WHAT-IF ANALYSIS THROUGH SIMULATION-OPTIMIZATION HYBRIDS

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Public policy issues are extremely complex, occur in rapidly changing environments characterized by uncertainty, and involve conflicts among different interests. Our society is ever more complex due to globalisation, enlargement and the rapidly changing geo-political situation. Therefore, the effects of any intervention become more difficult to assess. Of course, it is becoming ever more important to ensure that actions are effectively tackling the real challenges that this increasing complexity entails.

The majority of policy models rely on agent-based simulation (Troitzsch et al., 1999; Matthews et al., 2007; Gilbert, 2010) where agents represent the parties involved in the decision-making and implementation process. The hypothesis is that for modelling complex systems, agent-based simulation is a suitable approach to understand such systems in a more natural way. In particular, agent-based models enable the use of computer experiments to support a better understanding of the complexity of economic, environmental and social systems, structural changes, and endogenous adjustment reactions in response to a policy change. In addition to agent-based simulation models, which provide *individual level models*, we claim that the policy planning activity needs a global perspective that faces the problem at a global level and should tightly interact with the individual level model. The policy maker must take decisions by perceiving a set of (possibly conflicting) objectives, and satisfying a set of constraints while at the same time reducing negative impacts and enhancing positive impacts on the environment, society and economy. Simulation could be therefore used to understand the impact of her decisions via what-if analysis or scenario analysis.

If a decision maker received no useful feedback regarding the impact of decisions, this would be the worst outcome of all. However, typically at present a policy maker devises a set of scenarios to be simulated and evaluates the impact of the taken decisions. The process iterates as soon as the policy maker finds a solution that satisfies her. The simplest way to improve this process is to aid the decision maker in the first step of her process, by designing a Decision Support System (DSS) for the selection of (Pareto) optimal points corresponding to specific political actions. In brief, the problem components that the policy maker should take into account, namely impacts on environment, economy, financial aspects, territory-based constraints, and objectives, can be cast as a combinatorial optimization and decision problem and solved using the appropriate techniques, described e.g. in (Gavanelli et al., 2010). Despite being more sophisticated than the *manual* approach, this secondary process still exhibits a generate-and-test behaviour. In other words, the decision making and optimization component operates within the confines of a limited information set and is not guided toward simulation-reasonable solutions.

We propose an approach that enables a tight interaction between a simulator and a decision making component based on machine learning. Machine learning is used to synthesize constraints for the decision making component from simulation results. We have experimented this technique on the Italian Emilia-Romagna region, and in particular on its Regional Energy Plan. The definition of the plan is

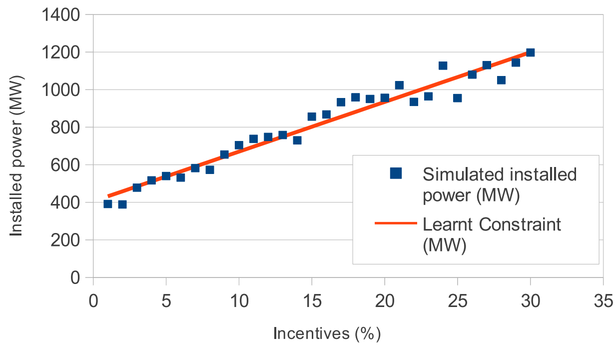

Figure 1: Learned function.

provided by a decision support system by casting the problem in a mathematical model and solving it through optimization techniques. On the other hand, the implementation strategy, namely the definition of the percentage of incentives to reach the objectives of the regional plan, can be only understood through agent-based simulation. We have performed a large number of simulations (1500) for each value of incentives from 1% to 30% in steps of 1%. Each simulation has 1000 agents and we recorded, for each simulation the total installed power in MW of Photovoltaic plants. We have therefore passed these data to various regression algorithms and the best one was the linear regression. We obtained a linear relation between the incentive and the installed MW, as depicted in figure 1, and inserted this relation into the decision support model.

We are now studying an alternative approach that maintains close connections between simulation and the decision-making components, and abandons the generate and test behaviour. The approach is based on the game theoretic principles of Mechanism Design.

When one assumes that agents are all self-interested and rational utility maximizers, one can apply the solution concepts of Nash Equilibrium to predict expected outcomes. This is an attractive concept for policy makers because it can aid the predictability of novel economic policies or initiatives.

Cleverly designed economic mechanisms (or auctions) can allocate resources and determine payments that are resilient to manipulation. The design of subsidy schemes to support the construction of public goods is particularly challenging (Laffont, 1987). Our setting involves a possibly large number of agents and a set of renewable technologies so tractability concerns must also be borne in mind (Nisan and Ronen, 2001). The key design challenge concerns the *free rider problem* and consequent under provision of public goods.

References

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