Tutorial on Norm Synthesis in Normative Multi-Agent Systems

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• Tutor:
  Dr. Maite López-Sánchez
  University of Barcelona
• Teaching material based on
  – SOAS subject from the interuniversity master on Artificial Intelligence (UPC-UB-URV)
  – Related Research papers
  – Co-authored research work:
    • Ph.D. student Eva Bou (co-sup.: J.A. Rodríguez- Aguilar, IIIA)
    • PhD. thesis by Jordi Campos (co-sup: Dr. Marc Esteva, IIIA).
    • Ph.D. thesis on on-line norm synthesis by Javier Morales. Co-supervisor: Dr. Juan A. Rodríguez-Aguilar (IIIA-CSIC)
    • Research collaborations: Dr. Jaime S. Sichman (Univ. Sao Paulo), Dr. Wamberto Vasconcelos (Univ. of Aberdeen), 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/
Tutorial Outline

Contents: Modules

1. Introduction to Norms and Normative MAS.
2. Overview of approaches to norm synthesis.
3. On-line automatic norm synthesis.
4. Demo and hands-on activity
Schedule

The tutorial will last for 3h:30 min or 4h

- 9:15 h: NMAS introduction
- 9:45 h: Norm synthesis overview (45’ aprox.)
- 10:30 h: Break (15’)
- 10:45 h: On-line automatic norm synthesis
- 11:45 h: Break (15’)
- 12:00 h: Demo and hands-on activity (45’ if interest in playing with the code)
- 12:45 h: Wrap-Up & comments
Objectives for the tutorial

• To introduce NMAS
  – MAS Design considerations.
  – Norms, laws, social conventions and rules as agent coordination mechanisms

• Be familiar with a framework to test on-line NMAS
  – On-line automatic norm synthesis
  – Put it in practice
Tutorial Outline

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1. Introduction to Norms and Normative MAS.
2. Overview of approaches to norm synthesis.
3. On-line automatic norm synthesis.
4. Demo and hands-on activity
• 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 definition from Merriam-Webster dictionary:
  – a principle of right action binding upon the members of a group and serving to guide, control, or regulate proper and acceptable behavior
  – a pattern or trait taken to be typical in the behavior of a social group
  – …
Norms

Norm definition from Britannica.com: Norm, also called Social Norm, rule or standard of behaviour shared by members of a social group. Norms may be internalized —i.e., incorporated within the individual so that there is conformity without external rewards or punishments, or they may be enforced by positive or negative sanctions from without.

The social unit sharing particular norms may be small (e.g., a clique of friends) or may include all adult members of a society.

Norms are more specific than values or ideals: honesty is a general value, but the rules defining what is honest behaviour in a particular situation are norms.
Coordination by norms and social laws, “Introduction to MAS” book by Wooldridge:

- A norm is an established, expected pattern of behaviour.
  - Human example: to form a queue when waiting for a bus
  - Norms may not be enforced
  - Social laws usually carry with them some authority

Alternative definition:
- Norms = constraints + punishment
• Conventions are key in the social process:
  – Provide agents with a template upon which to structure their action repertoire -> simplify agent's decision-making process
  – **Balance** between:
    • Individual freedom and
    • The goal of the agent society
• How do norms come to exist within a society?
  – Offline design
  – Emergence
  – On-line generation
Norm categories I

- R. Tuomela:
    - Rule norms: imposed by authority based on an agreement between the members (e.g. one has to pay taxes).
    - Social norms: apply to large groups (e.g. one should not litter)
    - Moral norms: appeal to one’s conscience (e.g. one should not steal).
    - Prudential norms: based on rationality (e.g. one ought to maximize one’s expected utility)
Norm Categories:

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)...

Boella and van der Torre

- Regulative norms: obligations, prohibitions and permissions
- Constitutive norms: create institutional facts like property or marriage as well as the modification of normative system itself
• Norms and BDI agents
  – Normative decision theory: BOID
  – “Norm-based behaviour modification in BDI agents” Meneguzzi and Luck AAMAS’09
  – Dignum et al.
  – Introducing obligations in agents
• We take a system perspective: NMAS
• Normative MAS @Dagstuhl 2007
Normative MAS @Dagstuhl 2007

A normative multiagent system is a multiagent system together with normative systems in which:

- Agents can decide whether to follow the explicitly represented norms, and
- the normative systems specify how and in which extent the agents can modify the norms.
• Normative MAS @Dagstuhl 2007
  – AAMS journal 2008 by Boella, van der Torre and Verhagen:

  A normative MAS contains mechanisms to:
  • Represent, communicate, distribute, detect, create, modify, and enforce norms.
  • Deliberate about norms and detect norm violation and fulfillment.
• Dagstuhl 2012
• Some related questions:
  – Who dictates norms?
  – Who spreads them?
  – What norm does apply to an agent?
  – How the agent decides whether to fulfill or violate it?
  – Who/how detects if the agent complies with it?
  – What are the consequences?
  – Should this norm change?
Some related questions:

- Who dictates norms?
- Who spreads them?
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Further questions:

- Are norms hierarchical?
- Are norms local?
- Are norms imprecise?
- Do agents internalise (adopt) norms?
- If other agents do not comply with a norm, should an agent bother about it?
- Do we need additional incentives? (rewards, environment)
Further Questions III

- Further questions:
  - Should we consider norm exceptions?
  - How norms relate to organisations? (modularity, abstractions)
  - How do we design norms? (to coordinate, organize, guide, regulate, or control interaction)
  - Norm representation (logics, operational,..)
  - Can we have conflicts between norms?
• Normative MAS @Dagstuhl 2015
  – Normative systems are systems in the behavior of which norms play a role and which need normative concepts in order to be described or specified.
    • deal with obligations, permissions and prohibitions
  – A normative MAS combines models for normative systems with models for MAS. […]
    • They use sociological theories from sociology, economics, legal science, etc.
• Deontic Logic (DL):
  – Despite the philosophical position that norms are neither true nor false
  – Obligations treated as goals in AI
  – NORMAS: action and time DL

• Two distinct philosophical traditions:
  – Von Wright: norms and normative propositions
  – Alchourron: prescriptive and descriptive obligations
Norms and game theory

Further issues

- Norms as a mechanism in a game-theoretic setting:
  - D. Lewis “master and slave” game
  - E. Bulygin “rex, minister and subject” game
  - G. Boella c.s.: violation games, institutionalized games, negotiation games, norm creation games, control games
- DTGT vs DL (van der Torre):
  - DTGT: each agent has its own utility
  - DL: there is a single global utility
Applications:

- Contracts (e-commerce)
- International trade
- Social norms in 3D VW (e.g. Second Life)
- Human Computer Interaction
- “What if” scenarios for policy makers
- Organizations
- What else?
Calvinball is a game invented by Calvin in which one makes the rules up as one goes along. Rules cannot be used twice. No Calvinball game is like another. The game may involve wickets, mallets, volleyballs, and additional equipment as well as masks.

There is only one permanent rule in Calvinball: One can't play it in the same way twice. For example, in one game of Calvinball, the goal was to capture one's opponent's flag, whereas in a different game of Calvinball, the goal was to score points by hitting badminton shuttlecocks against trees using a croquet mallet. An apparent rule in Calvinball is that one must wear a black mask and...
Other practical issues

- Implementation issues:
  - Are norms explicitly represented in the system?
    - If so: In which language? Are they “hardcoded”?
    - How do agents reason about them?
  - Define how norms support agent coordination
  - Decide whether norms:
    - are created by a legislation authority,
    - emerge spontaneously or
    - are negotiated among agents,
1. Introduction to Norms and Normative MAS.

2. Overview of approaches to norm synthesis.
   - Off-line norm synthesis.
   - ...

3. On-line automatic norm synthesis.

4. Demo and hands-on activity
Social norms in practice: traffic laws (Shoham and Tennenholtz, 1996).

- Two-dimensional grid world populated by mobile robots.
- More than one robot at a cell is a collision.
- Robots collect and transport items from cell to cell.
- Goal: design a law that prevents collisions.

Which norms would you define?
• Social norms in practice: traffic laws (Shoham and Tennenholtz, 1996).
  – First option: law which completely constrains the movements of robots, so that they must all follow a single, completely predetermined path, leaving no possibility of collision:
Norm design

Social norms in practice: traffic laws (Shoham and Tennenholtz, 1996).

First option: law which completely constrains the movements of robots, so that they must all follow a single, completely predetermined path, leaving no possibility of collision:

- 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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This rule:
- 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: changing directions help.
Offline norm design

- Off-line norm design:
  - 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)
Environment: $Env = \langle E, e_0, \tau \rangle$

- $E$ a finite set of discrete, instantaneous states:
  $$E = \{ e, e', \ldots \}.$$

- Agent **actions** transform the environment:
  $$Ac = \{ \alpha, \alpha', \ldots \}$$

- A *run*, $r$, is a sequence of interleaved environment states and actions:
  $$r^E: e_0 \xrightarrow{\alpha_0} e_1 \xrightarrow{\alpha_1} \cdots \xrightarrow{\alpha_{u-1}} e_u$$
  $$r^Ac: e_0 \xrightarrow{\alpha_0} e_1 \xrightarrow{\alpha_1} \cdots \xrightarrow{\alpha_{u-1}}$$

- A **state transformer** function represents behavior of the environment
  $$\tau: \mathcal{R}^{Ac} \rightarrow \varphi(E)$$
Agent: \( Ag : \mathcal{R}^E \rightarrow Ac \)

- Function which maps runs to actions
  - An agent makes a decision about what action to perform.
  - Perceive function: maps environment states to percepts
    \( E \rightarrow Per \)
- Reactive agent: maps percepts to actions \( Per^* \rightarrow Ac \)
- Deliberative agent:
  - **Action function**: maps internal states to actions \( I \rightarrow Ac \)
  - **Next function**: maps an internal state and a percept to an internal state
    \( I \times Per \rightarrow I \)

A **system** is an agent-environment pair

- \( R(Ag, Env) : \) set of runs of agent \( Ag \) in environment \( Env \)
• Offline norm design:
  – Define agents as functions from runs (end in environmental states) to actions:
    • Ag: $R^E \rightarrow Ac$
    • A **constraint** is then a pair <$E'$, $\alpha$> where
      – $E' \subseteq E$ is a set of environment states
      – $\alpha \in Ac$ is an action
      Reading: “if the environment is in some state $e \in E'$, then the action $\alpha$ is forbidden”.
  – A **social law** is a set of such constraints
  – An **agent is legal** to respect a social law if it never attempts to perform a forbidden action in this law.
Offline norm design:

When social laws are useful?

- Focal states: always legal: agents should be always be able to ‘visit’ them:

- If the environment is at $e \in F$, it should be possible for the agent to act so as to be able to guarantee that any other state $e' \in F$ is brought about.

- A useful social law is one that does not constrain the actions of agents so as to make this impossible.
1. Introduction to Norms and Normative MAS.

2. Overview of approaches to norm synthesis.
   - Off-line norm synthesis.
   - Norm emergence
   - Norm agreement
   - Norm adaptation
   - On-line norm synthesis
Norm mechanisms

Two approaches for building a normative behaviour in an agent.

- Top-down: institutional mechanism specifies norms.
- Bottom-up: mechanisms that can help a norm to emerge: “Don’t do to them what you don’t want them to do to you”
Norm emergence

• Norm Emergence:
  - Agents have to reach a *global agreement* on the use of social conventions by using only *locally available information*:
    • Global: all agents use it
    • Local: each agent decides to adopt one based solely on its own experiences
Norm Emergence:

- Scenario: the tee shirt game:
  - All agents have a blue and a red tee shirt
  - They should end up wearing the same colour
  - Play: initially, random colour selection
    - Rounds: each round:
      » form pairs of agents: they see the colour of the other agent in the pair
      » At the end: they are allowed to change colour (no messages)
  - Agents need a decision making process based on their memory about previously encountered agents

Let’s play it!
Norm emergence

Tee Shirt Game II

Some decision making alternatives:

– Simple majority: adopt the most seen colour
– Simple majority with agent types:
  • Agents are of two types
  • Agents of the same type exchange memories and adopt them as if they were their own (type confidence).
– Simple majority with communication on success:
  • Communicate useful memories (to pair agents) only if a certain success is reached (prevents noise communication)
– Highest cumulative reward:
  • Use the strategy with highest cumulative payoff (required)

If still in the mood: play the first one…
• Moreover:
  – Agents can periodically forget everything (memory restart)
    • Agents are open to new ideas
  – Efficiency measure: time to convergence
  – Colour adoption can be seen as a strategy or convention to adopt.

• Issues:
  • Strategy changing cost
  • Stability: keep agreements in the society
• Results:
  – All alternatives led to emergent conventions
  – Best results: Highest cumulative reward:
    • Bounded time to convergence
    • It is stable: once reached, agents do not diverge from the norm.
    • Efficient: agents’ payoff is not worse than the one they would have received had they stuck with the strategy they initially chose.
• Exercise: implement a simulation of the tee shirt game with agents
  – Choose one strategy for agents that considers previously encountered agents
  – Check convergence
  – Run it a number of times
  – Optional: combine different strategies
• Title: A categorization of simulation works on norms
• Authors: Bastin Tony Roy Savarimuthu and Stephen Cranefield (Univ of Otago, New Zeland)
• Year: 2009
• Abstract:
  – Norms are expectations of behaviours of the agents in a society.
  – Being autonomous:
    • agents might not always follow the norms.
    • they themselves can evolve new norms while adapting to changing needs.
  – Paper:
    • Propose a life-cycle model for norms (based on simulation)
    • discuss different mechanisms used by researchers to study norm creation, spreading, enforcement and emergence
• What are norms?
  – Expectations of an agent about the behaviour of other agents in the society
    • help in sustaining social order and increase the predictability of behaviour in the society.
  – Fulfilling a generalized expectation of behaviour
  – = to conventions
  – Members adhere to norms:
    • for shame,
    • fear to authority,
    • rational appeal to norms,
    • willingness to follow the crowd…
  – Violations may be punished
 Norm aspects:
- Normative expectation of a behavioural regularity +
- Norm spreading factor:
  - Notion of advice from powerful leaders
  - Sanctioning mechanism:
    - Monetary (or utilitarian)
    - Physical
    - Emotional (reputation, isolation,..)
- Imitation
- Learning
Research paper 1

A categorization of simulation works on norms

- Phases for norm life-cycle

![Diagram showing phases of norm construction and mechanisms used by norm simulation models]
Phases of norm-life cycle:

1. Norm creation -> proposed norm
2. Spreading -> internalized norms (agents subscribe to norms)
3. Enforcement -> punishment (norm violator)
4. A norm has emerged if:
   - It has spread (i.e. it is followed by a considerable proportion of an agent society and this fact is recognized by most agents)
   - Without being explicitly created.
1. Norm creation:
   - The mechanism by which an agent in the society comes to know what the norm of the society is.
   - Approaches:
     • Top-down:
       - Off-line designer:
         » + control
         » - predictability
       - Powerful leader
         » Norm leader provides norms to follower agents
     • Enterpreneurial:
       - An agent comes up with a norm and recommends it to other agents
     • Cognitive:
       - Agents recognize what the norms of a society are
       - based on the observations of interactions (inference).
2.- Norm spreading

