Composing games into complex institutions

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May 13, 2023

Game theory, since its development by von Neumann and Morgenstern [1], has proliferated through the biological and social sciences as a powerful formalism for modeling strategic and cooperative interactions. Economics in particular has applied it to core disciplinary questions, with a keen interest in analytical modeling and the formal properties of game solutions. However, this wildly successful research agenda has obscured other promising uses of game theory. For instance, game theory has also long been recognized as a potential tool for the faithful description and detailed design of realistic social institutions [2]. Calls for this high-fidelity or "descriptive" game theory have been heard from disciplines as diverse as international development [3], law [4], animal behavior [5], institutional economics [6], and sustainability [7]. For example, political scientist Elinor Ostrom introduced the "action situation" framework as an empirically grounded generalization of game theory for structuring ethnographic description [8], and she imagined formal representations of institutions in terms of systems of linked action situations. The economist Leonid Hurwicz pursued the same conception of institutions as linked systems of games [9]. In these approaches, the central questions about an institution may not involve its solutions but the uniqueness of its decision structure or its structural complexity relative to comparable institutions.

These new uses require scale, heterogeneity, and overall complexity that existing game forms were never intended to represent. We highlight the need for a theory of complexes of games that permits modularity, abstraction, and other core principles of software engineering. In particular, in this talk we demonstrate how compositional game theory [10] and the open games engine can be effectively applied to five cases across auction theory, sustainability science, institutional economics, contract law, and smart contract engineering. Three of these cases were presented in a recently-published paper in PLOS ONE, while two cases represent follow-up work built on top of the results of the aforementioned paper. In each of these very different cases, we will emphasize (1) the practical ways in which categorical ideas enter into and help support the practice of institutional modeling and design, and (2) the practical limitations of our existing tooling, with an eye to more scalable applications for institutional design.
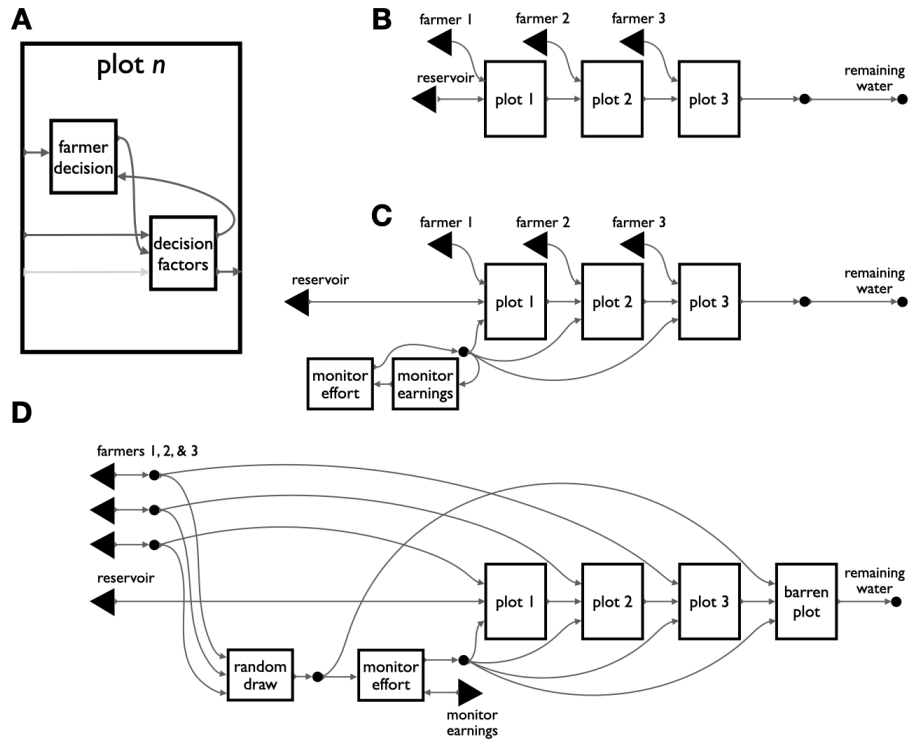
Figure 1: **Irrigation game with rotating monitor.** An example of a case study in sustainability science. In this game, drawn from a case of Nepali farmers in the common-pool resource management literature, upstream farmers are incentivized to draw a maximum of water without concern for the water needs of downstream farmers. A monitor role can exert effort to check compliance and administer punishments, and this role can be assigned to a third party or either of the agents occupying each farmer role.

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