when infringed, did some conflicts actually arise?
  - If infringed + no conflicts → ***Unnecessary***
  - If infringed + conflicts → ***Necessary***

13. Automatic norm generation + evaluation

Execute the strategy:

1. Set NormSynthesisExample **defaultValue=«5»** in **parameters.xml** (in NormLabSimulators project, **repast-settings/TrafficJunction.rs**) and save the file.
2. Execute the simulator
   - NormLabSimulators project, launchers/: TrafficJunctionSimulator.launch > Run As …
3. Observe how it generates norms and evaluates them.
   - Effectiveness and necessity of each norm change along time (select a norm and click on button *Show* performance ranges).



Tutorial outline

NormLab **execution**:

6-8. Execution examples

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14. SIMON: generation + evaluation + refinement

SIMON is a **complete norm synthesis strategy** that uses norm evaluation to refine norms

SIMONStrategy (in NormSynthesisMachine project, src **es.csic.iiia.nsm.strategy.simon** package) :

Whenever the strategy is **executed:**

- It generates norms
- It evaluates norms
- It **refines them :** how?

```
public NormativeSystem execute() {
  this.nsMetrics.resetNonRegulatedConflicts();
  this.visitedNorms.clear();

  /* Norm generation */
  List<Norm> normsActivated = this.normGenerator.step(viewTransitions, conflicts);

  /* Norm evaluation */
  this.normEvaluator.step(viewTransitions, normApplicability,
      normCompliance, normGroupCompliance);

  /* Norm refinement */
  this.normRefiner.step(normApplicability, normsActivated);

  /* Manage lists that control new additions to the normative network,
   * normative system, as well as norms that have been removed */
  this.manageNormControlLists();

  /* Return the current normative sys
  return normativeNetwork.getNormativ
}
```

step(…) method in **SIMONNormRefiner** (in NormSynthesisMachine project, src es.csic.iiia.nsm.strategy.simon package)

14. SIMON: generation + evaluation + refinement

Norm refinement:

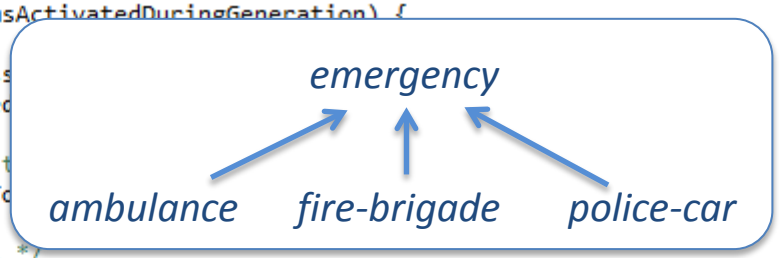
1. Norms are **generalised** if their (effectiveness **and** necessity) **> threshold.**

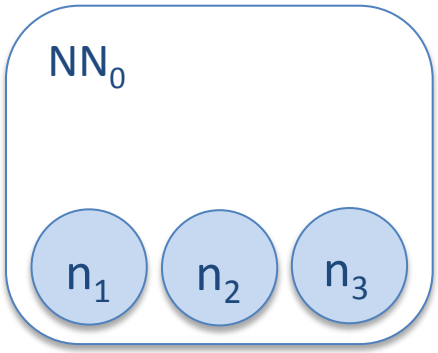
```
public void step(Map<ViewTransition, NormsApplicableInView> normApplicability,
    List<Norm> normsActivatedDuringGeneration) {

  List<Norm> processed = new ArrayList<Norm>();
  List<Norm> visited = new ArrayList<Norm>();

  /* Compute norms that must be revised */
  List<Norm> normsToRevise = this.checkNormsToRevise(normApplicability);

  /* Classify norms */
  this.normClassifications = this.normClassifier.step(normsToRevise);

  /* Refine norms based on norm classifications */
  for(Norm norm : normClassifications.keySet()) {
    if(processed.contains(norm)) {
      continue;
    }
    List<NormAttribute> attributes = normClassifications.get(norm);

    boolean isIneffective = attributes.contains(NormAttribute.INEFFECTIVE);
    boolean isUnnecessary = attributes.contains(NormAttribute.UNNECESSARY);
    boolean isGeneralisable = attributes.contains(NormAttribute.GENERALISABLE);

    /* If the norm is whether ineffective or unnecessary, then deactivate
     * it (specialise it into its children) */
    if(isIneffective || isUnnecessary) {
      visited.clear();
      specialiseDown(norm, NetworkNodeState.DISCARDED, visited);
    }
    /* If the norm has enough utility to be generalised,
     * then try to generalise it */
    else if(isGeneralisable) {
      generaliseUp(norm, genMode, genStep);
    }
    /* Update complexities metrics */
    this.nsMetrics.incNumNodesVisited();
  }
}
```