- Mechanisms:
  - leadership,
  - Imitation: “When in Rome do as the Romans”
  - machine learning,
  - cultural and evolutionary
• 3.- Norm enforcement
  – Process by which norm violators are discouraged through some form of sanctioning:
    • Punishment (fitness, emotion)
    • Reputation
  – Can be considered as part of 2.-spreading (Axelrod)
4. Norm emergence:
   - Reaching some significant threshold in the extent of the spread of a norm.
     - Ex.: a society is said to have a norm of gift exchange at Christmas if more than x% of the population follows such a practice.
     - The value of x has varied from 35 to 100 across different simulation based studies of norms.
   - Approaches:
     - An agent comes to know about a norm through mechanisms such as leadership or imitation and when it accepts the norm it contributes to norm spreading and emergence.
     - A cognitive agent generates a personal norm based on observation:
       - Many cognitive agents could generate similar personal norms and for an external observer it might seem that a norm has emerged in a society.
       - Cognitive agents could communicate norms and verify norms.
         » micro interactions between agents lead to the macro effect of establishing a norm
A categorization of simulation works on norms:

**Social power based mechanisms**
- **Punishment**
  - Axelrod, 1986
  - Lopez, 2003
- **Leadership**
  - Hoffman, 1986
  - Boman, 1997
  - Verhagen, 2001
  - Savarimuthu et al., 2007 a, b

**Learning based mechanisms**
- **Machine learning**
  - Shoham and Tennenholtz, 1992
  - Kittock, 1993
  - Walker and Wooldridge, 1995
  - Sen and Ariaou, 2007
  - Pujol, 2006
- **Imitation**
  - Epstein, 2001
  - Andrighetto et al., 2008
  - Campenni et al., 2008
- **Reputation mechanism**
  - Castelfranchi et al., 1998
  - Hales, 2002

**Off-line design mechanism**
- Shoham and Tennenholtz, 1995
- Conte and Castelfranchi, 1995

**Cognitive mechanism**
- Andriehetto et al., 2008
- Campenni et al., 2008

**Emotion based mechanism**
- Fix et al., 2006

**Network topology based works**
- Kittock, 1993
- Pujol, 2006
- Nakamaru and Levin, 2004
- Anghel et al., 2006
- Savarimuthu et al., 2007 b, c

**Cultural and evolutionary mechanisms**
- Boyd and Richerson, 1985
- Axelrod 1986
- Chalub et al., 2006

Missing: incentive mechanisms (R Centeno, H Billhardt)
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- Previous work: framework for executable specification of norm-governed MAS:
  - Specified at design-time

- Paper research: specifications may be modified at run-time by the members of the system
  - Action language to encode specifications
  - Scenario: argumentation protocol
• In some open MAS,
  – environmental,
  – social or other conditions
may favour, or even require, specifications to be modifiable during the system execution.
• Ex.:
  – A malfunction of a large number of sensors in a sensor network,
  – Manipulation of a voting procedure due to strategic voting,
  – When an organisation conducts its business in an inefficient manner.
• Assumptions:
  – Open MAS:
    • Agents developed by different parties
    • No direct access to agent’s internal state
    • Agents may fail to conform to the system specification in order to achieve their individual goals.
    • Examples:
      – Virtual Organisations, electronic marketplaces, argumentation (dispute resolution) protocols, negotiation protocols
  – Adoption of a bird’s eye view of the system
Normative System:

- Actuality and ideality do not necessarily coincide
  - Actuality: what is the case
  - Ideality: what ought to be the case

- Specification of what is permitted, prohibited and obligatory.

- Institutional power:
  - Designated agents, when acting in specified roles, are empowered by an institution to create specific relations or state of affairs
  - Ex.: an agent is empowered to award a contract (to create a bundle of normative relations between the contracting parts).
• Brewka’s dynamic argument systems:
  – Argument systems in which, at any point in the disputation, participants may start a meta level debate:
    • The rules of order become the current point of discussion with the intention of altering these rules
Protocol participants can alter the rules of a protocol $P$ during its execution:

- $P$: **object protocol**
- Participants start a **meta protocol** to alter $P$:
  - Add a new rule-set
  - Delete an existing one or
  - Replace an existing rule-set with a new one
- This can be done recursively
Ex. scenario:
- Both object and meta protocols are argumentation protocols
• Event Calculus:
  – action language to formalize system specifications for representing and reasoning about actions or events and their effects.

• Basic elements:
  – **Fluent** $F$:
    • property that can have different values along time
  – **Term** $F=V$ : fluent $F$ has value $V$ if:
    • $F=V$ has been *initiated by an action* before and
    • *Not terminated by another* action in the meantime.
• RTFD* (Rescher’s Theory of Formal Disputation)
  — Argumentation (dispute resolution) protocol
  — Formalisation in Event Calculus:
    • Roles:
      – Proponent: claims the topic of the argumentation
      – Opponent
      – Determiner
    • Proponent starts the protocol (claims the topic)
Protagonists (proponent & opponent) take turns to perform actions:

<table>
<thead>
<tr>
<th>Action</th>
<th>Textual Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>claim(Protag, Q)</td>
<td>Protag claims Q</td>
</tr>
<tr>
<td>concede(Protag, Q)</td>
<td>Protag concedes to Q</td>
</tr>
<tr>
<td>retract(Protag, Q)</td>
<td>Protag retracts Q</td>
</tr>
<tr>
<td>deny(Protag, Q)</td>
<td>Protag denies Q</td>
</tr>
<tr>
<td>declare(Det, Protag)</td>
<td>Det declares Protag the winner of the disputation</td>
</tr>
<tr>
<td>objected(Ag)</td>
<td>Ag objects to an action</td>
</tr>
</tbody>
</table>

Ag’s action Act is followed by a time period where:
- Ag may not perform any actions,
- The other participants may object to Act
• When the period of the argumentation elapses the Determiner declares a winner that is:
  – The proponent if both participants accept the topic.
  – The opponent if proponent does not accept the topic.
  – Any of them if the proponent accepts the topic and the opponent does not
- Each protocol level (PL) has its own protocol state:
  - Add a parameter into the representation:
    - Ex.: Claim(Protag, Q, PL)

- Rules of the argumentation protocol:
  - ‘core’: always part of the protocol specification
  - ‘replaceable’: by meta-protocol during protocol execution
    - Ex: replace the `accept' rule with the `sic' rule

- Rule sets:
  - ‘active’: part of the protocol at given PLs (ex.: 1, 2):
    holdsAt(active(R)=[0,2], t)
  - ‘inactive’.
• Transition protocol
  – To start a protocol of level n+1 to modify the protocol rules of level n.
• Example:
  – $PL=n$, a protagonist proposes a modification of the rules of this protocol level.
    • If the protagonist is empowered to propose such a change then the protocol of level n+1 begins;
    • Otherwise the proposal is ignored.
  – The topic of the n+1 protocol is the proposed rule modification
  – If the agent that successfully proposed the modification is declared the winner of the argument of level n+1 then the rules of level n will be modified.
- Replaceable rule: sic
A Dynamic Argum. Prot.

Animation of a 2-level argument system II

- **PL= 0:**
  - t=0
    - proponent = ag1
    - Topic Q: “Jack is a murderer”
  - t=14
    - New evidence Q' on Q by ag1: “victim’s blood on Jack’s shoe”
    - Opponent= ag2
    - Ag2 objects to Q'
    - Effects of Q':
      - \[ \text{premise(agent1 ; on(blood; shoe); 0 )=t} \]
      - \[ \text{premise(agent2 ; on(blood; shoe); 0 )=u} \]
      - Ag2’s objection does not block the effects because Q' is not objectionable
A Dynamic Argum. Prot.

Animation of a 2-level argument system III

- PL = 0:
  - t = 14
    - sic rule applies: both protagonists accept Q'
  - t = 15 (Ag2 turn to speak)
  - t = 18:
    - Ag2 claims Q'': “Q' was obtained illegally“
  - t = 30 (Ag1 turn to speak)
  - t = 31
    - Ag1 concedes Q'' (but does not change Q' acceptance due to sic)

<table>
<thead>
<tr>
<th>Time</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>claim(agent₁, murderer(jack), 0)</td>
</tr>
<tr>
<td></td>
<td>...</td>
</tr>
<tr>
<td>14</td>
<td>claim(agent₁, on(blood, shoe), 0)</td>
</tr>
<tr>
<td>14</td>
<td>objected(agent₂, 0)</td>
</tr>
<tr>
<td>15</td>
<td>oTimeout(0)</td>
</tr>
<tr>
<td>18</td>
<td>claim(agent₂, illegal_info(on(blood, shoe)), 0)</td>
</tr>
<tr>
<td>30</td>
<td>pTimeout(0)</td>
</tr>
<tr>
<td>31</td>
<td>concede(agent₁, illegal_info(on(blood, shoe)), 0)</td>
</tr>
<tr>
<td>45</td>
<td>oTimeout(0)</td>
</tr>
<tr>
<td>46</td>
<td>propose(agent₂, replace(sic, sic Ill_info), 0, 0)</td>
</tr>
<tr>
<td>49</td>
<td>claim(agent₂, replace(sic, sic Ill_info), 1)</td>
</tr>
<tr>
<td></td>
<td>...</td>
</tr>
<tr>
<td>77</td>
<td>dTimeout(1)</td>
</tr>
<tr>
<td>78</td>
<td>declare(det, agent₂, 1)</td>
</tr>
<tr>
<td>93</td>
<td>endTimeOut(1)</td>
</tr>
<tr>
<td></td>
<td>...</td>
</tr>
<tr>
<td>135</td>
<td>endTimeOut(0)</td>
</tr>
</tbody>
</table>
• **PL= 0:**
  - t=45 (Ag2 turn to speak)
  - t=46
    - Ag2 proposes a rule change sic -> sic_ill_info that is successful:

• **PL=1**
  - t=49:
    - proponent = ag2
    - Topic Q1: “change sic for sic_ill_info” to deal with illegal information
  - t=77 Determiner turn
  - t=78
    - Det declares ag2 the winner.

<table>
<thead>
<tr>
<th>Time</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>claim(agent₁, murderer(jack), 0)</td>
</tr>
<tr>
<td></td>
<td>...</td>
</tr>
<tr>
<td>14</td>
<td>claim(agent₁, on(blood, shoe), 0)</td>
</tr>
<tr>
<td>14</td>
<td>objected(agent₂, 0)</td>
</tr>
<tr>
<td>15</td>
<td>oTimeout(0)</td>
</tr>
<tr>
<td>18</td>
<td>claim(agent₂, illegal_info(on(blood, shoe)), 0)</td>
</tr>
<tr>
<td>30</td>
<td>pTimeout(0)</td>
</tr>
<tr>
<td>31</td>
<td>concede(agent₁, illegal_info(on(blood, shoe)), 0)</td>
</tr>
<tr>
<td>45</td>
<td>oTimeout(0)</td>
</tr>
<tr>
<td>46</td>
<td>propose(agent₂, replace(sic, sic_ill_info), 0, 0)</td>
</tr>
<tr>
<td>49</td>
<td>claim(agent₂, replace(sic, sic_ill_info), 1)</td>
</tr>
<tr>
<td></td>
<td>...</td>
</tr>
<tr>
<td>77</td>
<td>dTimeout(1)</td>
</tr>
<tr>
<td>78</td>
<td>declare(det, agent₂, 1)</td>
</tr>
<tr>
<td>93</td>
<td>endTimeout(1)</td>
</tr>
<tr>
<td></td>
<td>...</td>
</tr>
<tr>
<td>135</td>
<td>endTimeout(0)</td>
</tr>
</tbody>
</table>
• **PL=1**
  - t=78
    • Det declares ag2 the winner:
• **PL=0 the rule is changed**
  - sic becomes inactive at PL=0
• **PL=1**
  - t=93: PL 1 Ends
• **PL=0**
  - t=94: If retroactive effects:
    • accepts(Ag1,Q',0) != true
    • accepts(Ag2,Q',0) != true

### Animation of a 2-level argument system V

<table>
<thead>
<tr>
<th>Time</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>claim(agent₁, murderer(jack), 0)</td>
</tr>
<tr>
<td></td>
<td>...</td>
</tr>
<tr>
<td>14</td>
<td>claim(agent₁, on(blood, shoe), 0)</td>
</tr>
<tr>
<td>14</td>
<td>objected(agent₂, 0)</td>
</tr>
<tr>
<td>15</td>
<td>oTimeout(0)</td>
</tr>
<tr>
<td>18</td>
<td>claim(agent₂, illegal_info(on(blood, shoe)), 0)</td>
</tr>
<tr>
<td>30</td>
<td>pTimeout(0)</td>
</tr>
<tr>
<td>31</td>
<td>concede(agent₁, illegal_info(on(blood, shoe)), 0)</td>
</tr>
<tr>
<td>45</td>
<td>oTimeout(0)</td>
</tr>
<tr>
<td>46</td>
<td>propose(agent₂, replace(sic, sic_ill_info), 0, 0)</td>
</tr>
<tr>
<td>49</td>
<td>claim(agent₂, replace(sic, sic_ill_info), 1)</td>
</tr>
<tr>
<td></td>
<td>...</td>
</tr>
<tr>
<td>77</td>
<td>dTimeout(1)</td>
</tr>
<tr>
<td>78</td>
<td>declare(det, agent₂, 1)</td>
</tr>
<tr>
<td>93</td>
<td>endTimeOut(1)</td>
</tr>
<tr>
<td></td>
<td>...</td>
</tr>
<tr>
<td>135</td>
<td>endTimeOut(0)</td>
</tr>
</tbody>
</table>
Tutorial Outline

Contents: Modules

1. Introduction to Norms and Normative MAS.
2. Overview of approaches to norm synthesis.
   - Off-line norm synthesis.
   - Norm emergence
   - Norm agreement
   - Norm adaptation
   - On-line norm synthesis
Adaptation of
Autonomic Electronic Institutions
through norms and institutional agents

Eva Bou, Maite López-Sánchez, J. A. Rodríguez-Aguilar
Institut d’Investigació en Intel·ligència Artificial (IIIA-CSIC)
Universitat de Barcelona (UB)
• Electronic Institution: regulated virtual environment where agents interact

• Autonomic Electronic Institution:

\[<PS, N, DF, G, P_i, P_e, P_a, V, \delta, \gamma>\]

• \(N\): set of Norms, norm \(N_i\) has parameters \(p^{N_{i1}}, \ldots, p^{N_{im_i}}\)

• \(G = \{c_1, \ldots, c_p\}\) set of institutional Goals defined as constraints: \(c_i\) is an expression \(g_i(V) \preccurlyeq [m_i, M_i]\)

• \(\delta : N \times G \times V \rightarrow N\) normative transition function, to adapt to changing circumstances
• Adapt $\delta, \gamma$ to $A$

```
A
```

```
I_1
I_j
I_k
```

```
Configurations
```

```
Fitness(A,I_1,G)
Fitness(A,I_j,G)
Fitness(A,I_k,G)
```

```
Configuration evaluation
```

```
New configurations
```

```
Crossover and mutation
```

```
I_{i_1} ...
I_{i_k}
```
• Adapt $\delta$, $\gamma$ to $A$

Agent population

Configuration evaluation

Fitness($A, I_i, G$)

Configuration adaptation

Crossover and mutation

New configurations

$I_1$

$\ldots$

$\ldots$

$I_k$

$I_j = \{<p_{N11}, \ldots, p_{N1m1}>, \ldots, <p_{N11}, \ldots, p_{N1mn}>, <p_{R11}, \ldots, p_{R1q1}>, \ldots, <p_{R11}, \ldots, p_{R1q}>, \ldots\}$

Learn $\delta$

Learn $\gamma$
Case Study: Traffic Regulation Authority as an AEI.

