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Special Issue on
ICT-based strategies for environmental conflicts

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Abstract: The special issue on *ICT-based strategies for environmental conflicts* - to be published in the journal *Strategic Behavior and the Environment* - contains four peer-reviewed articles devoted to the analysis of multi-agents decision problems arising from the exploitation of environmental resources, and where Information and Communications Technologies are crucial for the design and the implementation of environmental policies. In this short presentation of the special issue, the Guest Editors provide a brief summary of the contributed papers, together with some insights gained from their original motivations and main results.

Introduction

Information and Communication Technologies (ICTs) can be critical for new environmental policies that may affect human communities, both at local and at international levels. For instance, technological advances require systems that can optimize the use of telecommunications infrastructures and standardized software to address environmental management needs. Or, they may demand the implementation of algorithms reducing the energy consumption of computing and of managing communication networks. However, most of these ICT applications involve multiple actors interacting via complex protocols that make it difficult to implement coordinated strategies aimed to improve resource management, networking, and information exchange.

The goal of the Special Issue on *ICT-based strategies for environmental conflicts* is to present contributions from different areas of strategic behaviour analysis dealing with multi-agents decision problems arising from the exploitation of environmental resources, and where ICTs are crucial for the selection or the implementation of environmental policies. With this objective, particular emphasis has been given to the discussion of ICT applications addressing one or more of the following environmental issues.

The first issue deals with the analysis of policies providing a valuable contribution to sustainable environmental management by improving the monitoring and the coordination of different stakeholders. As discussed in Dovers [7], this kind of analysis requires the "integration" of environmental, social, economic aspects and other multi-disciplinary issues as well as stakeholder interests, and

where the meaning of the term "integration" is intended to be established in a very broad manner, including the response across social systems, the collection of information and knowledge sharing. In this direction, Bottero et al. [6] in this collection, introduce an application of a Multiple Criteria Decision Aiding method to support the preparation of a land-use plan for a small town in Italy, taking into account the main steps of the process aimed to involve the population in planning decisions.

Another issue treated in this book is the formulation of protocols enabling a more efficient allocation of natural resources or providing incentives for reducing the consumption of energy, water and other natural resources through more efficient procedures. For example, the carbon footprint of ICT technologies themselves represents an important and ever-increasing contribution of the global CO2 emissions. In order to reduce their carbon footprint, emerging ICT technologies are embedded with energy-aware protocols and energy saving techniques (Bolla et al. [5]). The role of interactions among agents is taken into account in Bianzino et al. [3] in this collection, re-introducing and discussing some energy-aware routing approaches in backbone networks, which take into account the criticality of devices in the considered network scenario, the relevance for network connectivity of the devices and the amount of traffic that they are routing.

The third issue deals with the analysis of socio-ecological communities and the amount of data that is generated during our everyday activities on Internet and other modern communication technologies, which opens new questions in organizational and societal behaviour. For example, how can we explain the organizational behaviour of communities by gathering network data through the interaction among people? Can we explain how human communication dynamics in natural resource governance is linked to the organizational formation of social networks (Bodin and Crona [4])? Moreover, designing ideal platforms for communication and debate about environmental problems is central to overcome physical and social barriers and allowing for the formation of special-interest social networks and virtual communities. Moretti [12] re-introduces some applications from the literature of coalitional games, aimed at modelling social dimensions like Resilience and Social Capital, and shows some direction to empirically test on data such applications within the MAS (Multiple Agent System) framework applied to the evolution of social ecosystems.

The fourth and final issue is related to the definition of incentives and mechanisms to support the right of access to information related to the quality and the utilization of environmental resources. A way to achieve it is to support the concept of open source for wireless, mobile phone and web-based applications. Open source systems are very vulnerable to malicious attacks, and policies aimed to guarantee the correct users' access need to be implemented. Tembine [15] in this book, analyzes the problem of ensuring security for cognitive radio in wireless networks using mean field stochastic games. The first function of cognitive radio networks is to serve the demand of spectrum of licensed users (primary users), allowing for the accommodation of the demand of spectrum of external secondary radio devices (secondary ussers). In this context, Tembine

[15] proposes an optimal strategy against possible malicious attakers and focuses on exploiting mobility and energy savings.

In the following sections we introduce the individual papers presented in this special issue, the original motivations, the methodology employed and the main results.

