NormLab: A Framework to Support Research on Norm Synthesis[*]

(Demonstration)

Javier Morales[1,2], Iosu Mendizabal[1]
[1](IIIA) Artificial Intelligence Research Institute
(CSIC) Spanish Council for Scientific Research
jmorales@iiia.csic.es
iosu.mendizabal@gmail.com

David Sánchez-Pinsach[2], Maite Lopez-Sanchez[2]
[2]University of Barcelona
Barcelona, Spain
sdividis@gmail.com
maite@maia.ub.es

Michael Wooldridge
Dept. of Computer Science
University of Oxford
Oxford, United Kingdom
mjw@cs.ox.ac.uk

Wamberto Vasconcelos
Dept. of Computing Science
University of Aberdeen
Aberdeen, UK
wvasconcelos@acm.org

ABSTRACT

MAS research has investigated norms as a means to coordinate open multi-agent systems (MAS). This has spurred a strand of research on on-line norm synthesis algorithms for MASs. However, to the best of our knowledge, currently there is no computational framework to support the development and study of on-line norm synthesis. Here we present NORMLAB, a novel framework to support norm synthesis research, highlighting its important features. We also outline the operation of two novel on-line norm synthesis strategies, which significantly outperform the state of the art.

Categories and Subject Descriptors

I.2.11 [**Artificial Intelligence**]: Distributed Artificial Intelligence —*Multiagent Systems*

1. INTRODUCTION

Norms can be employed to coordinate interactions between agents within Multi-Agent Systems (MASs). However, computing a normative system (i.e., a set of norms) that will effectively coordinate a MAS is a computationally complex (NP-hard) problem [5]. Two approaches for norm synthesis have been considered in the literature: off-line and on-line. While off-line approaches (such as [5]) aim at synthesising normative systems at design time, on-line approaches synthesise normative systems at runtime. Even though MAS research has investigated the on-line synthesis of norms, to the best of our knowledge, there is no computational framework supporting the development and study of on-line norm synthesis.

The purpose of this demo (available at [4]) is two-fold. First, we introduce NORMLAB, a framework to support the development and analysis of on-line norm synthesis strategies in a controlled, simulated multi-agent environment. NORMLAB incorporates facilities to develop, monitor, and evaluate different on-line norm synthesis strategies. Furthermore, it includes a library of state-of-the-art on-line norm synthesis strategies, namely S-SIMON [3], D-SIMON [3] and IRON [2]. Such library provides researchers on norm synthesis with reference implementations and benchmarking strategies.

Second, we briefly introduce and compare the three norm synthesis strategies included in NORMLAB. Our purpose is to illustrate that optimistic norm synthesis strategies, such as S-SIMON and D-SIMON, outperform pessimistic ones, such as IRON, with respect to the novel key criteria of minimality and simplicity introduced in [3]. On the one hand, minimality is concerned with minimising the number of norms in a normative system imposed on agents. On the other hand, simplicity is concerned with synthesising norms that are *easy* to reason about by agents. We demonstrate that both S-SIMON and D-SIMON synthesise smaller and easier normative systems than IRON. The explanation to this observation is rooted in the way the three synthesis strategies perform norm generalisations, where norm generalisation is conceived as an operation to join several norms into a general norm that concisely represents them all in a simpler way. As an example of a generalisation in a road traffic scenario, a norm such as "give way to emergency vehicles" is more general than having a separate norm for every different type of emergency vehicle (e.g., police, ambulance, fire brigade). Notice that a norm generalisation reduces the number of norms in a normative system, (leading from 3 norms to 1 norm in this example), hence favouring minimality. Moreover, a general norm is simpler than the specific norms it generalises because it is easier to reason with. Thus, general norms favour simplicity of normative systems.

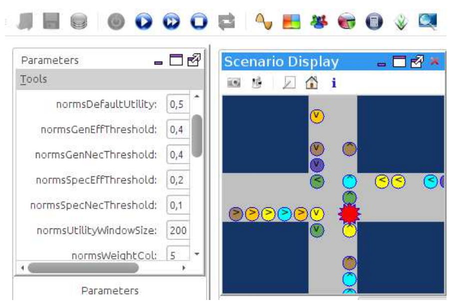

Figure 1: GUI of a simulated traffic scenario.

2. NORMLAB AT A GLANCE

NORMLAB is a framework to support norm synthesis research. Its primary goal is to ease the development and empirical analysis of

[*]Funded by AT(CSD2007-0022), COR(TIN2012-38876-C02-01/02), and 2009-SGR-1434. M. Wooldridge was supported by ERC under Adv. Grant 291528 ("RACE").

Appears in: *Alessio Lomuscio, Paul Scerri, Ana Bazzan, and Michael Huhns (eds.), Proceedings of the 13th International Conference on Autonomous Agents and Multiagent Systems (AAMAS 2014), May 5-9, 2014, Paris, France.*

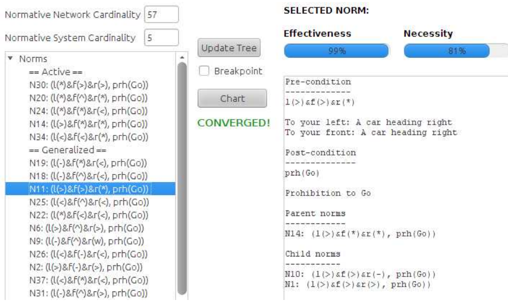

Figure 2: The norms visualiser.