- Simulation: Simma MAS tool
- We focus on a two-road junction (traffic scene)
  - Cars: external agents
  - Agents’ institutional state:
    \[ P_a = \langle a_1, \ldots, a_n \rangle, \]
    where \( a_j \) represents \( A_j \)
    \[ a_j = \langle x_j, y_j, h_{jx}, h_{jy}, \text{speed}_j, \text{indicator}_j, \text{offenses}_j, \text{accidents}_j, \text{distance}_j, \text{points}_j \rangle \]
• **Norms:**
  – Have associated penalties (point reductions).
  – Related to actions performed by cars:
    • Right priority norm
    • Front priority norm

<table>
<thead>
<tr>
<th>Action</th>
<th>$\text{in}(a_i, J_{BE}, t - 1) \land \text{in}(a_i, (x_i^{t-1} + h_i^{x}, y_i^{t-1} + h_i^{y}), t) \land \neg \text{indicator}(a_i, \text{right}, t - 1)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-conditions</td>
<td>$\text{right}(a_i, a_j, t - 1)$</td>
</tr>
<tr>
<td>Consequence</td>
<td>$\text{points}^t_i = \text{points}^{t-1}<em>i - \text{fine}</em>{\text{right}}$</td>
</tr>
</tbody>
</table>
• **Car agents** decide whether to comply with a norm based on four parameters:

\[
<\text{fulfill}_\text{prob}, \text{high}_\text{punishment}, \text{inc}_\text{prob}, \text{police}>
\]

\[
\text{final}_\text{prob} = \begin{cases} 
\text{police} \cdot \text{fulfill}_\text{prob} & \text{fine} \leq \text{high}_\text{punishment} \\
\text{police} \cdot (\text{fulfill}_\text{prob} + \text{inc}_\text{prob}) & \text{fine} > \text{high}_\text{punishment}
\end{cases}
\]

• **Institutional agents** in the traffic scene represent Traffic Authority employees (police agents).
• Goals:
  
  – constraints upon a combination of reference values:

  \[ G = \langle g(\text{col}) \in [0, \text{maxCol}], \ g(\text{off}) \in [0, \text{maxOff}], \ g(\text{crash}) \in [0, \text{maxCrash}], \ g(\text{block}) \in [0, \text{maxBlock}], \ g(\text{expel}) \in [0, \text{maxExpel}], \ g(\text{police}) \in [0, \text{maxPolice}] \rangle \]

  – \( g_i \) function over the reference values

  – degree of satisfaction of a goal \( f(x, [m, M], \mu) \)

\[
f(x, [m, M], \mu) = \begin{cases} 
\frac{\mu}{e^{k \frac{x-m}{M-m}}} & x < m \\
1 - (1 - \mu) \frac{x-m}{M-m} & x \in [m, M] \\
\frac{\mu}{e^{k \frac{x-M}{M-m}}} & x > M
\end{cases}
\]

\( m=20, M=40, \mu=0.5, k=0.75 \)
• **Fitness function** to combine multiple goals:

\[
O(V) = \sum_{i=1}^{\left| G \right|} w_i \sqrt{f(g_i(V), [m_i, M_i], \mu_i)}
\]

- \(w_i\) weighting factors

\[
O(V) = \frac{4}{10} \cdot \sqrt{f(g(\text{col}), [0, \text{maxCol}], \frac{1}{2})} + \frac{4}{10} \cdot \sqrt{f(g(\text{off}), [0, \text{maxOff}], \frac{1}{2})} + \\
\frac{1}{10} \cdot \sqrt{f(g(\text{expel}), [0, \text{maxExpel}], \frac{3}{4})} + \frac{1}{10} \cdot \sqrt{f(g(\text{police}), [0, \text{maxPolice}], 0)}
\]
## Results

### Learning

<table>
<thead>
<tr>
<th>Parameters</th>
<th>population1</th>
<th>population2</th>
<th>population3</th>
<th>population4</th>
<th>population5</th>
</tr>
</thead>
<tbody>
<tr>
<td>fulfills_prob</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>high_punishment</td>
<td>5</td>
<td>8</td>
<td>10</td>
<td>12</td>
<td>14</td>
</tr>
<tr>
<td>inc_prob</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
</tr>
</tbody>
</table>

**Diagram**

- **Parameters**
  - $I_1 = \{fine_{right}, fine_{front}, police\}$
  - $I_k$

- **Configuration evaluation**
  - AEI Simulation
  - Fitness($A, I_1, G$)

- **Configuration adaptation**
  - Crossover and mutation
  - New configurations
  - $I_1 \rightarrow I_k$
### Results II

<table>
<thead>
<tr>
<th>Parameters</th>
<th>population1</th>
<th>population2</th>
<th>population3</th>
<th>population4</th>
<th>population5</th>
</tr>
</thead>
<tbody>
<tr>
<td>fulfill_prob</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>high_punishment</td>
<td>5</td>
<td>8</td>
<td>10</td>
<td>12</td>
<td>14</td>
</tr>
<tr>
<td>inc_prob</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Population</th>
<th>Learned fine_{right}</th>
<th>Learned fine_{front}</th>
<th>Learned police</th>
<th>Goal satisfaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>population1</td>
<td>15, 12, 7</td>
<td>8, 14, 13</td>
<td>0.93, 0.93, 0.93</td>
<td>0.699, 0.7, 0.691</td>
</tr>
<tr>
<td>population2</td>
<td>13, 13, 14</td>
<td>10, 11, 9</td>
<td>0.93, 0.93, 0.93</td>
<td>0.689, 0.694, 0.691</td>
</tr>
<tr>
<td>population3</td>
<td>15, 12, 15</td>
<td>14, 11, 15</td>
<td>0.93, 0.87, 0.93</td>
<td>0.685, 0.681, 0.685</td>
</tr>
<tr>
<td>population4</td>
<td>15, 13, 15</td>
<td>14, 13, 13</td>
<td>0.93, 0.93, 0.87</td>
<td>0.676, 0.686, 0.68</td>
</tr>
<tr>
<td>population5</td>
<td>15, 15, 15</td>
<td>15, 15, 8</td>
<td>0.93, 0.93, 0.93</td>
<td>0.668, 0.674, 0.677</td>
</tr>
</tbody>
</table>

\[
final\_prob = \begin{cases} 
police \cdot fulfill\_prob & \text{fine} \leq high\_punishment \\
police \cdot (fulfill\_prob + inc\_prob) & \text{fine} > high\_punishment 
\end{cases}
\]
AEI learns traffic norms that fulfill its goals for different agent populations.
Future Work

• Extend institutional adaptation capabilities to dynamically adapt to any change in the population.
  – CBR approach

• Develop a more complex traffic network:
  – decentralized approach where different areas (i.e., junctions) are regulated by different institutions.
Self-adaptation in Autonomic Electronic Institutions through Case-Based Reasoning

Eva Bou, Maite López-Sánchez, J. A. Rodríguez-Aguilar
Institut d’Investigació en Intel·ligència Artificial (IIIA-CSIC)
Universitat de Barcelona (UB)

Adapting Autonomic Electronic Institutions to Heterogeneous Agent Societies

Eva Bou, Maite López-Sánchez, J. A. Rodríguez-Aguilar, Jaime S. Sichman
IIIA-CSIC, UB, Univ. de Sao Paulo
Learning Model

General Process

- Adapt $\delta, \gamma$ to $A$

1st step: Genetic Algorithms (GA)

Lean best parameters for prototypical agent populations

2nd step: Case-Based Reasoning (CBR)

Adapt to any agent population

- CBR: Solves new problems reusing past experiences:
  - uses solutions from similar problems previously learnt (cases).

- Problem: given the current agent population, provide the best parameters so to accomplish institutional goals.
• Case similarity function: (distance)
  
  — Aggregated function:
  
  \[ S(C^i, C^j) = w_1 \cdot s_{AEI}(C^i, C^j) + w_2 \cdot s_{V}(C^i, C^j) + w_3 \cdot s_{pop}(C^i, C^j) \]
  
  — attribute distance:
  
  \[ \text{sim}(\text{attr}^i, \text{attr}^j) = \frac{|\text{attr}^i - \text{attr}^j|}{\max(\text{attr}) - \min(\text{attr})} \]
Traffic AEI

Learning: Genetic Algorithm

**Agent population**

\[ I_j = \{ < p_{11}^N, \ldots, p_{1m}^N >, \ldots, < p_{11}^R, \ldots, p_{1q}^R >, \ldots, < p_{11}^R, \ldots, p_{1q}^R > \} \]

- \( \text{learn } \gamma \)
- \( \text{learn } \delta \)

**Configuration evaluation**

- \( \text{AEI simulation} \)
- \( \text{Fitness}(A, I_j, G) \)

**New configurations**

- \( \Gamma_1 \)
- \( \ldots \)
- \( \Gamma_k \)

**Configuration adaptation**

- \( \text{Cross simulation} \)
• Case definition

  – $N^p$: norm parameters ($fine_{right}, fine_{front}$)
  – $PS^p$: performative structure parameter ($police$)
  – $V$: reference values ($col, crash, off, block, expel$)
  – $pop$: statistic data about agent population’s behaviour ($mean_{off}, median_{off}, ...$)
  – $N^p*$: norm parameters’ best values ($fine^*_{right}, fine^*_{front}$)
  – $PS^p*$: performative structure parameter’s best value ($police^*$)
• Case generation:
  – 7 prototypical populations
  – AEI’s 108 (=6x6x3) different parameters:
    • $fine_{right}, fine_{front} \in \{0, 3, 6, 9, 12, 15\}$
    • $police \in \{0.8, 0.9, 1\}$

### Empirical Evaluation

Building the Knowledge Base

- 756 cases
- 2000 ticks each

<table>
<thead>
<tr>
<th>Populations</th>
<th>Pop. 1</th>
<th>Pop. 2</th>
<th>Pop. 3</th>
<th>Pop. 4</th>
<th>Pop. 5</th>
<th>Pop. 6</th>
<th>Pop. 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>fulfill_prob</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>high_punishment</td>
<td>0</td>
<td>3</td>
<td>5</td>
<td>8</td>
<td>10</td>
<td>12</td>
<td>14</td>
</tr>
<tr>
<td>inc_prob</td>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
</tr>
<tr>
<td>fine*_{right}</td>
<td>2</td>
<td>5</td>
<td>8</td>
<td>11</td>
<td>13</td>
<td>14</td>
<td>15</td>
</tr>
<tr>
<td>fine*_{front}</td>
<td>1</td>
<td>4</td>
<td>6</td>
<td>9</td>
<td>12</td>
<td>13</td>
<td>15</td>
</tr>
<tr>
<td>police*</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>
• Can the AEI adapt to any agent population?
  – Experimental setting:
    • Initially: \( \text{fine}_{\text{right}} = \text{fine}_{\text{front}} = 0 \) and \( \text{police} = 0.8 \)
    • Population A = Pop1 …..Pop15 , Population B = Pop7
    • Every step AEI checks if adaptation is required
      – If Goals are not satisfied (\( G < G^* - \varepsilon \)) \( \rightarrow \) Retrieve a case from the KB

(1 step = 2000 ticks)
Can the AEI satisfy its goals?

- \( G \geq G^* - \varepsilon \)
- 750 experiments:
  - 15 pop x 50 runs
Can the AEI satisfy its goals?

Most times YES

Number of experiments stabilized in first 10 steps (population A = Pop1 …Pop15):

<table>
<thead>
<tr>
<th>Steps</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>Not stabilized</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stabilized</td>
<td>0</td>
<td>518</td>
<td>153</td>
<td>36</td>
<td>19</td>
<td>9</td>
<td>5</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Percentage stabilized</td>
<td>0</td>
<td>69</td>
<td>20.4</td>
<td>4.8</td>
<td>2.5</td>
<td>1.2</td>
<td>0.7</td>
<td>0.3</td>
<td>0.1</td>
<td>0.1</td>
<td>0.8</td>
</tr>
</tbody>
</table>

Number of experiments stabilized in last 10 steps (change to population B = Pop7):

<table>
<thead>
<tr>
<th>Steps</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
<th>17</th>
<th>18</th>
<th>19</th>
<th>20</th>
<th>Not stabilized</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stabilized</td>
<td>157</td>
<td>332</td>
<td>102</td>
<td>70</td>
<td>46</td>
<td>15</td>
<td>15</td>
<td>8</td>
<td>4</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Percentage stabilized</td>
<td>20.9</td>
<td>44.2</td>
<td>13.6</td>
<td>9.3</td>
<td>6.1</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>0.5</td>
<td>0.1</td>
<td>0</td>
</tr>
</tbody>
</table>
Adaptive Organisation-Centred Multi-Agent Systems

Jordi Campos Miralles

Summary of Ph.D. Dissertation
Barcelona, July 2011

Supervisors:
Maite López-Sánchez (Universitat de Barcelona, UB)
Marc Esteva (Institut d'Intel·ligència Artificial, IIIA-CSIC)
- Abstract architecture with 2 levels:
  - Domain-Level (DL) = agents organised to perform domain's activity
and a **Meta-Level (ML)** = agents (assistants) organised to assist DL (eg. to adapt its org.)
Hence we call this abstract architecture: Two-Level Assisted MAS Architecture (2-LAMA)
2-LAMA: adaptation

- $\alpha^N$: $\text{Env}_{DL} \times \text{AgP}_{DL} \times \text{Norm}_{DL} \times \text{Goals}_{DL} \rightarrow \text{Norm}_{DL}$

Norm adaptation function
2-LAMA: distributed

- $\alpha^N$: $\text{EnvP}_{DL} \times \text{AgP}_{DL} \times \text{Norm}_{DL} \times \text{Goals}_{DL} \rightarrow \text{Norm}_{DL}$
- $\alpha^N = \beta_{\alpha^N}(\{\alpha_1^N .. \alpha_n^N\})$ agreement function
2-LAMA: information

Information: **Local**  **Remote** = summaries of other local info.

\[ \alpha_i^N :Env_{Pi} \times Ag_{Pi} \times (\text{Sum}_{Pj})^{n-1} \times \text{Norms} \times \text{Goals} \rightarrow \text{Norms} \]
adaptation frequency should keep the adapt. cost below the benefits it generates.

- This cost depends on: information retrieval, computation, adoption and transition.
P2P data sharing network:

- to share 1 piece of data among all computers (peers) following a simplified version of the standard BitTorrent protocol, consuming the minimum time (goal).
P2P as an OCMAS

- **OCMAS view:**
  - Comput. = Agents
  - Net = Environment
  - Protocols, Social struc., Restrictions = Org.
P2P as an AOCMAS

- **AOCMAS** view:
  - Comput. = **Agents**
  - Net = **Environment**
  - Protocols, Social struc., Restrictions = **Org.**

*Adaptation* to env./pop. changes may improve perf.
Network abstraction

Network: packet switching transport
- Msgs split into packets that share links in time
Network abstraction

- **Network: packet switching transport**
  - Msgs split into packets that share links in time
    - $\text{msg}_{\text{latency}} = f(\ \text{msg}.\text{length}, \#\text{links}, \text{links.usage} )$
2-LAMA on P2P scenario

Network (physical network)

ISP

aggregated

individual

cluster

inet

2lama (overlay network)

ml

na2

na3

na1

n12

n9

n10

n11

n1

n2

n3

n4

n5

n6

n7

n8

r1

r0

r3

p1

p2

p3

p4

p5

p6

p7

p8

p9

p10

p11

p12

a1

a2

a3

p0
2-LAMA on P2P scenario

DL norms:

\( \text{norm}_{FR} \): “a peer cannot send data to \( > \text{max}_{FR} \) simult.”