14. SIMON: generation + evaluation + refinement

Norm refinement:

1. Norms are **generalised** if their (effectiveness **and** necessity) ≥ gen. **threshold**.





Normative system
$NS_0=\{n_1, n_2, n_3\}$

n_1: Give way to ambulances
n_2: Give way to fire brigade
n_3: Give way to police cars

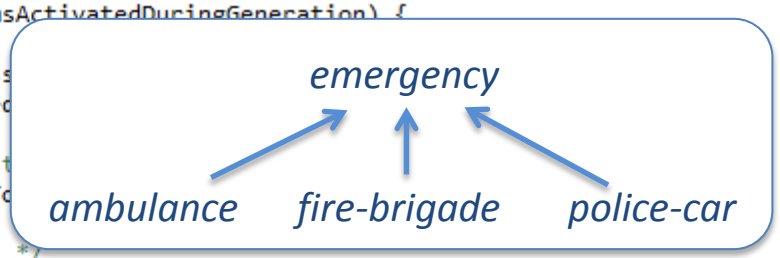
```
public void step(Map<ViewTransition, NormsApplicableInView> normApplicability,
    List<Norm> normsActivatedDuringGeneration) {

  List<Norm> process
  List<Norm> visited

  /* Compute norms t
  List<Norm> normsTo

  /* Classify norms */
```

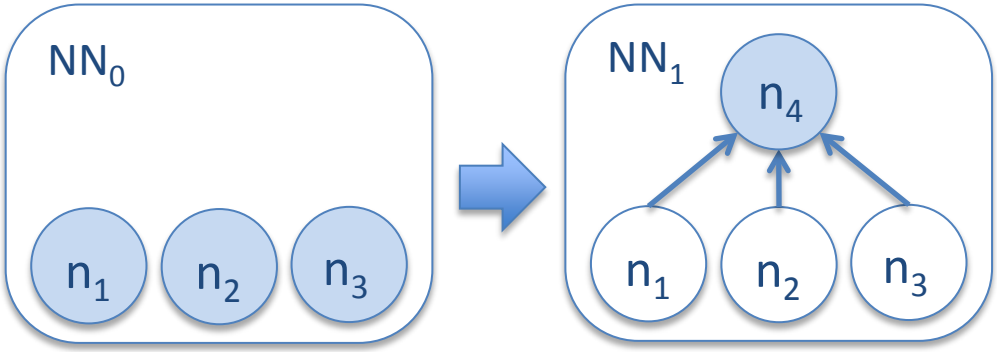
```
/* If the norm has enough utility to be generalised,
 * then try to generalise it */
else if(isGeneralisable) {
  generaliseUp(norm, genMode, genStep);
}

  /* Update complexities metrics */
  this.nsMetrics.incNumNodesVisited();
 }
}
```

14. SIMON: generation + evaluation + refinement

Norm refinement:

1. Norms are **generalised** if their (effectiveness **and** necessity) ≥ gen. **threshold.**





New Normative system $NS_1=\{n_4\}$

Increases Compactness

n_1: Give way to **ambulances**
n_2: Give way to **fire brigade**
n_3: Give way to **police cars**
n_4: Give way to **emergency** vehicles

```
public void step(Map<ViewTransition, NormsApplicableInView> normApplicability,
    List<Norm> normsActivatedDuringGeneration) {

  List<Norm> process
  List<Norm> visited

  /* Compute norms t
  List<Norm> normsTo

  /* Classify norms */
```

```
  /* If the norm has enough utility to be generalised,
   * then try to generalise it */
  else if(isGeneralisable) {
    generaliseUp(norm, genMode, genStep);
  }

  /* Update complexities metrics */
  this.nsMetrics.incNumNodesVisited();
 }
}
```

14. SIMON: generation + evaluation + refinement

Norm refinement:

1. Norms are **generalised**
2. Norms are **specialised** if their (effectiveness **or** necessity) **<** esp. **threshold**

