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The engineering of circular causality for specialization and design of complex systems: cad2CAS and casCAD2

Key words: Decentralized Autonomous Organizations and Operations; Parallel Intelligence;Governance Mechanism

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Motivation

1. Decentralized autonomous organizations and operations (DAOs), equipped with innovative mechanisms, enable new possibilities for transforming traditional social collaborative relationships.

2. As a complex system encompassing both social complexity and engineering complexity, DAO mechanisms need to dynamically adapt to the changing external environment. Traditional top-down approaches cannot effectively deal with these problems.

3. The circular causality theory views the operation of complex systems as a continuously evolving dynamic process, providing new perspectives to address these challenges.

Method

The objective of setup loop can be expressed as follows:

$$M^* = \arg\min_{M}(\mathrm{diff}(M(C), F(C)))$$

The participants' strategies for M can be expressed as follows:

$$C^* = \arg\min_{C} V(M(C))$$

where the optimal strategy c_i^* constantly maintains

$$v_i(M(c_i^*), \theta) \geq v_i(M(c_i'), \theta), \forall c_i' \in C_i / c_i^*$$

Thus a causal chain is formatted which can be represented as

$$M \rightarrow C \rightarrow M$$

The objective of governance loop can be expressed as follows:

$$A^* = arg \min_{A \subseteq \mathcal{A}} \max_{C} E(M(C))$$

The mechanism is evaluated by finding the maximum global loss:

$$E^* = \max_{C} E(M(C))$$

where

$$E = f(MEL, MRL)$$

$$MEL = diff(M(C), F(C)) \qquad MRL = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(MEL_i - \overline{MEL})^2}$$

Thus a causal chain is formatted which can be represented as

$$A \rightarrow E \rightarrow A$$

Method

Algorithm 1 Circular loop for DAOs

Input: objectives and the desired outcomes of the mechanism, participant behaviors, system constraints, and external conditions

```
Initialize the DAO mechanism M*, the participants' strategy C*, the set of artificial worlds W(C*, M*), and the set of optimal actions A_opt
while True do
    Set A_opt as an empty set
    for each artificial world w_j ∈ W do
        Construct N parallel computational experiments based on the data collected
        for each computational experiment l ∈ {1, 2, ..., N} do
            Perform the experiments within the artificial world w_j
            Evaluate the mechanism's performance using E(M*_{w_j}(C*_{w_j}))
            Determine the optimal actions A_{w_j} for world w_j based on the analysis
            Add the optimal actions A_{w_j} to the set of optimal actions A_opt
        end for
    end for
    Provide guidance for participants or updating for the DAO mechanism M*, based on the evaluation results and the set of optimal actions A_opt
    Update the participants' strategy C*
end while
```

The governance lifecycle of a DAO is composed of two iterative processes: the setup loop and the governance loop.

By integrating the setup loop and governance loop of mechanisms, we can establish a cyclical and iterative method for mechanism design, evaluation, and guidance, drawing on the theory of parallel intelligence.

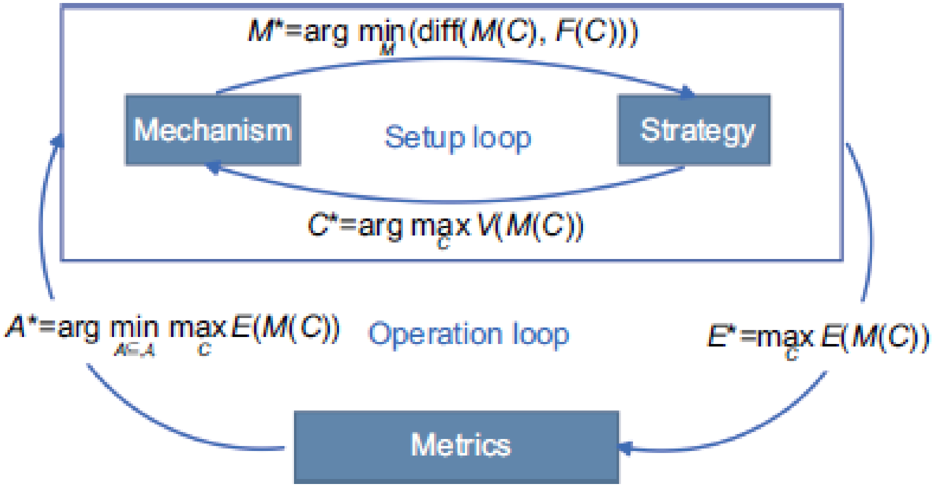

Fig. 1 **Causality loop in DAO mechanism design**

Method

Computer-aided dynamic design for complex adaptive systems (cad2CAS) is designed to assist the setup loop.