Example: \( \text{max}_{FR} = 2 \)
2-LAMA on P2P scenario

**DL norms:**

- \[ \text{norm}_{FR}: \text{“a peer cannot send data to} > \text{max}_{FR} \text{ simult.”} \]
- \[ \text{norm}_{BW}: \text{“a peer cannot use} > \text{max}_{BW} \text{ bandwidth.”} \]

Network (physical network)

- \( n_1 \)
- \( n_2 \)
- \( n_3 \)
- \( n_4 \)
- \( n_5 \)
- \( n_6 \)
- \( n_7 \)
- \( n_8 \)
- \( n_9 \)
- \( n_{10} \)
- \( n_{11} \)
- \( n_{12} \)

ISP (overlay network)

- \( a_1 \)
- \( a_2 \)
- \( a_3 \)

2lama (overlay network)

- \( dl \)
- \( ml \)

Example:

- \( \text{max}_{BW} = 75\% \)
Visual representation of Meta-Level and Domain-Level activity.
Adaptation Mechanisms

\[ \alpha^{Rel} = \text{optimiseLatencies} \]

\[ \alpha^N = \{ \text{heuristic}, \text{cbr} \} \]

\[ M/L \]

\[ \text{AssistF} \]

\[ \alpha^{Rel} = \text{optimiseLatencies} \]

\[ \alpha^N = \{ \text{heuristic}, \text{cbr} \} \]

\[ \text{DL} \]

\[ \text{socStr}_{DL} \]

\[ \text{socConv}_{DL} \]

\[ \text{norms}_{DL} \]

\[ \circ \quad \text{param}_x \quad \circ \]

\[ \circ \quad \text{param}_y \quad \circ \]

\[ \text{instances} \]

\[ \text{role}_l \]

\[ \text{role}_m \]

\[ \text{rel}_n \]
• $\alpha_i^{N} : \text{KnowP} \times \text{Goals} \times \text{Norms} \rightarrow \text{Norms}$

• **Idea:** to use machine learning to learn this relation.

• **Issues:**
  - unknown appropriate norms
  - credit assignment problem
  - large state space

a tailored version of Case-Based Reasoning (CBR)
Tailored CBR: a case

- **Case:**
  - **Problem:**
    - *sharing state*: Completeness, Waiting
    - *comm. capacity*: SrvBW, RcvBW, RcvEffBW
    - *current norms*: OldMaxFR, OldMaxBW
      - *absolute values in order to normalise*: SeedBW, LeechBW, NumPeers
  - **Solution:**
    - *new norms*: NewMaxFR, NewMaxBW
  - **Evaluation:**
    - *effectiveness of the solution*: Goodness
Tailored CBR

to provide a new situation

Scenario

New problem

Retrieve

to fetch similar cases

Cases

Cases

Cases

Cases

Cases

Retrieve cases

to extract a single solution

Reuse

Suggested solution via voting ($\beta^N_A$)

Revise

to update case-base

Confirmed solution

Retain

to update case-base

Retrieved cases

Outcome

to apply the new solution

Scenario

to provide a new situation

Scenario
Visual exploration of norm evolution.
● Name: **BitTorrent** standard protocol (BT)
● Type: *non-adaptive* coordination model
● Observations:
  ● we use it as a **base-line**
  ● it has a single **Tracker** (~ directory service)
  ● it has a **random** factor
- Name: **2-LAMA** with social relationships adaptation and **Norm adaptation** using a **CBR** approach (2L-S-N-CBR)

- Type: **adaptive** coord. model

Observations:
- **dynamic adaptation** method
- requires **training**
- the **order** of initial data positions during the training is **relevant**
### Results

<table>
<thead>
<tr>
<th></th>
<th>BT</th>
<th>2L-S</th>
<th>2L-S-N-Heu</th>
<th>2LAMA-CBR</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>time</strong></td>
<td>986.2</td>
<td>793.1</td>
<td>744.5</td>
<td>732.6</td>
</tr>
<tr>
<td><strong>net</strong></td>
<td>206,592.0</td>
<td>338,448.3</td>
<td>300,755.0</td>
<td>348,399.6</td>
</tr>
<tr>
<td><strong>netSat</strong></td>
<td>0.177</td>
<td>1.813</td>
<td>2.126</td>
<td>1.846</td>
</tr>
</tbody>
</table>

2LAMA-CBR is **the fastest**. Results statistically significant.

2LAMA-CBR is **uses the network most**.

2LAMA-CBR learns to use intensively the network **without** achieving too much saturation.
2LAMA-CBR learns to use intensively the network without achieving too much saturation.
**Results**

**CBR learns:** ▼maxFR does not always imply ▼netSat.

**Example:**
If a source is serving to some agents with smaller BW, ▼maxFR may saturate receivers' individual links.

```
maxFR=2
▼maxFR

maxFR=1
```

2LAMA-CBR learns to use intensively the network **without** achieving **too much saturation**.
Exploring Open MAS issues

- Preliminary results about:
  - Entering / Leaving agents
  - Norm violations

2-LAMA is robust in Open MAS contexts.

2LAMA-CBR is still the fastest has a moderate time increment
1. Introduction to Norms and Normative MAS.

2. Overview of approaches to norm synthesis.
   - Off-line norm synthesis.
   - ...

3. On-line automatic norm synthesis.

4. Demo and hands-on activity
Norm set-up

Related Work: Open Challenges

- Norm synthesis: (Shoham & Tennenholtz)
  - Formal, exhaustive, **NP-complete**
  - Disallow (& ensure) access to undesirable (& goal) states in the state space
Norm set-up

Related Work: Open Challenges

• **Norm synthesis:** (Shoham & Tennenholtz)
  
  – Formal, exhaustive, **NP-complete**
  
  – Disallow (& ensure) access to undesirable (& goal) states in the state space

• **Norm agreement:** (Artikis et al.)
  
  – Democratic, convergence
  
  – Agents *enriched* with agreement capabilities.
• Norm emergence: (Conte, Sen, Villatoro,...)
  – Ex: driving on the left/right
  – Convergence (initial conditions)
  – Agents choose a solution from a space of alternative solutions (known at design time)
    • Repeated two-player games
    • Topology of relationships
    • Observation for norm adoption / Internalisation
• **Automatic norm generation**
  – Regulatory agents propose norms to avoid conflicts in agent interactions
    • Requires conflict detection
    • Does not search the complete state space
  – Norm evaluation based on
    • Agent responses (violations and compliances)
    • Consequences (conflicts)
Norm Generation
A proposal
Norm Generation
A proposal
Norm Generation

A proposal

Social Norms

proposal
Norm Generation

A proposal

Social Norms

proposal

evaluation
Norm Generation

A proposal

Social Norms

Proposal

Evaluation

Consequences

Norm compliance

N  N

N  N

meaning
Norm Generation
A proposal

Social Norms

Top-down
Bottom-up

Goal: conflict avoidance
Dynamicity
Division of concerns

proposal
evaluation
• Non-intrusive, autonomy preserving, norm generation mechanism
  – Norm quality measured based on
    • System objectives
  – Norm compliance/violation evaluated in terms of
    • System Objectives
    • (No prescribed penalties)
  – General system objective:
    • Avoid conflicts
1. Introduction to Norms and Normative MAS.

2. Overview of approaches to norm synthesis.

3. **On-line automatic norm synthesis.**
   - AAMAS 2013.
   - AAMAS 2014

4. Demo and hands-on activity
Automated Synthesis of Normative Systems

Javier Morales, Maite López-Sánchez, Juan A. Rodríguez-Aguilar, Michael Wooldridge, Wamberto Vasconcelos
1. Introduction

Individuals within a society continuously interact → Conflicts raise naturally
1. Introduction

Individuals within a society continuously interact → **Conflicts** raise naturally

Human societies avoid undesirable situations (i.e., conflicts) by including regulations.
1. Introduction

Likewise human societies, we can avoid conflicts in a Multi-Agent System (MAS) by including regulations.
Possible approach: **Off-line** norm design.

1. Generate all system states (off-line).
2. Identify undesired system states.
3. Synthesise norms to avoid undesired states.

**Not feasible for Open Multi-agent Systems**

1. Large scenario → Impossible to generate all system states.
2. Uncertainty → We do not know agents’ behaviour.
3. Dynamic systems → System changes along time.
Research problem: How to synthesise a normative system that helps a MAS to avoid undesirable states (conflicts)?

Assumption: Uncertainty about the MAS composition and agents’ behaviour → We cannot design the normative system off-line.

Our approach: An on-line mechanism for the automated synthesis of normative systems for MAS.
2. Research problem and approach

MAS interaction
2. Research problem and approach

Sensing → MAS interaction

agents actions
2. Research problem and approach

- On-line norm synthesis
- MAS interaction
- Sensing
- conflicts
- agents actions
2. Research problem and approach

- Sensing
- MAS interaction
- On-line norm synthesis
- Norms
- Conflicts
- Agents actions
2. Research problem and approach

On-line norm synthesis

Sensing

MAS interaction

conflicts

norms

agents actions
2. Research problem and approach

- On-line norm synthesis
- MAS interaction
- Sensing
- agents actions
- conflicts norms
2. Research problem and approach

On-line norm synthesis

Sensing

MAS interaction

conflicts

agents actions

norms
2. Research problem and approach

On-line norm synthesis

conflicts

Sensing

agents actions

MAS interaction

norms
2. Research problem and approach

On-line norm synthesis

conflicts

Sensing

norms

agents actions

MAS interaction
3. Scenario: The traffic intersection

MAS interaction example = **Simulated** discretized traffic intersection:
- **Agents** are cars.
- **Conflicts** are collisions among cars.
- **MAS goal** is to avoid collisions among cars.

![Simulated traffic intersection scenario](image-url)
4. Automated Synthesis of Normative Systems

On-line norm synthesis

- Sensing
- MAS interaction
- conflicts
- norms
- agents actions
4. Automated Synthesis of Normative Systems

1. Conflict detection by MAS observation.
4. Automated Synthesis of Normative Systems

1. **Conflict detection** by MAS observation.

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

2. For each detected **conflict** $\rightarrow$ **Synthesis** of new norms.
   - New norms are aimed to avoid the conflict in the future.

But... are synthesised norms good enough for avoiding conflicts?
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.

3. **Evaluation** of synthesised norms.
   1. Are synthesised norms **effective**?
   2. Are they really **necessary**?
We evaluate the performance of norms in base of their effectiveness and necessity:

- **Effectiveness:** Do norms avoid conflicts when agents comply with them?
- **Necessity:** Do conflicts arise when agents do not comply with norms?
4. Automated Synthesis of Normative Systems

**Effectiveness:**

Consider the following norms...

1. **Give way** to your left.

2. **Never give way.**
Effectiveness:

Consider the following norms...

1. **Give way** to your left.

   **IF** Agents **apply** it, **NO collisions** arise $\rightarrow$ **EFFECTIVE** norm

2. **Never give way.**
**Effectiveness:**

Consider the following norms...

1. **Give way** to your left.
   
   *IF Agents apply it, NO collisions arise ➔ EFFECTIVE norm*

2. **Never give way.**
   
   *IF Agents apply it, collisions arise ➔ INEFFECTIVE norm*
Necessity:

Consider the following norms...

1. **Give way** to your left.

2. **Stop** if you do not perceive any car.
Necessity:

Consider the following norms...

1. Give way to your left.

\[
\text{IF Agents violate it, collisions arise} \rightarrow \text{NECESSARY norm}
\]

2. Stop if you do not perceive any car.
Necessity:

Consider the following norms...

1. **Give way** to your left.
   
   IF Agents violate it, collisions arise → **NECESSARY** norm

2. **Stop** if you do not perceive any car.
   
   IF Agents violate it, no collisions arise → **UNNECESSARY** norm
4. Automated Synthesis of Normative Systems

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.

3. **Evaluation** of synthesised norms.
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   2. Are they really **necessary**?
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.

3. **Evaluation** of synthesised norms.
   1. Are synthesised norms **effective**?
   2. Are they really **necessary**?

4. **Refinement** of norms. Norms that do not perform well (ineffective and unnecessary norms) are removed.
IRON (Intelligent Robust On-line Norm synthesis mechanism) solves the on-line automated norm synthesis problem.
4. IRON: Automated Synthesis of Normative Systems

IRON (Intelligent Robust On-line Norm synthesis mechanism) solves the on-line automated norm synthesis problem.
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4. IRON: Automated Synthesis of Normative Systems

IRON (*Intelligent Robust On-line Norm synthesis mechanism*) solves the on-line automated norm synthesis problem.

![IRON Machine Diagram]

- **Scenario-dependant inputs**
- **IRON Machine**
- **S E N S O R S**
- **View**
- **Normative system**
- **Norm-aware multi-agent system**

**IRON Machine** solves the on-line automated norm synthesis problem.
IRON (Intelligent Robust On-line Norm synthesis mechanism) solves the on-line automated norm synthesis problem.
A norm is an **IF ... THEN ...** rule like:

![Diagram of a car moving left to right with a stop sign]

\(<\text{left(car-to-right)} \& \text{front(-)} \& \text{right(-)}, \text{obl(stop)}>\)

- IRON synthesises norms from the agents’ perspective → **Agents can understand norms.**

- Whenever the local perception of a agent satisfies the precondition (IF) of a norm, then the norm **applies to the agent.**
A norm is an **IF ... THEN ...** rule like:

\[\text{left(car-to-right)\&front(-)\&right(-), obl(stop)}\]

Formally, a norm is of the form \(\langle \varphi, \Theta(ac) \rangle\)

- \(\varphi\) is the precondition.
- \(ac\) is an action available to the agents.
- \(\Theta(ac)\) is a deontic operator.

To synthesise norms, IRON uses a BNF grammar:

\[
\begin{align*}
\text{Norm} & ::= \langle \varphi, \Theta(ac) \rangle \\
\varphi & ::= \langle \varphi \& \varphi \rangle \mid \alpha \\
\Theta & ::= \text{obl} \mid \text{perm} \mid \text{prh} \\
Ac & ::= ac_1 \mid ac_2 \mid \ldots \mid ac_n \\
\alpha & ::= p^n(\tau_1, \ldots, \tau_n)
\end{align*}
\]
IRON (Intelligent Robust On-line Norm synthesis mechanism) solves the on-line automated norm synthesis problem.
4. IRON: Automated Synthesis of Normative Systems

IRON Machine

INPUT

SENSORS

OUTPUT
4. IRON: Automated Synthesis of Normative Systems

IRON Machine

Normative Network
4. IRON: Automated Synthesis of Normative Systems

IRON Machine

Normative Network

write

Control Unit

Operators

Strategy

read

INPUT

OUTPUT

SENSORS

S E N S O R S
4. IRON: Automated Synthesis of Normative Systems

IRON Machine

INPUT

Normative Network

read

write

OUTPUT

Control Unit

Operators

Strategy

SENSORS

read

write
4. IRON: The Normative Network

- **Data structure** to represent explored norms.
- **Nodes** stand for norms.
- **Edges** stand for **generalisation relationships** between norms.
- A normative network represents a normative system $\Omega$ as its active norms.

\[ \Omega = \{n_4\} \]
4. IRON: The Normative Network

\[ \Omega = \{n_4\} \]

- \( n_1 \): Give way to police cars
- \( n_2 \): Give way to fire-trucks
- \( n_3 \): Give way to ambulances
- \( n_4 \): Give way to emergency vehicles
4. IRON: Automated Synthesis of Normative Systems

IRON Machine

INPUT

Normative Network

write

read

CONTROL UNIT

Operators

Strategy

OUTPUT

SENSORS
Operators apply changes to the Normative Network \(\rightarrow\) Transitions from one \textbf{normative system} to another.
Operators apply changes to the Normative Network \( \rightarrow \) Transitions from one **normative system** to another.