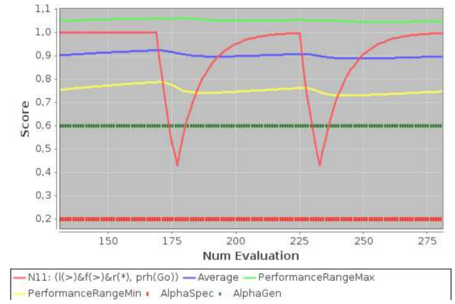

Figure 3: Evolution of a norm's effectiveness along time.

norm synthesis strategies. With this aim NORMLAB is equipped with the following core components:

A simulation engine. NORMLAB incorporates a simulation environment of a traffic scenario where vehicles are modelled as agents. Within this setting, the purpose of a norm synthesis strategy is to synthesise norms for the vehicles in the simulated scenario. Figure 1 depicts the display output by NORMLAB's traffic scenario simulator. The figure shows a traffic scenario composed of two orthogonal roads. Coloured balls represent travelling vehicles, the arrows inside vehicles represent their travelling directions, and red stars represent collisions among vehicles (i.e., conflicts).

A general architecture. NORMLAB includes an implementation of the domain-independent, general architecture for a norm synthesis machine introduced in [2]. It supports the implementation of a computational model of the norm synthesis cycle, composed of four steps that are continuously performed: (1) sensing of the interactions in the MAS; (2) synthesis of a new normative system by means of a norm synthesis strategy; (3) evaluation of the normative system; (4) delivery of the normative system to the agents in the MAS. Therefore, the norm synthesis process and outcome will vary depending on the norm synthesis strategy employed at step 2.

An API to ease norm synthesis development. NORMLAB provides an Application Programming Interface (API) that supports the implementation of new norm synthesis strategies. NORMLAB's API is based on the general architecture included in the framework. Moreover, it offers: (i) a collection of data structures and operators to represent and operate with norms and normative systems; and (ii) functions to evaluate norms and normative systems in terms of their effectiveness, necessity, minimality and simplicity.

A library of state-of-the-art norm synthesis strategies implementing: S-SIMON [3], D-SIMON [3], and IRON [2]. It provides researchers on norm synthesis with reference implementations that are intended as a stepping stone towards their own developments. Furthermore, they are also included for benchmarking purposes.

Monitoring facilities. NORMLAB provides the following monitoring facilities: (i) a GUI of the simulated scenario (Fig. 1); (ii) a norm information panel (Fig. 2) depicting the synthesised norms, along with their states, evaluations, and relationships; (iii) graphs to track the evolution of a norm's evaluation. In particular, Fig. 3 depicts a graph showing norm's effectiveness along time.

3. DEMONSTRATING NORM SYNTHESIS STRATEGIES

The main difference between S-SIMON, D-SIMON and IRON norm synthesis strategies is based on their generalisation method. Both S-SIMON and D-SIMON adopt an *optimistic* approach that requires less information than IRON, since they generalise norms with partial evidence while IRON requires full evidence. Considering again the traffic scenario, IRON requires a norm for each kind of emergency vehicle (e.g., police, ambulance, fire brigade), whereas both S-SIMON and D-SIMON can generalise to a norm such as "give way to emergency vehicles" as soon as they synthesise norms for a subset of such vehicles. Particularly, S-SIMON implements a direct or shallow generalisation, whereas D-SIMON takes a deeper analysis of the normative system and discovers additional partial generalisations. This partial generalisation is based on an *anti-unification* method [1], which generalises terms to their *least common subsumer* (i.e., the most specific term that is common to all of them).

Partial generalisation allows S-SIMON and D-SIMON to outperform IRON, increasing the minimality and simplicity of resulting normative systems. Specifically, D-SIMON is the best-in-class strategy, managing to synthesise normative systems that are up to 41.93% more minimal and 60.68% simpler than those synthesised by IRON.

4. CONCLUSIONS

Normative multi-agent systems constitute an extremely active research area. Nevertheless, to the best of our knowledge, it lacks computational frameworks supporting the development and study of on-line norm synthesis. Against this background, this demo presents NORMLAB, a novel framework to enable the development and analysis of on-line norm synthesis algorithms in a controlled, simulated multi-agent environment. Furthermore, it includes a library of state-of-the-art on-line norm synthesis strategies (S-SIMON, D-SIMON and IRON). This library provides researchers on norm synthesis with reference implementations and benchmarking strategies. NORMLAB has been conceived to reduce the burden of designing and implementing new on-line norm synthesis strategies from scratch. Our analysis of the norm synthesis strategies included in NORMLAB indicates that there are research opportunities in the design and implementation of novel on-line synthesis strategies.

5. REFERENCES

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

[2] J. Morales, M. Lopez-Sanchez, J. A. Rodriguez-Aguilar, M. Wooldridge, and W. Vasconcelos. Automated synthesis of normative systems. In *AAMAS 2013*, pages 483–490, 2013.

[3] J. Morales, M. Lopez-Sanchez, J. A. Rodriguez-Aguilar, M. Wooldridge, and W. Vasconcelos. Minimality and simplicity in the automated synthesis of normative systems. In *AAMAS 2014*, 2014.

[4] J. Morales, I. Mendizabal, D. Sanchez-Pinsach, M. Lopez-Sanchez, M. Wooldridge, and W. Vasconcelos. Normlab: A framework to support research on norm synthesis (demo). http://youtu.be/g9shlgttZnI.

[5] Y. Shoham and M. Tennenholtz. On social laws for artificial agent societies: off-line design. *Artificial Intelligence*, 73(1-2):231–252, February 1995.