Growth Potential and Prevailing Challenges in Games for Scientific Research

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Introduction

Citizen Science Games (CSGs) and Scientific Discovery Games (SDGs) have been found to be highly effective in enabling both high-quality scientific research and deep public engagement in science[1,2]. This has been shown in a variety of projects spanning multiple source institutions, scientific fields, and types of tasks. However, this is in spite of significant constraints[3] on resources, expertise, and principled research and development of effective design, implementation, and best practices, suggesting this modality has a substantial potential for impact to be realized with additional investment.

Background

Framing scientific research problems as games provides a useful framework to make research accessible and motivating for the general public. Problems unsolved by conventional methods can be abstracted in a way where human intuition and creativity can be harnessed at scale - even at a scale of millions of contributors[4] who would otherwise have little or no ability to contribute to the problem, but could individually or collectively lead to breakthroughs. In addition to being uniquely effective in research, this also allows for intimate public engagement in science, even in conventionally inaccessible fields - especially in games like Eterna where wet-lab experiments and analysis are part of the game loop[5]. CSGs include “data-centric” games such as Galaxy Zoo, Eyewire, and Project Discovery as well as “expertise-centric” CSGs (ECCSGs) such as Foldit and Eterna in which players even develop a domain expertise complementary to scientific domain experts[6].

User Experience, Human-Computer Interaction, and Effective Design

An effective user experience is both part of the benefit of CSGs but also a key challenge - it must be approachable, accessible, intuitive, and fun in order for it to be successful. This applies across the user interface, game loop, instructional design, player community, and so forth. However, historically teams developing CSG have lacked expertise in this area[3], and this leads to substantial barriers to success, particularly in ECCSGs[7,8]. Focused resources on these areas could substantially improve the ability to attract, retain, and develop critical expertise in players. While it may present differently, effective user experience is also liable to be highly applicable to the broader citizen science field as well.

Hybrid Intelligence, AI In-The-Loop, and Human-Centered AI

The role of citizen science has come into question given increased AI capabilities, but effective combination of human and machine intelligence can still provide outsized results[9]. SDGs are increasingly integrating ML and AI methods into gameplay as tools (ie, providing partial, local, or incremental solutions) and feedback (ie, metrics or scoring). Eyewire has players guide AI in identifying neurons; Foldit has introduced neural-net tools and integration with AlphaFold; Eterna used player strategies[5] and moves[10] to train AI design tools and used data sourced from players to create models[11,12] which have since been integrated into the game itself. These have proved the utility of combining the strengths of human, machine, and collective intelligence, cooperatively performing tasks with superior results and improving through continuous learning - that is, hybrid intelligence[9,13]. However, in practice there are substantial limitations in this human/machine cooperation and learning. Often machine assistance is deployed in

relatively limited ways compared to the space of possible assistance, opportunities to tune and guide AI systems are limited, and feedback loops are long or non-existent (ie, learning is not truly continuous). SDGs are ripe for enhancement through deeper human-computer integration, and present a fertile space for development of hybrid intelligence and human-centered AI[14] approaches more generally.

Policy and Ethics

There are a number of critical prevailing questions around policy and ethics in CSGs. Concerns have been raised across data quality and trust, accountability, and privacy of participants, transparency with participants, credit, remuneration, and the value of participant work, access, equity, and embedded biases, and so forth. This is complicated by the ambiguous role of participants between game players, research subjects, and researchers leading to a gap in both norms and regulations[15,16].

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