**create**: Synthesises a norm and adds it to the normative network

\[
\begin{align*}
\Omega &= \{n_1\} \\
\Omega &= \{n_1, n_2\}
\end{align*}
\]
4. IRON: Operators

Operators apply changes to the Normative Network → Transitions from one **normative system** to another.

**create**: Synthesises a norm and adds it to the normative network

```
create: Synthesises a norm and adds it to the normative network

NN₀
Ω={n₁}
→
NN₁
Ω={n₁, n₂}
```

**deactivate**: Deactivates a norm in the normative network

```
deactivate: Deactivates a norm in the normative network

NN₀
Ω={n₁, n₂}
→
NN₁
Ω={n₁}
```

- Active
- Inactive
Operators apply changes to the Normative Network \( \rightarrow \) Transitions from one **normative system** to another.

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

\[
\begin{align*}
\text{NN}_0 & \rightarrow \text{NN}_1 \\
\Omega &= \{n_1, n_2\} & \Omega &= \{n_3\}
\end{align*}
\]
Operators apply changes to the Normative Network \(\rightarrow\) Transitions from one **normative system** to another.

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

\[
\begin{align*}
\Omega &= \{n_1, n_2\} \\
\Omega &= \{n_3\}
\end{align*}
\]

**specialises:** Undoes a norm generalisation

\[
\begin{align*}
\Omega &= \{n_3\} \\
\Omega &= \{n_1, n_2\}
\end{align*}
\]
4. IRON: Strategy

1. **Conflict detection** from perceptions of the MAS.

2. **Norm Synthesis:** For each detected conflict, it uses operator `create` to synthesise norms.

3. **Norm evaluation:** Evaluates norms effectiveness and necessity based on their outcomes in the MAS.

4. **Norm refinement:** Deactivates ineffective and unnecessary norms by means of operator `deactivate`. Generalises and specialises norms using operators `generalise` and `specialise`.
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**Creation of new norms → Based on experience**

We require an AI technique to store experiences and their solutions, and learn from them.
Case Based Reasoning (CBR). Solving problems based on the following principle:
• Similar problems have similar solutions.

**Case base:** Experience is stored in the form of cases, each case with its solution.

Whenever we want to solve a new problem (case):
Quan volem resoldre un nou problema (cas):

1. Build new description of the case
2. Search into the case base for the most similar problem.
3. Adapt its solution to the new case.
4. Revise the solution: Does it work?
5. If the new case is relevant and its solution works, store new case.
Case Based Reasoning (CBR). Solving problems based on the following principle:
• Similar problems have similar solutions.

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4. Revise the solution: Does it work?
5. If the new case is relevant and its solution works, store new case.

**Problem:** CBR requires a human to revise solutions and evaluate how good they are. In our case... **Unsupervised CBR.**
Initially empty Case Base

New Conflict description arrives
Initially empty Case Base

New Conflict description arrives

Search for a similar situation

4. IRON: Strategy. Norm synthesis
Initially empty Case Base

New Conflict description arrives

Search for a similar situation

No similar case is found

Unsupervised CBR System

Initially empty Case Base

Case Base

New Conflict description arrives

Search for a similar situation

No similar case is found

4. IRON: Strategy. Norm synthesis
4. IRON: Strategy. Norm synthesis

Initially empty Case Base

New Conflict description arrives

Search for a similar situation

No similar case is found

Generate a new random solution

Store new case
Initially empty Case Base

New Conflict description arrives

Search for a similar situation

No similar case is found

Generate a new random solution

Store new case

4. IRON: Strategy. Norm synthesis
4. IRON: Strategy. Norm synthesis
4. IRON: Strategy. Norm synthesis

Case 1

Case Description

Case Solution List

View $v_{s}^{t-1}$

View $v_{s}^{t}$

Solution

STOP
4. IRON: Strategy. Norm synthesis

Case 1

Case Composition

Case Base

Case Description

Case Solution List

STOP obligation to ONE of collided cars
4. IRON: Strategy. Norm synthesis

Case 1

Case Description

Case Solution List

View $v_{s}^{t-1}$  

View $v_{s}^{t}$  

Solution
Consider the following conflict:

Conflicting agents: \{ag_1, ag_2\}

Agent actions \((t-1 \rightarrow t):\)
\{ag_1: Go, ag_2: Go\}

New norm
Consider the following conflict:

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

**Agent actions** \((t-1 \rightarrow t)\):

\{ag_1: Go, ag_2: Go\}

**New norm**
Consider the following conflict:

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

**Agent actions** \((t-1 \rightarrow t)\):
\{ag_1: Go, ag_2: Go\}

**New norm**
Initially empty Case Base

New Conflict description arrives

Search for a similar situation

No similar case is found

Generate a new random solution

Store new case

4. IRON: Strategy. Norm synthesis
4. IRON: Strategy. Norm synthesis

Initially empty Case Base

New Conflict description arrives

Search for a similar situation

A similar case is found

Generate a new random solution

No similar case is found

Store new case
4. IRON: Strategy. Norm synthesis

Initially empty Case Base

New Conflict description arrives

Search for a similar situation

No similar case is found

Generate a new random solution

Store new case

A similar case is found

Adapt best solution to solve the current conflict
4. IRON: Strategy

1. **Conflict detection** from perceptions of the MAS.

2. **Norm Synthesis:** For each detected conflict, it uses operator `create` to synthesise norms.

3. **Norm evaluation:** Evaluates norms effectiveness and necessity based on their outcomes in the MAS.

4. **Norm refinement:** Deactivates ineffective and unnecessary norms by means of operator `deactivate`. Generalises and specialises norms using operators `generalise` and `specialise`.
Norms are evaluated based on the conflicts that arise after agents apply/violate them.

Consider a car $c_1$ and a norm $n_1$ to avoid collisions

a. If $c_1$ applies $n_1$ and **collides** → Ineffective norm.
b. If $c_1$ applies $n_1$ and **does not collide** → Effective norm.
c. If $c_1$ violates $n_1$ and **does not collide** → Unnecessary norm.
d. If $c_1$ violates $n_1$ and **collides** → Necessary norm.

**Effectiveness**

\[
\mu_{\text{eff}}(n, t) = (1 - \alpha) \cdot \mu_{\text{eff}}(n, t - 1) + \alpha \cdot r_{\text{eff}}(n, t)
\]

\[
r_{\text{eff}}(n, t) = \frac{\omega_A \cdot m_{A\bar{c}}(n)}{\omega_A \cdot m_{A\bar{c}}(n) + \omega_A \cdot m_{Ac}(n)}
\]

**Necessity**

\[
\mu_{\text{neq}}(n, t) = (1 - \alpha) \cdot \mu_{\text{neq}}(n, t - 1) + \alpha \cdot r_{\text{neq}}(n, t)
\]

\[
r_{\text{neq}}(n, t) = \frac{\omega_V \cdot m_{Vc}(n)}{\omega_V \cdot m_{Vc}(n) + \omega_V \cdot m_{V\bar{c}}(n)}
\]
4. IRON: Strategy

1. **Conflict detection** from perceptions of the MAS.

2. **Norm Synthesis**: For each detected conflict, it uses operator `create` to synthesise norms.

3. **Norm evaluation**: Evaluates norms effectiveness and necessity based on their outcomes in the MAS.

4. **Norm refinement**: Deactivates ineffective and unnecessary norms by means of operator `deactivate`. Generalises and specialises norms using operators `generalise` and `specialise`. 
For each norm:

1. **IF** its effectiveness **OR** necessity is under a deactivation threshold, then **specialise** the norm if it is general, or **deactivate** it if it’s a leave.

2. **IF** its effectiveness **AND** necessity is above a generalisation threshold, then try to **generalise**.
4. IRON: Strategy. Norm generalisation
4. IRON: Strategy. Norm generalisation example
4. IRON: Strategy. Norm generalisation example
4. IRON: Strategy. Norm generalisation example
4. IRON: Strategy. Norm generalisation example

Left hand side
Priority norm
4. IRON: Strategy. Norm specialisation example
4. IRON: Strategy. Norm specialisation example
4. IRON: Strategy. Norm specialisation example

Specialise the General norm

Child norms Are activated
4. IRON: Strategy. Norm specialisation example

Specialise The norm

...
4. IRON: Strategy. Norm specialisation

Deactivate the norm
In this simple scenario we may synthesise many candidate norms...

1. Give way to left.
2. Give way to right.
4. Stop always.
5. Never stop.
6. Stop when you perceive a car behind you.
7. ...

What *combination* of candidate norms (i.e., normative system) may achieve MAS goals?
In this simple scenario we may synthesise many candidate norms...

1. Give way to left.
2. Give way to right.
4. Stop always.
5. Never stop.
6. Stop when you perceive a car behind you.
7. ...

In this scenario: **216** candidate norms $\rightarrow 2^{216} = 10^{65}$ candidate normative systems.
5. Empirical evaluation

1. A **typical execution** of the norm synthesis process.
   - IRON successfully synthesises normative systems that avoids collisions.

2. A **robustness analysis** that the tolerance of IRON to non-compliant behaviour (norm violations).
   - IRON synthesises normative systems even for high norm violation rates.
5. Empirical evaluation

Prototype Execution

1. Tick 13: first collisions arise and IRON synthesises first norms.

2. Tick 35: IRON generalises norms.

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

4. Tick 13349: Simulation stops because of convergence.
5. Empirical evaluation

Robustness Analysis

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

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

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

- We have contributed to the automated synthesis of normative systems.
- Our norm synthesis mechanism is based on:
  • A set of core synthesis operators.
  • Effectiveness and necessity as the means of evaluating norms.
- Empirical evaluation shows that IRON successfully synthesises norms even in presence of non-compliant behaviour.

Future work

- To investigate further relationships between norms in the normative network.
- Extend the norm synthesis process to create norms with sequences of views \((t-n, ..., t)\) instead of \((t-1, t)\).
1. Introduction to Norms and Normative MAS.

2. Overview of approaches to norm synthesis.

3. **On-line automatic norm synthesis.**
   - AAMAS 2013.
   - AAMAS 2014

4. Demo and hands-on activity
Minimality and Simplicity in the On-line Automated Synthesis of Normative Systems

Javier Morales, Maite López-Sánchez, Juan A. Rodríguez-Aguilar, Michael Wooldridge, Wamberto Vasconcelos
Introduction

• Individuals interacting cause conflicts (undesired states).

• **Norms** are enacted to avoid conflicts.

• **Running example:** Road traffic.

• Norms can be employed to avoid undesirable states (i.e., conflicts) in Multi-Agent Systems.
How to synthesise a normative system that is 

*good enough* to regulate a *dynamic* Multi-Agent System?
How to synthesise a normative system that is *good enough* to regulate a *dynamic* Multi-Agent System?

1. Avoids *conflicts*
2. Avoids over regulation
3. *Easy* to reason about
An on-line norm synthesis strategy to synthesise conflict-free and compact normative systems.

The compactness of a normative system is measured by:
- Minimality: Size of the normative system.
- Simplicity: Size of its individual norms.

1. Avoids conflicts
2. Avoids over regulation
3. Easy to reason about
Research problem and approach

- Norm synthesis Machine
  - On-line norm synthesis strategy

MASS
- (domain interaction)

agents actions / conflicts

norms
Research problem and approach

Monitors the MAS detecting conflicts

Norm synthesis Machine

On-line norm synthesis strategy

MAS (domain interaction)

agents actions / conflicts

norms
Research problem and approach

Norm synthesis Machine

On-line norm synthesis strategy

MAS (domain interaction)

agents actions / conflicts

Synthesises norms to avoid conflicts in the future

norms

Research problem and approach
Research problem and approach

**Norm synthesis Machine**

On-line norm synthesis strategy

---

**SIMON**

Syntesises norms to avoid conflicts in the future

**agents actions / conflicts**

**MAS**

(demand interaction)

**norms**
SIMON: An On-line Norm Synthesis strategy

SIMON (Simple Minimal On-line Norm Synthesis)
SIMON (Simple Minimal On-line Norm Synthesis)

Step 1. For each detected conflict, SIMON generates a new active norm to avoid it in the future.
SIMON (Simple Minimal On-line Norm Synthesis)

Step 1. For each detected conflict, SIMON generates a new active norm to avoid it in the future.

Step 2. Evaluation of each norm in terms of whether it is effective and necessary:

- If agents comply with it, NO conflicts arise → EFFECTIVE
- If agents comply with it, conflicts arise → INEFFECTIVE
- If agents infringe it, conflicts arise → NECESSARY
- If agents infringe it, NO conflicts arise → UNNECESSARY
SIMON (Simple Minimal On-line Norm Synthesis)

Step 1. For each detected conflict, SIMON generates a new active norm to avoid it in the future.

Step 2. Evaluation of each norm in terms of whether it is effective and necessary.

Step 3. Refinement of norms. SIMON performs optimistic norm generalisations.

Aims at synthesising compact normative systems.
SIMON (Simple Minimal On-line Norm Synthesis)

**Step 1.** For each detected conflict, SIMON generates a new active norm to avoid it in the future.

**Step 2.** Evaluation of each norm in terms of whether it is effective.

**Step 3.** Refinement of norms. SIMON performs optimistic norm generalisations. Aims at synthesising compact normative systems.

Adapted from AAMAS’13
Based on three key components:

1. A *taxonomy* of terms to specify norms
2. An *optimistic* approach to norm generalisation
3. Novel norm generalisation *modes*
Norm examples (informal):

- Give way to ambulances
- Give way to fire brigade
- Give way to police cars

The terms employed to specify norms are part of a taxonomy.
SIMON: Norm refinement

Based on three key components:

1. A **taxonomy** of terms to specify norms
2. An **optimistic** approach to norm generalisation
3. Novel norm generalisation **modes**
SIMON: Norm generalisation

Norm generalisation

$N_{N_0}$

Normative system

$\{n_1, n_2, n_3\}$

$n_1$: Give way to **ambulances**

$n_2$: Give way to **fire brigade**

$n_3$: Give way to **police cars**
SIMON: Norm generalisation

Norm generalisation

\[ \text{Normative system } \{n_1, n_2, n_3\} \rightarrow \text{Normative system } \{n_4\} \]

\(n_1\): 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
SIMON: Norm generalisation

Norm generalisation

Conservative approach
Employs full evidence to generalise norms.
SIMON: Optimistic norm generalisation

Optimistic norm generalisation

Normative system \( \{n_1, n_2\} \)

- \( n_1 \): Give way to **ambulances**
- \( n_2 \): Give way to **fire brigade**

emergency

ambulance  fire-brigade  police-car
Optimistic norm generalisation

Normative system $\{n_1, n_2\}$

$n_1$: Give way to **ambulances**

$n_2$: Give way to **fire brigade**

**Most specific generalisation between two terms**

E. Armengol and E. Plaza.
Optimistic norm generalisation

- \( n_1 \): Give way to *ambulances*
- \( n_2 \): Give way to *fire brigade*
- \( n_4 \): Give way to *emergency* vehicles
1. Conservative generalisation requires **full evidence**.