Enabling public participation in Strategic Environmental Assessment: an application of Multicriteria Analysis

Marta Bottero, Valentina Ferretti, Giulio Mondini, Silvia Pomarico

Background: In the last decade, the design and the implementation of public policies in the domain of sustainable development has determined a rapidly growing interest for techniques of environmental impact assessment aimed at better linking the decision-making process and the opinions of the different stakeholders involved.
Methodology: This paper proposes a Multiple Criteria Decision Aiding method to support the preparation of a land-use plan for a small town in Italy, aimed at helping Decision Makers (DMs) to integrate the different opinions of the stakeholders (public authorities, citizens, associations, etc.). In this context, the Analytic Network Process (ANP) represents a theory of relative measurement on absolute scales of both tangible and intangible criteria based on both the judgement of experts and on existing data. The application of ANP has focused on the evaluation of the importance of the different areas with respect to the development of the Municipal Plan based on the information coming from the participatory process that had been conducted to develop the plan.
Results: Starting from the most relevant planning goals of citizens (and the actions that citizens would like to see implemented to achieve those goals), the municipal territory has been divided into five strategic areas according to their importance for the future development of the town. It has been shown that, via the ANP method, it is possible to achieve a transparent and traceable decision-making process facilitating deliberation, supporting communication with the DMs and granting a mutual understanding among stakeholders.

The Green-Game: accounting for device criticality in resource consolidation for backbone IP networks

Aruna Prem Bianzino, Jean-Louis Rougier, Claude Chaudet, Dario Rossi

Background: Telecommunication infrastructures are responsible of a large part of the carbon offprint of ICT technologies. As a consequence, the research community is showing an ever increasing interest in studying techniques and algorithms to reduce the energy consumption of ICT systems.
Methodology: In this paper, the problem of reducing power consumption in backbone networks is studied according to an energy-aware routing approach

and keeping into account the contribution of devices in the network to provide a good quality of service (QoS) level. Different models have discussed, with the objective to summarize the contribution of devices using power indices (and in particular the Shapley value) of particular coalitional games defined over the set of the elements of a backbone network. Such coalitional games incorporate the information about the network structure (e.g., the connectivity of sub-networks), the amount of traffic that the devices are routing and the network robustness (i.e., possible failure scenarios).
Results: The ranking provided by the Shapley value of such games has been used to drive a resource consolidation process, i.e., the selection of those devices that should be switched off first in order to reduce the energy consumption keeping into account the expected global performance of the network. Such a ranking has been compared with different ranking methods on a realistic network scenario. The results yielded by this comparison show that the Shapley value ranking may provide high energy savings with a smaller impact on the expected QoS levels on the network.

On the role of coalitional network games in modelling the social dimension in ecosystem management

Stefano Moretti

Background: Most of the computational approaches in the literature concerning the management of natural and social systems have not been rigorously validated using empirical data. For example, models based on Multi-Agent Systems (MASs) have been widely used to compare different self-governance policies aimed at avoiding the collapse of environmental resources, but they present huge difficulties to be validated on complex scenarios dealing with large social interaction datasets.
Methodology: This paper discusses two important families of indicators for social-ecological systems: Resilience, aimed to analyse the ability of social ecosystems to absorb changes on both human and ecological variables, and Social Capital, intended as an assessment of the set of all those human relations which are important for the sustainability issue. In particular, the paper presents a review of the main applications based on coalitional games that model these two fundamental indicators for social ecosystems on a micro scale, and they have proved their feasibility and efficiency even on macro situations, where the number of nodes of networks scales up dramatically.
Results: The paper discusses several models from the literature of coalitional games aimed at measuring multi-dimensional social attributes of Resilience and Social Capital. Such models could be empirically tested within the MASs framework in order to verify their ability to predict the evolution of social ecosystems. Several numerical examples from different fields of network analysis are provided.

Energy-constrained mean field games in wireless networks

Hamidou Tembine

Background: Cognitive radios are wireless devices that can autonomously and dynamically adapt the characteristics of their transmissions (waveform, energy, channel, spectrum, networking protocols etc.) in order to better serve the primary users (PUs), who are those licensed to use the spectrum. However, cognitive radio aims at accommodating the spectrum access of extra radio devices referred to as secondary users (SUs) under the constraint that PUs have to be as little affected as possible by the presence of SUs. Moreover, due to intrinsic characteristics of dynamic spectrum access, cognitive radio networks are very vulnerable to malicious attacks that may concern both PUs and SUs.
Methodology: This paper proposes a feedback strategy against the attackers and focuses on exploiting mobility and energy consumption by considering wireless networks where users are distributed in an Euclidean space and have a limited energy, and where SUs decide their transmission power depending on their remaining battery state and the signal strength of PUs. The modelling approach is based on mean field games, that are used to define and evaluate macroscopic properties of dynamic wireless networks, representing wireless networks as a collection of interacting nodes characterized by dynamic random processes in an Euclidean space.
Results: The proposed mean field framework allows for the description of the evolution of the density distribution and the associated performance metrics using coupled dynamical equations. Explicit formulas and algorithms are given for the management of the power of PUs and SUs keeping into account attackers' strategies. A complete characterization of the optimal distribution of the energy and of the payoff function (based on the Shannon information rate) is provided.

