Institut de Recherche
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Model-Checking and Automated Mechanism Design

Context

Mechanism design consists of designing a game with respect to some intended properties; it is traditionally a manual activity. Designer creates a set of rules describing the mechanism (eg: Auction) and will then manually check the properties of the mechanism. Such representation is usually ad hoc. *Automated Mechanism Design* aims at creating mechanisms in an automatic way [CS02, San03], i.e., based on computational techniques. In [PW03], the authors advocate for using logic-based technique for automating mechanism design.

In line with this goal, some works started to investigate application of formal methods to the semi-automatic or automatic verification for mechanism design [W+07, THW11]. Recently in [MMMP21], we show that Strategy Logic [CHP10] is a good candidate for a general-purpose logic for mechanism design. To do so we describe how an Auction can be encoded as a Concurrent Game Structure and how classical expected Auction properties may be represented as logical formulae, that is explicit plain objects. More precisely, we can encode in Strategy Logic concepts as Nash Equilibrium or properties as Strategyproofness. We extend this work by showing how a Concurrent Game Structure may be synthetised [MMMP22] and how Uncertainty may be be considered [MMMP23]

In that context, the overall goal of this PhD proposal is to investigate (i) how a Concurrent Game Structure representing a Mechanism may be synthetized in an automated while keeping a good balance between compactness and complexity way and (ii) to model check the properties of the Mechanism. This PhD should then be viewed as building a full pipeline for automating Mechanism Design going from the creation of Mechanism to its evaluation.

Research topic

The starting point of this research is the quantitative version of Epistemic Strategy Logic: SLK[F] and the associated model-checking problem [MMMP21,MMMP22]. We have

shown that satisfiability is PSPACE under some conditions about the strategic behaviour of the bidders and that synthesis is in general *k*-EXPTIME.

A first challenge consists of creating a tool for automated verification of SLK[F]-formulas. To do so, the first step consists of implementing an extension of an existing tool, named MCMAS-SLK [ČLMM14], to handle quantitative information. MCMAS-SLK is a model checker for the verification of systems against specifications given in epistemic strategy logic (SLK). To do so, a promising starting point is the model checker for fuzzy computation tree logic (CTL) [PLCM15]. An open research question is the encoding of weighted concurrent game structure (wCGS) in a compact representation which are considered as input of MCMAS.

The second challenge concerns the generation of such Concurrent Game Structure. An immediate starting point is the Auction Specification defined with the help of an Auction Description Language [MP20, MBP21]: "executing" such description can generate wCGS. Numerous questions need to be investigated: does this lead to numerous models? Is there a minimal and canonical one? Are they any bisimulation relations among those wCGS?

Ongoing research in the field of Automated Mechanism also proposed promising paths: two popular techniques for generating mechanisms are Machine Learning [D+19] and linear programming [Voh11]. The thesis will investigate how mechanisms generated by such techniques can be encoded into wCGS.

Work on Auction and Strategic Reasoning in IRIT's AI department has been conducted since 2019 mainly by Laurent Perrussel and this work is related to the ANR Project AGAPE[1]. The proposed PhD project will co-tutored by *Laurent Perrussel* and *Guillaume Feuillade*.

Underlying theories and tools

- Non classical logic – Modal Logic
- Model checking and verification techniques
- Game theory and Mechanism Design

Expected agenda

Y1. Review literature. Work on model checker extension
Y2. Improvement of the model checker (efficiency – wCGS representation). Synthesis of Auction models based on ADL. Evaluation of the first version of the pipeline
Y3. Generating Auction models via Machine Learning and Linear Programming technique. Evaluation of the second version of the pipeline.

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