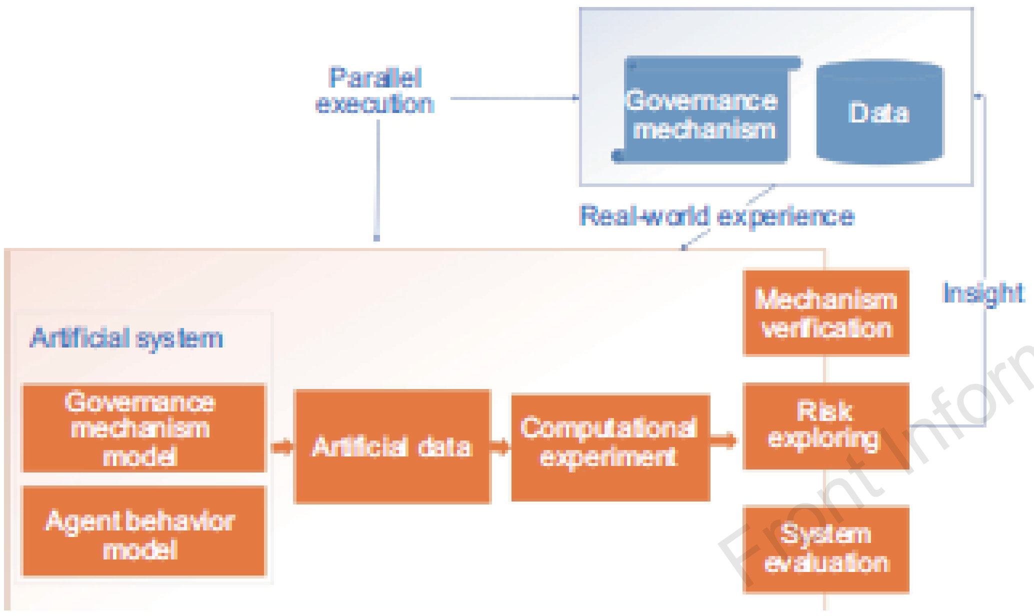

Fig. 2 Operational logic and workflow of cad2CAS

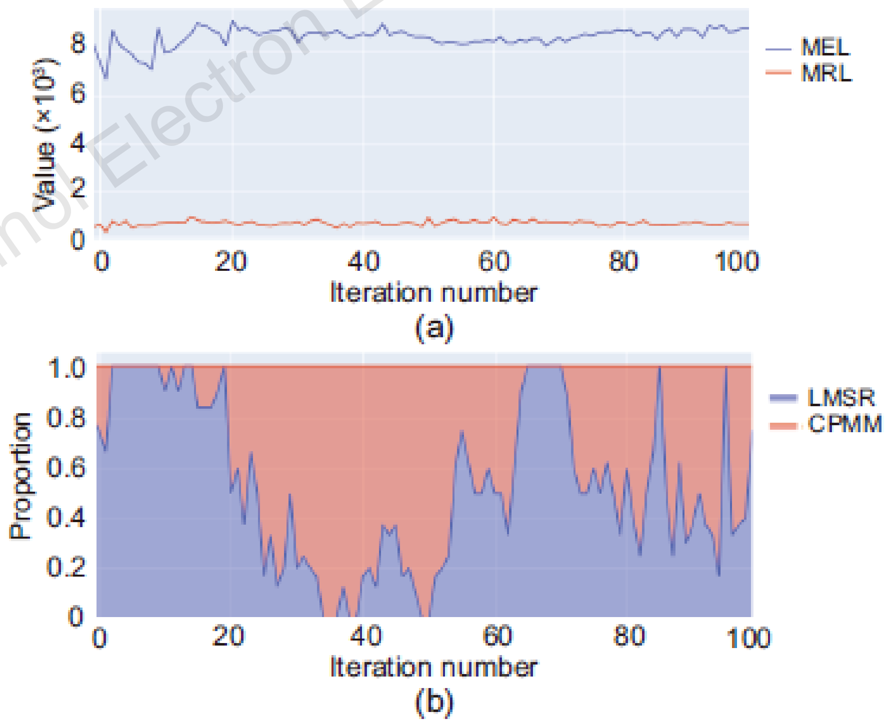

Fig. 4 Experimental results of MAM setup loop with cad2CAS: (a) changes of MRL and MEL during the iterations; (b) changes of market maker proportion during the iterations

Method

Complex adaptive system for computer-aided dynamic design (casCAD2) is designed to assist the governance loop.