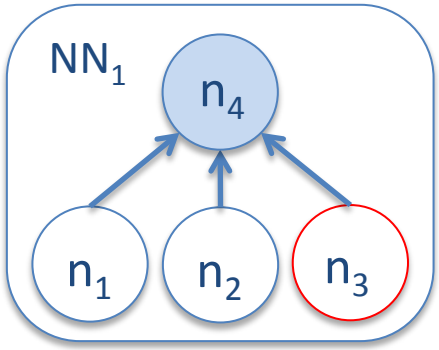
```
public void step(Map<ViewTransition, NormsApplicableInView> normApplicability,
    List<Norm> normsActivatedDuringGeneration) {

  List<Norm> processed = new ArrayList<Norm>();
  List<Norm> visited = new ArrayList<Norm>();

  /* Compute norms that must be revised */
  List<Norm> normsToRevise = this.checkNormsToRevise(normApplicability);

  /* Classify norms */
  this.normClassifications = this.normClassifier.step(normsToRevise);

  /* Refine norms based on norm classifications */
  for(Norm norm : normClassifications.keySet()) {
    if(processed.contains(norm)) {
      continue;
    }
    List<NormAttribute> attributes = normClassifications.get(norm);

    boolean isIneffective = attributes.contains(NormAttribute.INEFFECTIVE);
    boolean isUnnecessary = attributes.contains(NormAttribute.UNNECESSARY);
    boolean isGeneralisable = attributes.contains(NormAttribute.GENERALISABLE);

    /* If the norm is whether ineffective or unnecessary, then deactivate
     * it (specialise it into its children) */
    if(isIneffective || isUnnecessary) {
      visited.clear();
      specialiseDown(norm, NetworkNodeState.DISCARDED, visited);
    }

    /* If the norm has enough utility to be generalised,
     * then try to generalise it */
    else if(isGeneralisable) {
      generaliseUp(norm, genMode, genStep);
    }

    /* Update complexities metrics */
    this.nsMetrics.incNumNodesVisited();
  }
}
```

14. SIMON: generation + evaluation + refinement

Norm refinement:

1. Norms are **generalised**
2. Norms are **specialised** if their (effectiveness **or** necessity) **<** esp. **threshold**

Normative System $NS_1 = \{n_4\}$



n_1: Give way to **ambulances**
n_2: Give way to **fire brigade**
n_3: Give way to **police cars**
n_4: Give way to **emergency** vehicles

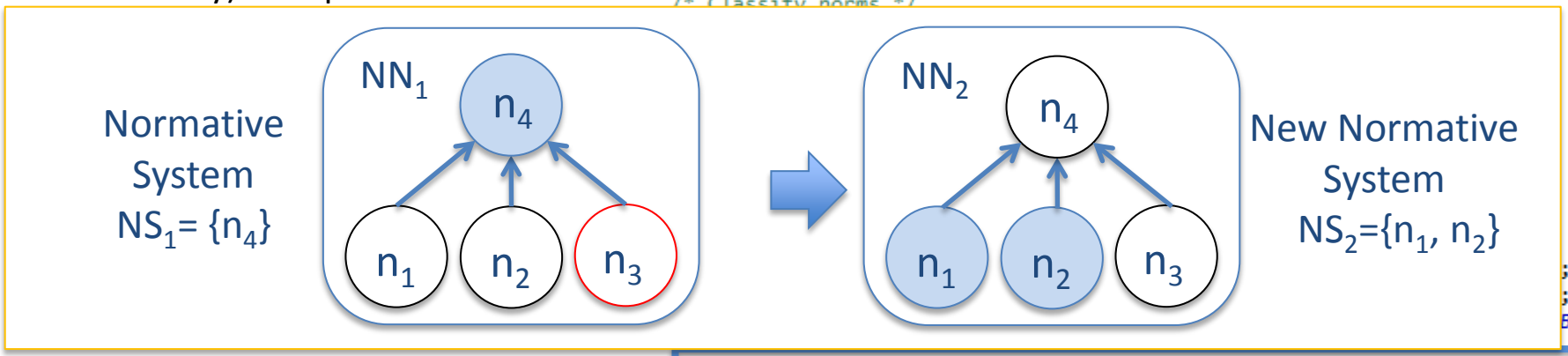
```
public void step(Map<ViewTransition, NormsApplicableInView> normApplicability,
    List<Norm> normsActivatedDuringGeneration) {

  List<Norm> processed = new ArrayList<Norm>();
  List<Norm> visited = new ArrayList<Norm>();

  /* Compute norms that must be revised */
  List<Norm> normsToRevise = this.checkNormsToRevise(normApplicability);

  /* Classify norms */
                                                                        ;
                                                                        ;
                                                                    BLE);

  /* If the norm is whether ineffective or unnecessary, then deactivate
   * it (specialise it into its children) */
  if(isIneffective || isUnnecessary) {
    visited.clear();
    specialiseDown(norm, NetworkNodeState.DISCARDED, visited);
  }

  /* If the norm has enough utility to be generalised,
   * then try to generalise it */
  else if(isGeneralisable) {
    generaliseUp(norm, genMode, genStep);
  }

  /* Update complexities metrics */
  this.nsMetrics.incNumNodesVisited();
 }
}
```

14. SIMON: generation + evaluation + refinement

Norm refinement:

1. Norms are **generalised**
2. Norms are **specialised** if their (effectiveness **or** necessity) **<** esp. **threshold**