2. Optimistic generalisation just requires **partial evidence**.

3. Optimistic generalisation expected to **increase** the number of generalisations.

   More **compact** normative systems
   (lower **minimality** and **simplicity**)
SIMON: Norm refinement

Based on three key components:

1. A taxonomy of terms to specify norms
2. An optimistic approach to norm generalisation
3. Novel norm generalisation modes
**Shallow** norm generalisation (S-SIMON)

- Compares norms that are **active** in the normative network.

**Normative system**

\[ \{n_1, n_2\} \]

\( n_1 \): Give way to **ambulances**

\( n_2 \): Give way to **fire brigade**
**Shallow** norm generalisation (S-SIMON)

- Compares norms that are **active** in the normative network.
- **Directly** generalises two active norms.

\[ \text{NN}_0 \]
\[ n_1, n_2 \]

\[ \text{Normative system } \{n_1, n_2\} \]

\[ \text{NN}_1 \]
\[ n_1 \]
\[ n_2 \]
\[ n_4 \]

\[ \text{Normative system } \{n_4\} \]

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

- emergency
- ambulance
- fire-brigade
- police-car
- private-car
- car
**Deep norm generalisation (D-SIMON)**

- Compares norms that are **active** in the normative network.

**Normative system**
\[ \{n_4, n_5\} \]

\( n_1 \): 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**
Deep norm generalisation (D-SIMON)

- Compares norms that are active in the normative network.
- Indirectly generalises two norms that are subsumed by two active norms.

**n₁**: Give way to **ambulances**

**n₂**: Give way to **fire brigade**

**n₃**: Give way to **police cars**

**n₄**: Give way to **emergency vehicles**

**n₅**: Give way to **private cars**

**n₆**: Give way to **cars**
SIMON: Shallow vs Deep norm generalisation

**Shallow** generalisation

Finds two active norms to generalise
**Shallow generalisation**

Generalises to a new norm

\[ n_e \]

- \[ n_a \]
- \[ n_b \]
- \[ n_c \]
- \[ n_d \]
**Shallow generalisation**

- $n_a$
- $n_b$
- $n_c$
- $n_d$

**Deep generalisation**

- $n_a$
- $n_b$
- $n_c$
- $n_d$

Finds two active norms
SIMON: Shallow vs Deep norm generalisation

**Shallow** generalisation

Finds two inactive norms to generalise

**Deep** generalisation

Finds two inactive norms to generalise
SIMON: Shallow vs Deep norm generalisation

**Shallow generalisation**

**Deep generalisation**

Generalises to a new norm
SIMON: Shallow vs Deep norm generalisation

**Shallow generalisation**

More **coarse**

**Deep generalisation**

More **fine-grained**
Our goal is to compare IRON (AAMAS 2013) and SIMON in terms of:

1. The **quality** of the normative systems that they synthesise.
2. The computational **costs** their synthesis processes require.
3. The **search space** of normative systems that they explore.

IRON performs conservative norm generalisations whereas SIMON performs optimistic norm generalisations.
Empirical evaluation: Scenario

We employ the same simulated traffic junction:

- **Agents** are cars.
- **Conflicts** are collisions among cars.
- **Our goal** is to synthesise normative systems that avoid collisions between cars.

Simulated traffic intersection scenario
Empirical evaluation: Norms

Norms

- **IF** ... **THEN**... rules.
- Norm precondition: Set of *predicates* with one *term* each.
- Norm postcondition: A *modality*.

Norm example

**Graphical representation**

**IF** `left(car-heading-right) & front(nothing) & right(nothing)` **THEN** `prohibition(go)`
Empirical results

**BENEFITS**

D-SIMON normative systems are up to 46% more minimal and 61% simpler than IRON’s.

**COSTS**

D-SIMON requires:

1. To synthesise more norms.
2. Extra convergence time.
Empirical results

Why does D-SIMON outperform IRON in terms of minimality and simplicity?
Empirical results

Why does D-SIMON outperform IRON in terms of minimality and simplicity?

D-SIMON focuses on an area of the search space with more compact normative systems.
Conclusions

1. Synthesising **conflict-free** and **compact** normative systems is important to:
   
   • Avoid **conflicts**.
   • Avoid **over regulation**.
   • Ease the reasoning of agents.

2. We have presented **SIMON**, a novel strategy for the on-line synthesis of conflict-free and compact normative systems.

3. **SIMON** shows that being **optimistic** (non requiring full evidence) and investing computational efforts on discovering **implicit relationships** (deep generalisation) pays off.

4. Applicable to other domains.
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)

Norms are like...

\[
\text{IF user(1) \& section(2) \& contentType(porn)} \\
\text{THEN prh(upload(content))}
\]
Case Study 2: Virtual Communities Simulator
NORM SYNTHESIS BECOMES A PARTICIPATORY MECHANISM:

Users choose community norms by means of their complaints.
1. Introduction to Norms and Normative MAS.
2. Overview of approaches to norm synthesis.
3. On-line automatic norm synthesis.
4. Demo and hands-on activity
Demo

NormLab: A framework to support research on norm synthesis

Choose a Norm Synthesis approach
- IRON (Intelligent Robust On-line Norm synthesis)
- SiMON (Simple Minimal On-line Norm synthesis)

Launch simulation
- On-line Community
- Traffic Junction

Norm generalisation settings
- Generalisation mode: Deep
- Generalisation step: 1

Javier Morales, Maite López-Sánchez, Juan A. Rodríguez-Aguilar, Michael Wooldridge, Wamberto Vasconcelos
1. What is NormLab?

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

*NormLab* allows to:

1. **Perform MAS simulations.** It incorporates two different MAS simulators: a traffic simulator, and an on-line community simulator.

2. **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.

3. **Develop and test custom norm synthesis strategies.** *NormLab* allows to develop custom on-line norm synthesis strategies to be tested on the MAS simulations.
What are the contents of this tutorial?

1. **An introduction** to NormLab
   1. The NormLab architecture.
   3. The NormLab simulators.

2. **Configuration** of the working environment
   1. NormLab download.
   2. NormLab installation.

3. NormLab **execution**:
   1. Execution examples.
   2. Guided development of different norm synthesis strategies.
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2. NormLab architecture

- NormLab
  - Norm Synthesis Machine
    - Norm synthesis strategies
  - MAS events
  - Norms
  - NormLabSimulators
    - MAS Simulators
      - Traffic junction simulator
      - On-line community simulator
2. NormLab architecture

NormLab

Norm Synthesis Machine

- Norm synthesis strategies
- MAS events
- Norms

NormLabSimulators

MAS Simulators

- Traffic junction simulator
- On-line community simulator

Simulator settings

Norm synthesis settings

Domain-dependent functions
2. NormLab architecture

NormLab

Norm Synthesis Machine

- Norm synthesis strategies

MAS events

Norms

NormLabSimulators

MAS Simulators

- Traffic junction simulator
- On-line community simulator

Norm synthesis settings

Domain-dependent functions

Simulator settings
3. The Norm Synthesis Machine

Norm Synthesis Machine

Scenario-dependant settings

Multi-agent System

MAS events.

Normative system

INPUT

OUTPUT

SENSORS

INPUT

OUTPUT

Multi-agent System
3. The Norm Synthesis Machine

Agents’ behaviours are simulated.

Scenario-dependant settings

MAS events...

Norm Synthesis Machine

Input

Output

S E N S O R S

Normative system

Multi-agent System
3. The Norm Synthesis Machine

**Input:** Agents’ behaviours (by observation)

**Output:** Normative system

**Input:** Scenario-dependant settings

**Output:** MAS events...

Multi-agent System

Agents’ behaviours are simulated
3. The Norm Synthesis Machine

Agents’ behaviours are simulated

Input: Agents’ behaviours (by observation)

Scenario-dependant settings

Normative system

MAS events...

Multi-agent System

Input: Agents’ behaviours (by observation)
3. The Norm Synthesis Machine

Scenario-dependant settings

**Input:** Agents’ behaviours (by observation)

Norm Synthesis Machine

MAS events...

Multi-agent System

**Output:** Normative system

**Agents’ behaviours are simulated**
4. The traffic simulator

- Based on Repast Simphony 2.1
- **Agents** are cars, and **conflicts** are collisions among cars.
- **The goal** is to synthesise normative systems that **avoid collisions** between cars.
What are the contents of this tutorial?

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

**Requirements**

- **Java JDK 1.6** or greater  [http://www.java.com](http://www.java.com)
- **Eclipse IDE** (just for Linux users)  [http://www.eclipse.org/downloads](http://www.eclipse.org/downloads)

**Downloads**

To use *NormLab* you need to download:

  Implements an API that allows to perform norm synthesis for MAS.
- **NormLab**: [http://normsynthesis.github.io/NormLabSimulators/](http://normsynthesis.github.io/NormLabSimulators/)  
  Contains the code of the two MAS simulators: traffic and on-line community.

Download both projects whether in a **ZIP** or **TAR.GZ** file.
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**
5.1. NormLab installation

Preparing the working environment

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

Preparing the working environment

1. Unzip **NormLabSimulators** and **NormSynthesisMachine** projects to your HOME folder.
   - For instance... «/Users/Javi/NormLab»
2. Open **Eclipse IDE**.
3. Import both projects **NormLabSimulators** and **NormSynthesisMachine** in Eclipse:
   1. File>New>Java Project.
   2. Uncheck «Use default location» and click on «Browse».
4. Import projects **NormLabSimulators** and **NormSynthesisMachine**.
5.2. NormLab structure

Before starting you need to know:

*NormLabSimulators* project is structured as follows:

- **src/onlinecomm**: The code of the on-line community simulator.
- **src/traffic**: The code of the traffic simulator.
- **launchers**: The launchers that allow to run the two simulators.
- **repastr-settings/OnlineCommunity.rs**: Basic Repast settings for the on-line community simulator.
- **repastr-settings/TrafficJunction.rs**: Basic Repast settings for the traffic junction simulator.
What are the contents of this tutorial?

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   1. Execution examples.
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Tutorial outline

NormLab execution:

1. Execution examples
   1. Example strategy 1: Returns an **empty** set of norms.
   2. Example strategy 2: Returns a fixed set of 1 **norm**.
   3. Example strategy 3: Returns a fixed set of 3 **norms**.

2. Guided development of different norm synthesis strategies
   1. Development of example strategy 1: **Empty** set of norms.
   2. Development of example strategy 2: Fixed set of 1 **norm**.
   3. Studying example 4: A strategy with norm **generation**.
   4. Studying example 5: A strategy with norm **generation + evaluation**.
   5. Studying SIMON: A strategy with norm **generation + evaluation + refinement**.
1. Execution examples
   1. **Example** strategy 1: Returns an **empty** set of norms.
   2. **Example** strategy 2: Returns a fixed set of **1 norm**.
   3. **Example** strategy 3: Returns a fixed set of **3 norms**.

2. Guided development of different norm synthesis strategies
   1. **Development** of example strategy 1: **Empty** set of norms.
   2. **Development** of example strategy 2: Fixed set of **1 norm**.
   3. **Studying** example 4: A strategy with norm **generation**.
   4. **Studying** example 5: A strategy with norm **generation + evaluation**.
   5. **Studying** SIMON: A strategy with norm **generation + evaluation + refinement**.
6. Example 1: Executing NormLab

*TrafficJunction* norm synthesis example 1

We are going to execute the *TrafficJunction* simulator with a very simple norm synthesis strategy, which is as follows:

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

**Consequences:** No norms are given to the agents → collisions are never removed.
6. Example 1: Executing NormLab

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».
6. Example 1: Executing NormLab

**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. Example 1: Executing NormLab

*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. Example 1: Executing NormLab

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**:

1. Execution examples
   1. **Example** strategy 1: Returns an **empty** set of norms.
   2. **Example** strategy 2: Returns a fixed set of **1 norm**.
   3. **Example** strategy 3: Returns a fixed set of **3 norms**.

2. Guided development of different norm synthesis strategies
   1. **Development** of example strategy 1: **Empty** set of norms.
   2. **Development** of example strategy 2: Fixed set of **1 norm**.
   3. **Studying** example 4: A strategy with norm **generation**.
   4. **Studying** example 5: A strategy with norm **generation + evaluation**.
   5. **Studying** SIMON: A strategy with norm **generation + evaluation + refinement**.
In the traffic simulator, cars perceive the scenario by means of the three cells in front of them:

Norms are...

- **IF ... THEN...** rules.
- Norm precondition: Set of *predicates* with one *term* each.
  - Three different predicates *(left, front, right)*.
  - Six different terms *(<, ^, >, v, -, w, *)* representing cars with different headings, term «-» stands for «nothing», «w» for «wall» and «*» for «anything».
- Norm postcondition: A *modality*.

**Graphical representation**

**IF** left(>) & front(-) & right(-) **THEN** prohibition(go)
7. Example 2: Using norms

*TrafficJunction* norm synthesis example 2

We are now going to execute the *TrafficJunction* simulator with a norm synthesis strategy that will avoid some (but not all) collisions between cars. With this aim, the strategy always returns a normative system with only one **left-side-priority** norm:

**Norm 1**

\[
\text{IF } \text{left}(>) \& \text{front}(* \& \text{right}(*)) \text{ THEN } \text{prohibition}(go)
\]
7. Example 2: Using norms

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 traffic simulator setting parameters.
3. Search for the parameter «NormSynthesisExample».
4. Set the field «defaultValue» with the value «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.
6. Do right click on the file launchers/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 one norm, and now cars occasionally stop to apply norm 1.

[Diagram of Synthesised norms with text: Car applying norm 1]
NormLab execution:

1. Execution examples
   1. **Example** strategy 1: Returns an **empty** set of norms.
   2. **Example** strategy 2: Returns a fixed set of **1 norm**.
   3. **Example** strategy 3: Returns a fixed set of **3 norms**.

2. Guided development of different norm synthesis strategies
   1. **Development** of example strategy 1: **Empty** set of norms.
   2. **Development** of example strategy 2: Fixed set of **1 norm**.
   3. **Studying** example 4: A strategy with norm **generation**.
   4. **Studying** example 5: A strategy with norm **generation + evaluation**.
   5. **Studying** SIMON: A strategy with norm **generation + evaluation + refinement**.
8. Example 3: Removing collisions

*TrafficJunction* norm synthesis example 3

We are now going to execute the *TrafficJunction* simulator with a norm synthesis strategy that avoids all possible collisions. With this aim, it always returns the following normative system:

\[
\text{IF } \text{left}(\ast) \& \text{front}^{\wedge} \& \text{right}(\ast) \text{ THEN prohibition(go)} \\
\text{IF } \text{left}(>) \& \text{front}(-) \& \text{right}(\ast) \text{ THEN prohibition(go)} \\
\text{IF } \text{left}(<) \& \text{front}(<) \& \text{right}(\ast) \text{ THEN prohibition(go)}
\]

To execute this example, you just have to **follow the steps in section 7**, but setting `defaultValue=«3»` of the NormSynthesisExample parameter (again in NormLabSimulators project, directory `repast-settings/TrafficJunction.rs`, file `parameters.xml`)
NormLab **execution:**

1. Execution examples
   1. **Example** strategy 1: Returns an **empty** set of norms.
   2. **Example** strategy 2: Returns a fixed set of **1 norm**.
   3. **Example** strategy 3: Returns a fixed set of **3 norms**.