Future Directions

At the end of the nineties, the Guest Editors of this special issue were involved in a project concerning the analysis of cost allocation methods for waste management (Moretti [11], Moretti and Patrone [13]). The project was aimed at studying the actual protocols used by consortia of Italian municipalities to share the costs of waste collection and disposal, and at comparing those protocols with the allocation rules proposed by cooperative game theory. It turned out that the rules used for cost allocation were very simple, and relied on the proportionality criterion (Moretti and Patrone [13]) applied, respectively, to population size, quantity of waste and surface of the municipalities (or, in some cases, to a linear combinations of these values). Moreover, the project pointed out to the difficulties of finding real data on waste management, and to the role played by costs related to the collection of the relevant data for building a game, due to the fact that those data were somehow estimated from very partial and incomplete informations.

Nowadays, things seem quite different, at least with respect to the availability of data on waste management. In fact, due to an increasing demand of transparency for public policies, associated with a substantial improvements of distributed technologies for the continuous data monitoring and sharing on several waste operations, an impressive number of large datasets about all stages of the waste life-cycle can be used to retrieve a very detailed account of the production, the collection and the disposal of waste over broad regions. By means of sensors inside trash containers, for instance, researchers my monitor on real time several variables related to the dynamic of waste production (Vicentini et al. [16]); the integration of several technologies of geographical positioning with geographic information systems allows users to continuously monitor the location of collection trucks via web-based applications (Arebey et al. [1]).

However, even if it seems more and more clear that game theoretic models (and in particular the cooperative ones) can be potentially used to analyse the interaction among several stakeholders and the stability of agreements on fair allocations of costs arising from waste management systems (Karmperis et al. [9]), still we have no evidence of cost allocation protocols based on game theoretic considerations that have been implemented in the standard practice of waste management. Fifteen years after the beginning of the project, it is then reasonable to ask whether the absence (with a few exceptions) of game theory in the standard practice of cost sharing in waste management is due to different reasons, other than the cost of collecting the pertinent information. Are there other cost items affecting a concrete application of game theoretic models? Are those cost items specifically referred to waste management, or they are connected to more general problems dealing with the analysis and the elaboration of large environmental datasets?

The idea of editing a special issue of *Strategic Behaviour and the Environment* devoted to ICT-based interaction situations, was partially inspired by the purpose of addressing the above questions. Now, the picture that emerges from the papers collected in this volume point out that the problem of computational complexity related to games can be to some extent overcome by the use of approximation techniques aimed to make good estimation both of the structure of the game and of the solution concepts associated with it (see, for example, Bianzino et al. [3] and Moretti [12]). On the other hand, looking at the different applications of game theoretic models in the literature, it seems that the environmental applications of game theoretic models on real data are still in an embryonic stage, despite the great interest shown for these applications by the scientific community (Bahn et al. [2], Parrachino et al. [14]).

In addition, nowadays, the possibility of quick access to large databases on various environmental issues, has made more evident the difficulties related to the game theoretic modelling process through the data or, more precisely, associated with the methods used to transform the big amount of information available in modern databases in the proper language of game theory. In other words, it seems that game theory still lacks the analytical substrate that has allowed, for example in biology and medicine through the specialization of informatics and statistics, to translate the large masses of data provided by new experi-

mental technologies to intelligible information in the light of modern biomedical theories. For example, as more and more detailed records on the behaviour of individuals in interaction situations are registered, such as in social, ecological or business networks, it is not at all clear how statistical or data-mining techniques can be used, in general, to aggregate this data at the level of larger communities (or, conversely, if only the information on communities exists, how to disaggregate it at the level of interaction between subgroups or individuals) (Kleinberg et al. [10]). Furthermore, due to the large dimension of environmental datasets, the applications of game theoretic models to the practice of environmental management need specific techniques of data processing that should be performed in an automatic or semi-automatic way (Elovici and Braha [8]).

In conclusion, the lesson learned from the collection of papers presented in this volume, tells us that the effective practice of game theory in the management of environmental issues (using models that are able to cope with the ever increasing availability of data concerning the interaction of the different actors involved) can not - and should not - disregard a good definition of general rules aimed at transforming (in a systematic way) the observed data into usable information in the context of a game. As it was previously the case for other disciplines, such as for biomedical applications or experimental physics, the definitions of these general rules should take place in parallel with the definition of statistical and data processing protocols specifically tailored to the language of game theory.

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