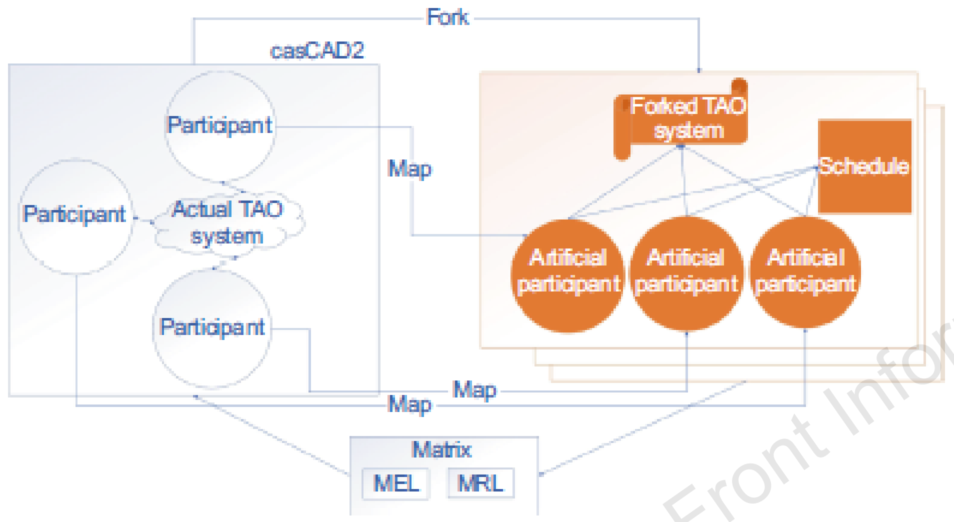

Fig. 3 Operational logic and workflow of casCAD2

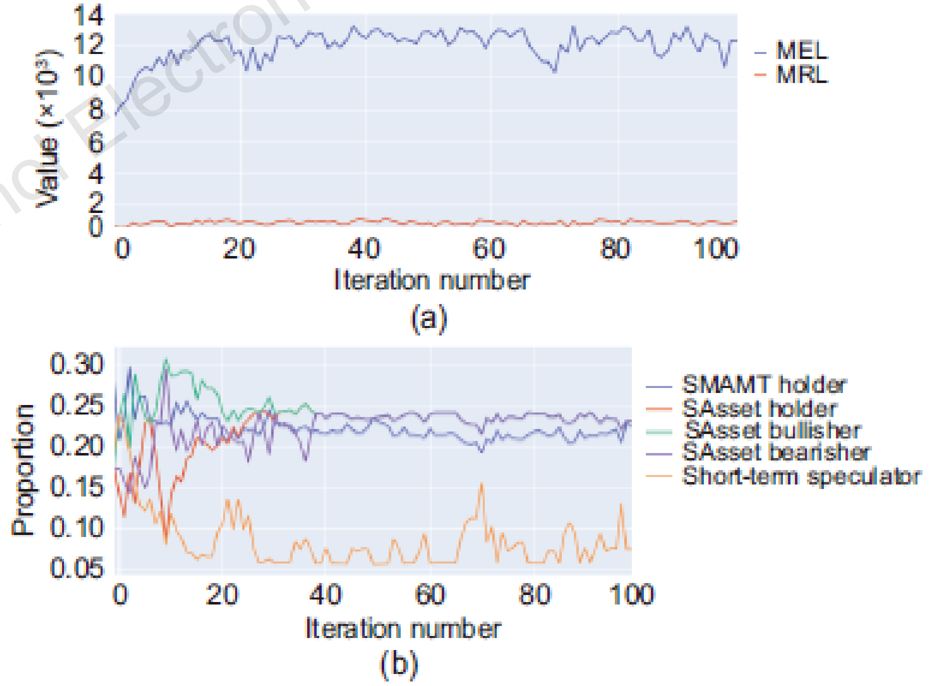

Fig. 5 Experimental results of MAM governance loop with casCAD2: (a) changes of MRL and MEL during the iterations; (b) changes of agent proportion during the iterations

Conclusions

1. We presented a dynamic iterative method for the engineering of DAO mechanisms, grounded on the parallel intelligence and circular causality theory.
2. We discussed the method from both theoretical and engineering perspectives and employed a case study to demonstrate how the proposed method can be applied in real-world scenarios.
3. We presented a unique viewpoint on mechanism design, interpreting it as a dynamic and iterative process.

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Fei-Yue WANG received his PhD degree in computer and systems engineering from the Rensselaer Polytechnic Institute, Troy, NY, USA, in 1990. He joined The University of Arizona in 1990 and became a Professor and the Director of the Robotics and Automation Laboratory and the Program in Advanced Research for Complex Systems. In 1999, he founded the Intelligent Control and Systems Engineering Center at the Institute of Automation, Chinese Academy of Sciences (CAS), Beijing, China, under the support of the Outstanding Chinese Talents Program from the State Planning Council, and in 2002. He was appointed as the Director of the Key Laboratory of Complex Systems and Intelligence Science, CAS, and the Vice President of Institute of Automation, CAS, in 2006. He found CAS Center for Social Computing and Parallel Management in 2008, and he became the State Specially Appointed Expert and the Founding Director of the State Key Laboratory for Management and Control of Complex Systems in 2011.

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