2. Guided development of different norm synthesis strategies
   1. **Development** of example strategy 1: **Empty** set of norms.
   2. **Development** of example strategy 2: Fixed set of **1 norm**.
   3. **Studying** example 4: A strategy with norm **generation**.
   4. **Studying** example 5: A strategy with norm **generation + evaluation**.
   5. **Studying** SIMON: A strategy with norm **generation + evaluation + refinement**.
9. Developing your own strategy

How are implemented all these examples? Let’s implement one of the examples!

We are now going to develop our own norm synthesis strategy. In particular, we are going to implement the norm synthesis strategy of example 1, which returns an **empty normative system**.

The first thing we must do is to indicate *NormLab* that we are going to use a custom norm synthesis strategy. With this aim, follow these steps:

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 traffic simulator setting 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 give it a custom norm synthesis strategy.

```xml
<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" />
```
Now, to create your norm synthesis strategy, just follow these steps:

1. In Eclipse (NormLabSimulators project), go to **package es.csic.iiia.normlab.traffic.custom.**
3. The interface will require you to implement two methods:
   1. `execute()`: Executes the norm synthesis strategy
   2. `getNonRegulatedConflictsThisTick()`: Returns a data structure containing the conflicts that the strategy has detected during the current tick

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

import java.util.List;
import java.util.Map;

import es.csic.iiia.nsm.config.Goal;
import es.csic.iiia.nsm.norm.NormativeSystem;
import es.csic.iiia.nsm.norm.generation.Conflict;

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

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

 @Override
 public Map<Goal, List<Conflict>> getNonRegulatedConflictsThisTick() {
     // TODO Auto-generated method stub
     return null;
 }
}
9. Developing your own strategy

We will create our strategy:

1. Create a new attribute `private Map<Goal, List<Conflict>> conflicts.`
2. Create a constructor for the class and, there, create the structure conflicts.
3. Make method `getNonRegulatedConflictsThisTick()` to return the attribute `conflicts`.
4. Your code should look like this:

```java
/**
 *
 */
public class MyFirstStrategy implements es.csic.iiiia.nsm.strategy.NormSynthesisStrategy {
    private Map<Goal, List<Conflict>> conflicts; // to save conflicts

/**
 *
 */
public MyFirstStrategy() {
    this.conflicts = new HashMap<Goal, List<Conflict>>();
}

@Override
public NormativeSystem execute() {
    return null;
}

@Override
public Map<Goal, List<Conflict>> getNonRegulatedConflictsThisTick() {
    return conflicts;
}
```
Now, let’s implement the `execute()` method, which implements the norm synthesis strategy. This method must return an object `NormativeSystem`, that contains the norms that will be given to the agents.

There are a couple things that we must take into account:

- The Norm Synthesis Machine keeps synthesised norms in a normative network.
- To be able to access to the normative network, and the different elements of the Norm Synthesis Machine, we must receive the `NormSynthesisMachine` as a parameter in our strategy:

Follow now these steps:

1. In the constructor of the class, add the parameter `es.csic.iitia.nsm.NormSynthesisMachine nsm`.
2. Now we can access the different elements of the Norm Synthesis Machine in our strategy.
3. Let’s obtain the Normative Network! Add the following attribute to your class:

   ```java
   private NormativeNetwork normativeNetwork;
   ```

4. Now, in your constructor, add the following code line to obtain the (initially empty) normative network:

   ```java
   this.normativeNetwork = nsm.getNormativeNetwork();
   ```

5. Finally, we will now return an empty normative system at the end of the strategy execution. Add the following line of code at the end of method `execute()`:

   ```java
   return this.normativeNetwork.getNormativeSystem();
   ```
Congratulations! You have created your first norm synthesis strategy, which returns an empty normative system. Your code should now look like this:

```java
package es.csic.iiiia.normlab.traffic.custom;
import java.util.HashMap;
import java.util.List;
import java.util.Map;
import es.csic.iiiia.nsm.config.Goal;
import es.csic.iiiia.nsm.net.norm.NormativeNetwork;
import es.csic.iiiia.nsm.norm.NormativeSystem;
import es.csic.iiiia.nsm.norm.generation.Conflict;

public class MyFirstStrategy implements es.csic.iiiia.nsm.strategy.NormSynthesisStrategy {
    private Map<Goal, List<Conflict>> conflicts; // to save conflicts
    private NormativeNetwork normativeNetwork;

    public MyFirstStrategy(es.csic.iiiia.nsm.NormSynthesisMachine nsm) {
        this.conflicts = new HashMap<Goal, List<Conflict>>();
        /* Get norm synthesis elements */
        this.normativeNetwork = nsm.getNormativeNetwork();
    }

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

    @Override
    public Map<Goal, List<Conflict>> getNonRegulatedConflictsThisTick() {
        return conflicts;
    }
}
```
And now... how to tell NormLab to use your norm synthesis strategy? We need to create an agent in the Traffic Simulator, which:

1. **Creates** and **configures** the Norm Synthesis Machine.
2. Adds **sensors** to the Norm Synthesis Machine to perceive the scenario.
3. **Creates** and **configures** the norm synthesis **strategy**.
4. **Executes** your strategy at every simulation step.

The traffic simulator incorporates a default Traffic Norm Synthesis Agent, which is implemented in class `DefaultTrafficNormSynthesisAgent` of package `es.csic.iiia.normlab.traffic.agent`.

Let’s take a look at it...
10. Executing your implemented strategy

Observe the constructor `DefaultTrafficNormSynthesisAgent()`. It performs these tasks:

1. Creates the norm synthesis machine with a given configuration.
2. Adds a set of sensors to the norm synthesis machine in order to perceive the scenario.
3. Sets the norm synthesis strategy.

```java
public DefaultTrafficNormSynthesisAgent(List<TrafficCamera> cameras,
                                          PredicatesDomains predDomains) {
    this.normativeSystem = new NormativeSystem();
    this.addedNorms = new ArrayList<Norm>();
    this.removedNorms = new ArrayList<Norm>();
    this.nsmSettings = new TrafficNormSynthesisSettings();
    this.dmFunctions = new TrafficDomainFunctions();

    /* 1. Create norm synthesis machine */
    this.nsm = new NormSynthesisMachine(nsmSettings, predDomains,
                                         dmFunctions, true);

    /* 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();
}
```

4. Executes the norm synthesis strategy at every simulation step.

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

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

To create the NormSynthesisMachine, it needs to create:

1. **NormSynthesisSettings**: The settings for the norm synthesis machine.
2. **PredicatesDomains**: Information about the agents’ language. That is, the predicates and terms the agents employ to describe the scenario from their local point of view.
3. **DomainFunctions**: Some domain-dependent functions that the Norm Synthesis Machine requires to synthesise norms (e.g., conflict detection, norm applicability).

```java
public DefaultTrafficNormSynthesisAgent(List<TrafficCamera> cameras, PredicatesDomains predDomains) {
    this.normativeSystem = new NormativeSystem();
    this.addedNorms = new ArrayList<Norm>();
    this.removedNorms = new ArrayList<Norm>();
    this.nsmSettings = new TrafficNormSynthesisSettings();
    this.dmFunctions = new TrafficDomainFunctions();

    /* 1. Create norm synthesis machine */
    this.nsm = new NormSynthesisMachine(nsmSettings, predDomains, 
                                          dmFunctions, true);

    /* 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();
}
```
10. Executing your implemented strategy

**NormSynthesisSettings**: An interface to be implemented (located in package `es.csic.iiia.nsm.config`)

1. `getNormSynthesisStrategy()`: Returns the norm synthesis strategy to use.
2. `getSystemGoals()`: A list of system goals. In traffic, the only goal is “to avoid collisions”.
3. `getNormsDefaultUtility()`: Norms’ default utility (0.5 by default).
4. `getNormEvaluationLearningRate()`: The $\alpha$ rate to evaluate norms (0.1 is ok).
5. `getNormsPerformanceRangesSize()`: The size of the window to compute norms’ performance ranges.
6. `getNormGeneralisationMode()`: SIMON’s norm generalisation mode (Shallow/Deep).
7. `public int getNormGeneralisationStep()`: SIMON’s norm generalisation step, namely the number of norm predicates that can be simultaneously generalised.
8. `getGeneralisationBoundary(Dimension dim, Goal goal)`: Returns the minimum value of Effectiveness/necessity that a norm’s performance must reach to be generalised.
9. `getSpecialisationBoundary(Dimension dim, Goal goal)`: Returns the value of Effectiveness/necessity under which a norm can be specialised.
10. `getNumTicksOfStabilityForConvergence()`: The number of simulation ticks without conflicts or changes to the normative system to converge.

An implementation of these settings for the traffic simulator is located in package `es.csic.iiia.normlab.traffic.normsynthesis`, class `TrafficNormSynthesisSettings`
10. Executing your implemented strategy

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

The traffic simulator creates predicates and their domains in (project NormLabSimulators) class `es.csic.iiia.traffic.TrafficSimulator`, method `createPredicatesDomains()`.

- Three different predicates (`l`, `f`, `r`) that represent the left, front and right positions in front of a car.
- Six different terms (`<`, `^`, `>`, `v`, `-`, `w`, `*`) representing cars with different headings, term `«-»` stands for «nothing», `«w»` for «wall» and `«*»` for «anything».
10. Executing your implemented strategy

**PredicatesDomains:** The traffic simulator creates predicates and their domains in class `es.csic.iii.traffic.TrafficSimulator`, method `createPredicatesDomains()`.

```java
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. Executing your implemented strategy

**DomainFunctions**: An interface to be implemented. Located in package `es.csic.iiia.nsm.config` (NormSynthesisMachine project).

1. **isConsistent(SetOfPredicatesWithTerms agentContext)**: Returns true if a set of predicates with terms is consistent with the domain. For instance, `(left(>), front(-), right(-))` is consistent. By contrast, `(left(>), front(<), right(-))` is not consistent, since two cars can not drive in opposite directions in the same lane.

2. **agentContextFunction(long agentId, View view)**: Returns the local perception of a given agent at a particular system state (received as a View).

3. **agentActionFunction(long agentId, ViewTransition viewTransition)**: Returns a list of the actions that an agent performed in the transition from a state $s_t$ to a state $s_{t-1}$.

4. **getNonRegulatedConflicts(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).

5. **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, `es.csic.iiia.normlab.traffic.normsynthesis` package, class `TrafficDomainFunctions`. 
10. Executing your implemented strategy

Now that we understand how *DefaultTrafficNormSynthesisAgent* works, let’s tell it to use your norm synthesis strategy:

1. Open class *DefaultTrafficNormSynthesisAgent* in package `es.csic.iia.normlab.traffic.agent`. This class implements the agent that «lives» in the traffic simulator, creates the norm synthesis machine and executes the strategy at every simulation tick.
2. Go to method *setCustomNormSynthesisStrategy()*
3. There, tell NormLab to use your norm synthesis strategy. Use this code:

   ```java
   /**
    * Sets a custom norm synthesis strategy
    */
   protected void setCustomNormSynthesisStrategy() {
       MyFirstStrategy myStrategy = new MyFirstStrategy(this.nsm);
       this.nsm.useStrategy(myStrategy);
   }
   ```

4. It is as simple as creating your norm synthesis strategy and telling the norm synthesis machine to use your strategy.
5. Execute the simulation as you did for example 1.

   **Congratulations, you are using your own strategy!**
NormLab execution:

1. Execution examples
   1. **Example** strategy 1: Returns an **empty** set of norms.
   2. **Example** strategy 2: Returns a fixed set of **1 norm**.
   3. **Example** strategy 3: Returns a fixed set of **3 norms**.

2. Guided development of different norm synthesis strategies
   1. **Development** of example strategy 1: **Empty** set of norms.
   2. **Development** of example strategy 2: Fixed set of **1 norm**.
   3. **Studying** example 4: A strategy with norm **generation**.
   4. **Studying** example 5: A strategy with norm **generation + evaluation**.
   5. **Studying** SIMON: A strategy with norm **generation + evaluation + refinement**.
11. Adding norms to your strategy

Let’s now **add some norms** to our strategy. We will use the same set of norms than used in the **example 2** (with one only left-hand-side priority norm).

1. In package `es.csic.iii.a.normlab.traffic.custom` (NormLabSimulators project), **copy** your first norm synthesis strategy (`MyFirstStrategy.java`) as a **new strategy** `MySecondStrategy.java`.
2. To add norms to the normative network we need to know the system goals (in traffic, the only system goal is to avoid collisions). With this aim, add the following attribute to your strategy.
   - `private List<Goal> goals;`
3. Now obtain the system goals in your constructor:
   - `this.goals = nsm.getNormSynthesisSettings().getSystemGoals();`
4. Your code should look like this:

```java
private List<Goal> goals;
private Map<Goal, List<Conflict>> conflicts; // to save conflicts
private NormativeNetwork normativeNetwork;

/**
 * @param nsm
 */
public MySecondStrategy(es.csic.iii.a.norm.NormSynthesisMachine nsm) {
    this.conflicts = new HashMap<Goal, List<Conflict>>();

    /* Get norm synthesis elements */
    this.goals = nsm.getNormSynthesisSettings().getSystemGoals();
    this.normativeNetwork = nsm.getNormativeNetwork();
}

/**
 */
@Override
public NormativeSystem execute() {
    return normativeNetwork.getNormativeSystem();
}
```
11. Adding norms to your strategy

1. Let’s create the normative system. Norms have four elements: (1) a norm precondition; (2) a modality (in our case, a prohibition); (3) an action to obligate/prohibit. In our implementation, the norm also includes the goal it is aimed to achieve.

2. Now, create a new method `createNormativeSystem()` that will add the norms to the normative network:

   ```java
   /**
    * Creates a normative system that allows all possible collisions in the road traffic scenario
    */
   private void createNormativeSystem() {

   /* Get system goal (to avoid collisions) */
   Goal goalAvoidCollisions = goals.get(0);

   /* 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, goalAvoidCollisions);

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

3. This code first gets the only system goal (to avoid collisions between cars)

4. Then, it creates a norm precondition (set of predicates with terms) and adds the predicates «l» (left), «f» (front) and «r» (right), with its corresponding term.

5. Finally, it creates the norm adding the pre-condition, the modality «Prohibition» over the action «Go», and the goal of the norm (to avoid collisions).
11. Adding norms to your strategy

1. Now, call method `createNormativeSystem()` at the end of your constructor. Your code should look like this:

```java
/**
 * 
 *
 * public class MySecondStrategy implements es.csic.iii.a.nsm.strategy.NormSynthesisStrategy {
 * 
 * private List<Goal> goals;
 * private Map<Goal, List<Conflict>> conflicts; // to save conflicts
 * private NormativeNetwork normativeNetwork;
 * 
 * /**
 * * @param nsm
 * */
 * public MySecondStrategy(es.csic.iii.a.nsm.NormSynthesisMachine nsm) {
 * this.conflicts = new HashMap<Goal, List<Conflict>>();
 * 
 * /* Get norm synthesis elements */
 * this.goals = nsm.getNormSynthesisSettings().getSystemGoals();
 * this.normativeNetwork = nsm.getNormativeNetwork();
 * 
 * this.createNormativeSystem();
 * }
 *
 * @Override
 * public NormativeSystem execute() {
 * return normativeNetwork.getNormativeSystem();
 * }
 */
```

2. At each execution, the strategy will return the norms that are active in the normative network (i.e., the normative system).
11. Adding norms to your strategy

To finish, set the traffic norm synthesis agent to use your new strategy.