Removes Under-performing norms



n_1: Give way to **ambulances**
n_2: Give way to **fire brigade**
n_3: Give way to **police cars**
n_4: Give way to **emergency** vehicles

```
public void step(Map<ViewTransition, NormsApplicableInView> normApplicability,
    List<Norm> normsActivatedDuringGeneration) {

  List<Norm> processed = new ArrayList<Norm>();
  List<Norm> visited = new ArrayList<Norm>();

  /* Compute norms that must be re
  List<Norm> normsToRevise = this.

  /* Classify norms */

                                                                        ;
                                                                        ;
                                                                    BLE);

  /* If the norm is whether ineffective or unnecessary, then deactivate
   * it (specialise it into its children) */
  if(isIneffective || isUnnecessary) {
    visited.clear();
    specialiseDown(norm, NetworkNodeState.DISCARDED, visited);
  }

  /* If the norm has enough utility to be generalised,
   * then try to generalise it */
  else if(isGeneralisable) {
    generaliseUp(norm, genMode, genStep);
  }

  /* Update complexities metrics */
  this.nsMetrics.incNumNodesVisited();
 }
}
```

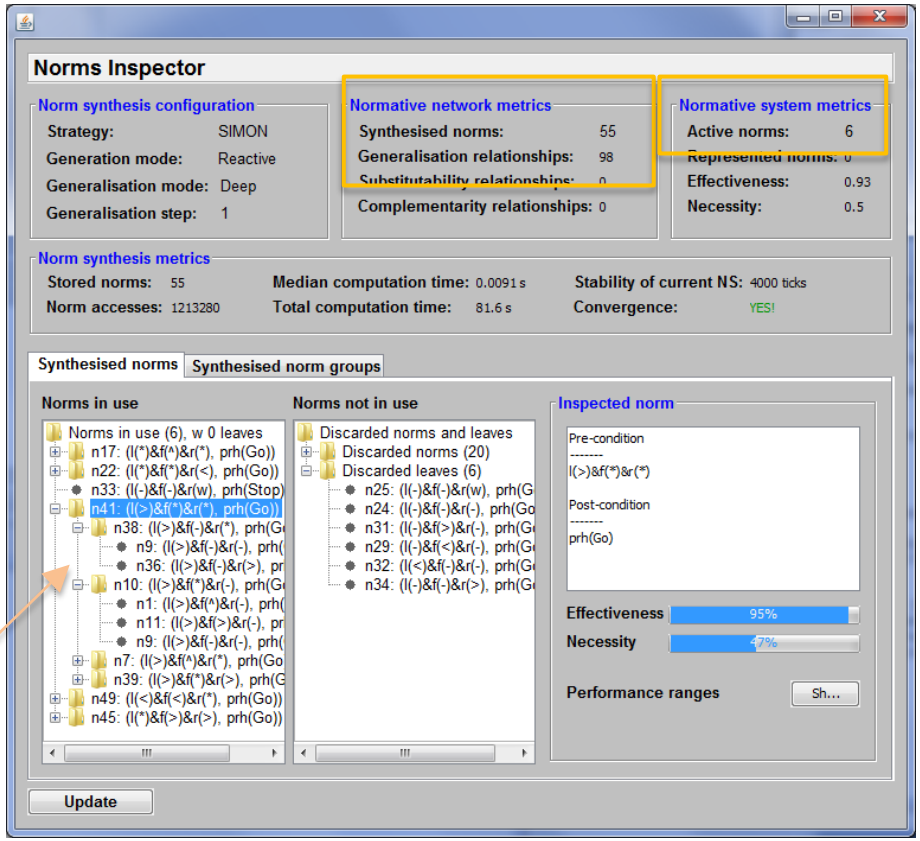
14. SIMON. A complete norm synthesis strategy

Execute SIMON strategy:

1. In **parameters.xml** (in NormLabSimulators project, repast-settings/TrafficJunction.rs) set:
   - **NormSynthesisExample** defaultValue=**«0»**
   - **NormSynthesisStrategy** defaultValue=**«2»** (2 stands for SIMON strategy)
   - **NormGeneralisationMode** defaultValue=**«1»** (***Deep*** norm generalisation)
   - **NormGeneralisationStep** defaultValue=**«1»** (generalises 1 predicate at a time)
   - Save the file.
2. Execute the simulator
   - NormLabSimulators project, launchers/: TrafficJunctionSimulator.launch > Run As …
3. Observe how it generates norms, evaluates, and refines them.
   - Compact Normative System.

Normative System: 6 norms
Normative Network: 55 norms
Generalisations: 98 relationships
- Ex: n41 generalises n38, n10, n7 and n39

Covergence at tick 9428



Norm Synthesis Competition

Challenge: Can you improve the synthesis strategy?

Participate!

July 2015: http://www.maia.ub.es/~maite/Teaching.html