1. Open class *DefaultTrafficNormSynthesisAgent* in package *es.csic.iiia.normlab.traffic.agent*. This class implements the agent that «lives» in the traffic simulator, creates the norm synthesis machine and executes the strategy at every simulation tick.

2. Go to method *setCustomNormSynthesisStrategy()*

3. There, tell *NormLab* to use your norm synthesis strategy. Use this code:

```java
/**
 * Sets a custom norm synthesis strategy
 */
protected void setCustomNormSynthesisStrategy() {
    MySecondStrategy myStrategy = new MySecondStrategy(this.nsm);
    this.nsm.useStrategy(myStrategy);
}
```

4. You can now execute the Traffic Simulator and see how your second strategy works. Observe that:
   1. The normative system contains now one norm.
   2. The unique norm is never evaluated (click on button *Show* of norms’ performance ranges).
1. Execution examples
   1. Example strategy 1: Returns an **empty** set of norms.
   2. Example strategy 2: Returns a fixed set of **1 norm**.
   3. Example strategy 3: Returns a fixed set of **3 norms**.

2. Guided development of different norm synthesis strategies
   1. Development of example strategy 1: **Empty** set of norms.
   2. Development of example strategy 2: Fixed set of **1 norm**.
   3. Studying example 4: A strategy with norm **generation**.
   4. Studying example 5: A strategy with norm **generation + evaluation**.
   5. Studying SIMON: A strategy with norm **generation + evaluation + refinement**.
Let’s see now how can we automatically generate norms on-line.

For this example we are going to use the code of example 4, which is located in the package `es.csic.iii.a.normlab.traffic.examples.ex4`.

There, we can find the following classes:

* **TrafficNSEExample4_NSAgent**
  - The agent that creates the Norm Synthesis Machine and executes the strategy.

* **TrafficNSEExample4_NSOperators**
  - Operators to **create**, **add**, **activate** and **deactivate** norms in the normative network.

* **TrafficNSEExample4_NSStrategy**
  - A norm synthesis strategy that generates norms to avoid arisen collisions in the future.
12. A strategy with automatic norm generation

Let’s see now how can we automatically generate norms on-line.

For this example we are going to use the code of example 4, which is located in the package `es.csic.iiia.normlab.traffic.examples.ex4`.

There, we can find the following classes:

- **TrafficNSExample4_NSAgent**: The agent that creates the Norm Synthesis Machine and executes the strategy.

- **TrafficNSExample4_NSOperators**: Operators to create, add, activate and deactivate norms in the normative network.

- **TrafficNSExample4_NSStrategy**: A norm synthesis strategy that generates norms to avoid arisen collisions in the future.

This agent works along the lines of the DefaultTrafficNormSynthesisAgent
TrafficNSExample4_NSOperators: How do operators work?

Create:
1. Receives a Conflict and a system Goal.
2. Employs a Case-Based Reasoning (CBR) norm generation approach to generate a norm aimed at avoiding the given conflict in the future.
3. If the norm does not exist in the normative network, then it adds it.
4. If the norm exists in the normative network, then it activates it (since it may be inactive).

Add:
1. Adds a norm to the normative network.
2. Activates the norm in the normative network.

Activate:
1. Sets the state of a norm as «Active» in the normative network

Deactivate:
1. Sets the state of a norm as «Inactive» in the normative network.
   → This operator is not invoked in this example since it does not refine norms (and hence does not deactivate norms).
12. A strategy with automatic norm generation

**TrafficNSExample4_NSStrategy:** How does the norm synthesis strategy work?

**Everytime the strategy is executed, it:**

1. **Perceives** the scenario by means of the monitor. It saves perceptions in the form of *ViewTransitions*. A *ViewTransition* describes a part of the scenario at time t-1 and at time t (that is, its transition from the previous to the current tick).

```java
/**
 * Calls scenario monitors to perceive agents interactions
 *
 * @return a {[code List]} of the monitor perceptions, where each perception
 * is a view transition from t-1 to t
 */
private void obtainPerceptions(List<ViewTransition> viewTransitions) {
    this.monitor.getPerceptions(viewTransitions);
}
```

2. **Detects conflicts** in perceptions by invoking method `getNonRegulatedConflicts()` of *DomainFunctions*.

```java
/**
 * Given a list of view transitions (from t-1 to t), this method
 * returns a list of conflicts with respect to each goal of the system
 *
 * @param viewTransitions the list of perceptions of each sensor
 */
protected Map<Goal, List<Conflict>> conflictDetection(
    List<ViewTransition> viewTransitions) {
    this.conflicts.clear();

    /* Conflict detection is computed in terms of a goal */
    for(Goal goal : this.nsmSettings.getSystemGoals()) {
        List<Conflict> goalConflicts = new ArrayList<Conflict>();

        for(ViewTransition vTrans : viewTransitions) {
            goalConflicts.addAll(dmfFunctions.getNonRegulatedConflicts(goal, vTrans));
        }
        conflicts.put(goal, goalConflicts);
    }
    return conflicts;
}
```
12. A strategy with automatic norm generation

3. **Generates norms** (one for each detected conflict) by means of operator `create`.

```java
/**
 * 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);
        }
    }
}
```

To execute this strategy, follow these steps:

1. In Eclipse, 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=«4»`.

Execute the simulator and see how, as long as cars collide, it generates norms to avoid those collisions in the future.
Tutorial outline

NormLab *execution*:

1. Execution examples
   1. **Example** strategy 1: Returns an *empty* set of norms.
   2. **Example** strategy 2: Returns a fixed set of *1 norm*.
   3. **Example** strategy 3: Returns a fixed set of *3 norms*.

2. Guided development of different norm synthesis strategies
   1. **Development** of example strategy 1: *Empty* set of norms.
   2. **Development** of example strategy 2: Fixed set of *1 norm*.
   3. **Studying** example 4: A strategy with norm *generation*.
   4. **Studying** example 5: A strategy with norm *generation + evaluation*.
   5. **Studying** SIMON: A strategy with norm *generation + evaluation + refinement*. 
We have seen how to automatically **generate** norms on-line. Let’s see now how can we automatically **evaluate** norms on-line.

For this example we are going to use the code of **example 5**, which is located in the package `es.csic.iiiia.normlab.traffic.examples.ex5`.

There, we can find the following classes:

- **TrafficNSExample5_NSAgent**
  The agent that creates the Norm Synthesis Machine and executes the strategy.

- **TrafficNSExample5_NSOperators**
  Operators to **create**, **add**, **activate** and **deactivate** norms in the normative network.

- **TrafficNSExample5_NSStrategy**
  A norm synthesis strategy that generates norms to avoid arisen collisions in the future, and continuously **evaluates** them in base of their outcomes in the scenario.

- **TrafficNSExample5_NSUtilityFunction**
  A function to **evaluate** norms’ utility based on their outcomes whenever agents fulfill/infringe norms.
We have seen how to automatically generate norms on-line. Let’s see now how can we automatically evaluate norms on-line.

For this example we are going to use the code of example 5, which is located in the package es.csic.iii.a.normlab.traffic.examples.ex5.

There, we can find the following classes:

- TrafficNSExample5_NSAgent
  The agent that creates the Norm Synthesis Machine and executes the strategy.

- TrafficNSExample5_NSOperators
  Operators to create, add, activate and deactivate norms in the normative network.

- TrafficNSExample5_NSStrategy
  A norm synthesis strategy that generates norms to avoid arisen collisions in the future, and continuously evaluates them in base of their outcomes in the scenario.

- TrafficNSExample5_NSUtilityFunction
  A function to evaluate norms’ utility based on their outcomes whenever agents fulfill/infringe norms.

You know how these things work...
13. Automatic norm generation + evaluation

How does norm evaluation work?

- Norm fulfilled + no conflicts $\rightarrow$ **Effective** norm (It avoids conflicts).
- Norm fulfilled + conflicts $\rightarrow$ **Ineffective** norm (It does not avoid conflicts).
- Norm infringed + no conflicts $\rightarrow$ **Unnecessary** norm (No conflicts arise when it is not fulfilled).
- Norm infringed + conflicts $\rightarrow$ **Necessary** norm (Conflicts arise when it is not fulfilled).

To evaluate norms at each tick, the norm synthesis strategy requires to retrieve:

1. The norms that have been **fulfilled** and **infringed** during the transition from the previous tick to the current tick.
2. Information about whether norm fulfilments and infringements led to conflicts or not in the current tick.
TrafficNSExample5_NSStrategy: How does this new norm synthesis strategy work?

Everytime this particular strategy is executed, it performs norm generation + norm evaluation. You already know norm generation. But... How is norm evaluation implemented?

Norm evaluation consists on the following steps:

1. **Compute norm applicability**, namely to retrieve the norms that applied to each agent in the simulation at time t-1.

   ```java
   protected Map<ViewTransition, NormsApplicableInView> normApplicability(
       List<ViewTransition> vTransitions) {
       this.normApplicability.clear();

       for(ViewTransition vTrans : vTransitions) {
           NormsApplicableInView normApplicability = this.normReasoner.getNormsApplicable(vTrans);
           this.normApplicability.put(vTrans, normApplicability);
       }
       return this.normApplicability;
   }
   
   ```

   - As you can see in the code, for each ViewTransition it employs a **NormReasoner** to compute the norms that apply to each agent in the viewTransition.
   - The NormReasoner employs the DomainFunctions to retrieve the norms that apply to each agent.
2. **Compute norm compliance**, namely to assess if agents **complied or not** with their applicable norms during the transition from the previous tick (time \(t-1\)) to the current tick (time \(t\)), and if they lead to **conflicts** or not.

```java
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);
        }
    }
}
3. **Update norms’ utilities** based on norm compliance.

```java
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);
            }
        }
    }
}
```

Each norm is evaluated in terms of:

- **The system goals.** Are norms useful to achieve system goals?  
  **Example:** In the case of traffic, are norms useful to avoid car collisions?

- **Two dimensions**, effectiveness and necessity. Are norms effective to avoid collisions? Are they necessary to avoid collisions?
Finally, the `normEvaluation()` method puts together norm applicability, norm compliance and update utilities:

```java
/**
 * Executes the norm evaluation phase
 */
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);
}
```

Let’s execute this strategy. Follow these steps:

1. In Eclipse, go to directory `repastr-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=«5»`. This will indicate `NormLab` that we do not want to load a pre-designed example.

Execute the simulator and see how now it generates norms and evaluates them. Observe how the effectiveness and necessity of norms change along time.
NormLab execution:

1. Execution examples
   1. Example strategy 1: Returns an empty set of norms.
   2. Example strategy 2: Returns a fixed set of 1 norm.
   3. Example strategy 3: Returns a fixed set of 3 norms.

2. Guided development of different norm synthesis strategies
   1. Development of example strategy 1: Empty set of norms.
   2. Development of example strategy 2: Fixed set of 1 norm.
   4. Studying example 5: A strategy with norm generation + evaluation.
   5. Studying SIMON: A strategy with norm generation + evaluation + refinement.
14. SIMON. A complete norm synthesis strategy

We are now going to see how to implement a complete norm synthesis strategy that performs:

1. Norm generation
2. Norm evaluation
3. Norm refinement

With this aim, we will execute the SIMON norm synthesis strategy. First of all, let’s tell NormLab that we want to execute SIMON:

1. In Eclipse, 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=«2». This will indicate NormLab that we want to use the SIMON norm synthesis strategy.
5. Search for the parameter «NormGeneralisationMode» and set the field defaultValue=«1». This will indicate NormLab that we want SIMON to use Deep norm generalisation.
6. Search for the parameter «NormGeneralisationStep» and set the field defaultValue=«1». This will indicate NormLab that we want SIMON to generalise just one norm predicate simultaneously in each norm generalisation.

You already know these phases
Let’s see how SIMON refines the normative system
14. SIMON. A complete norm synthesis strategy

Your `parameters.xml` file should look like this:

```xml
<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="2" />

<parameter name="NormGeneralisationMode" isReadOnly="false" displayName="NSM: Norm generalisation mode (SHALLOW/DEEP)" type="int"
  converter="repast.simphony.parameter.StringConverterFactory$IntConverter"
  defaultValue="1" />

<parameter name="NormGeneralisationStep" isReadOnly="false" displayName="NSM: Norm generalisation step" type="int"
  converter="repast.simphony.parameter.StringConverterFactory$IntConverter"
  defaultValue="1" />
```
Norm refinement: Generalises norms when possible, and specialises norms when necessary.

- Norm generalisations allow to synthesise compact normative systems by generalising several norms to one unique norms that implicitly represents them.
Norm generalisations allow to increase the compactness of the normative system

\[ \text{Normative system} \{n_1, n_2, n_3\} \]

- \( n_1 \): Give way to **ambulances**
- \( n_2 \): Give way to **fire brigade**
- \( n_3 \): Give way to **police cars**
14. SIMON. A complete norm synthesis strategy

**Norm generalisations** allow to increase the compactness of the normative system

\[ \text{Normative system } \{n_1, n_2, n_3\} \quad \rightarrow \quad \text{Normative system } \{n_4\} \]

- \( n_1 \): 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 specialisations allow to remove from the normative system those norms that under-perform.

- **n₁**: Give way to *ambulances*
- **n₂**: Give way to *fire brigade*
- **n₃**: Give way to *police cars*
- **n₄**: Give way to *emergency* vehicles
Norm specialisations allow to remove from the normative system those norms that under-perform.

\[ \text{NN}_1 \xrightarrow{} \{n_4\} \]

\[ \text{NN}_0 \xrightarrow{} \{n_1, n_2, n_3\} \]

- \(n_1\): Give way to \textbf{ambulances}
- \(n_2\): Give way to \textbf{fire brigade}
- \(n_3\): Give way to \textbf{police cars}
- \(n_4\): Give way to \textbf{emergency} vehicles
Norm refinement: **Generalises** norms when possible, and **specialises** norms when necessary.

1. Norms are **generalised** whenever their effectiveness and necessity are **over** a generalisation threshold.
2. Norms are **specialised** whenever their effectiveness or necessity are **under** a specialisation threshold.

```java
private void normRefinement() {
    /* Add norms that have been rewarded with a negative value */
    this.addNegRewardedNorms(negRewardedNorms);

    /* Monitor norm utilities to detect utilities passing thresholds */
    this.checkThresholds();

    /* Specialise norms that under perform */
    for(Norm norm : this.specialisableNorms) {
        specialiseDown(norm);
    }

    /* Generalise norms that may be generalised */
    for(Norm norm : this.generalisableNorms) {
        generaliseUp(norm, genMode, genStep);
    }

    /* Link new norms that have been generalised to
    * other potential child norms in the normative network */
    for(Norm normA : this.createdNorms) {
        for(Norm normB : this.normativeNetwork.getActiveNorms()) {
            if(!normA.equals(normB))
                this.searchRelationships(normA, normB, null, visitedNorms);
        }
    }
}
```