SELF-ORGANIZING ADAPTIVE STRATEGIES WITHIN ORGANIZATIONS OF ARTIFICAL AGENTS

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ABSTRACT

Organizational researchers suggest exploration and exploitation are two strategies for adapting to business change. But little is know about the how they are applied as businesses struggle to adapt to constantly shifting and changing environments. To yield insight into organizational adaptation processes, two experiments applied turbulent environmental changes to organizations of artificial-agents. Agents are not preprogrammed but instead they self-organize to adapt to change. This research explored efficacy of agent strategies applied to adapt to controlled levels of change. The first experiment revealed that artificial agent communities' best adapted to change with a middle of the road strategy, where they balanced exploring new opportunities with exploiting past successes. In the second experiment, agent communities devoted a portion of their resources to specialized "managerial" agents. Manager agents significantly improved the communities' adaptation success by discovering a new adaptation strategy. Experiment two reveals adaptation improves by oscillating between extremes of explorative and exploitive behavior.

INTRODUCTION

Organizational literature suggests exploration and exploitation are opposing business strategies for coping with perpetual change. But little is know about the complex evolutionary dynamics that develop as businesses adapt to changing global competition, technology and market environments. To yield insight into adaptation processes, an artificial-agent community was created and subject to varying intensities of environmental change. Agents' adaptive behaviors emerged from shared interactions where they exploited past successes while continually exploring new ways to adapt to change.

Evolutionary models are grounded in the new science of complexity that studies adaptation within dynamic environments. Agent-based computational models study complexity by simulating changes in external environments and tracking patterns of adjustment [1-3]. By considering underlying adaptive patterns researchers gain insight into how organizations may best respond to perpetual change.

Exploration and exploitation are two opposing strategies for adapting to change. Advocates of exploration argue that adapting to change requires diverse creative processes that continually introduce novelties and promote the unproven and untested. Advocates of exploitation argue that adaptation demands exploiting stable and proven strategies [4].

EVOLUTIONARY SIMULATION EXPERIMENTS

The following applied a model where genetic algorithms direct adaptive forces of exploration and exploitation within populations of artificial agents as they adapt to turbulent environments. Communities of agents apply genetic processes to combine the attributes of its best predicting members. The next generation of agents then exploits past agent successes. But, these past successes become less useful over time due to environmental change. Therefore, agents respond by introducing disruptions where other genetic processes promote exploration.

Two simulation experiments were devised for exploring the trade-offs between exploration and exploitation pressures on multi-agent communities. In the first, a full-factorial experimental design is applied to identify the factorial combinations that produced DA communities best adapted to three levels of environmental change: slow, intermediate and rapid. In the second experiment, managerial agents discovered, on their own, patterns of exploration and exploitation pressures to influence the next generation of DAs. Managerial Agents (MAs) were initialized with random setting directing combinations of exploration or exploitation. Manager agents then evolved genetic patterns to direct the adaptation strategies of the remaining agents' first level adaptations. The following describes each experiment's design and results and is followed by a discussion of corroborating research.

RESULTS

For the first experiment, all factorial combinations of the slow change environment produced agent communities that survived by consistently performing above the level of chance. An ANOVA analysis of the factor combinations for the slow changing environment revealed statistically significant main effects delineating the best adaptive policies of characteristic of high exploration. The analysis however revealed a complicated evolutionary landscape represented by a significant 4-way interaction among exploration and exploitation ($p < .01$).

In contrast, for the intermediate and rapidly changing environments, only one combination consistently produced survivors. Agent communities' best adapted to change the combination that achieves a static balance between levels of exploration and exploitation intensity ($p < .01$). For the second experiment, MA discovered patterns that produced significantly higher levels of adaptive success compared to Experiment One's best results ($p < .01$). A significant interaction effect between environmental change intensity level and adaptation indicates that the magnitude of the effect depends on the environmental change level. Slow changing environments proved most advantageous for MAs while the average MA effect for intermediate and rapid environments was significant but small.

The MAs discovered that the best patterns of evolutionary pressures formed a smoothed time series pattern across generations that oscillated between the opposite extremes of exploration and exploitation. The characteristic oscillation patterns were consistent across all levels of environmental change intensities. Figure 1 shows consistently oscillating patterns throughout all 25,000 agent generations for the intermediate change environment. Similar oscillation patterns are present for the low and rapidly changing environments. A steady state never appears and genetic combinations of pressure levels never precisely repeat. The diagrams show a convergence to an exploration phase with periodic jumps to an exploitation phase. Similar pattern were reveal across multiple experimental runs across all level of environmental turbulence.

DISCUSSION

Agents compete to encode and predict environmental states by applying their limited information collection, storage and analytical resources. Agent successes are shared though evolutionary networks where managerial agents directed trade-offs between exploration and exploitation processes to improve adaptation. MAs discovered oscillating cycles of that produced better agent adaptations than the best

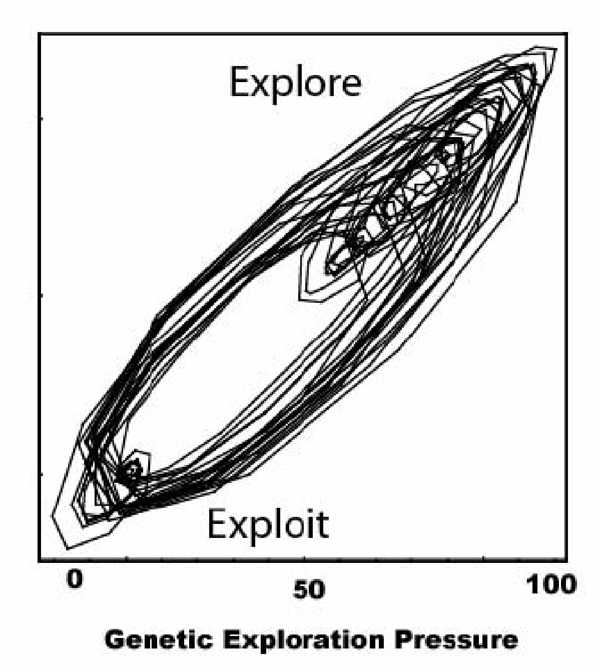

Figure 1. Experiment Two's self-organized environmental pressure trajectories for the intermediate change environment as traced over 25,000 agent generations.

contingent setting applied in Experiment one). In Experiment two, MA patterns never stabilized but dynamically oscillated between extremes of exploration and exploitation consistently across all levels of environmental change. MAs discovered oscillating cycles of that produced better agent adaptations than the best contingent setting applied in Experiment one. In Experiment two, MA patterns never stabilized but dynamically oscillated between extremes of exploration and exploitation consistently across all levels of environmental change. The results question other studies that argue for a static hybrid balancing exploration and exploitation.

A tension exists between an organization's proven strengths the continuous need to explore new ways to adapt to perpetual change. The experiments hint that oscillating tradeoffs between exploration and exploitation may improve an organizations ability to adapt. Given the model's findings, that a dynamically balanced oscillating approach promotes adaptation, managers should favor an approach that balances, over time, a phase of opportunistic exploration with a periodic return to focused and prudent exploitation. Further studies are needed to test the hypothesis that managerial effectiveness is improved by oscillating between dynamic attractors of experimentation and exploitation.

REFERENCES

[1] Cartier, M., *An Agent-Based Model of Innovation Emergence in Organizations: Renault and Ford Through the Lens of Evolutionism.* Computational & Mathematical Organization Theory, 2004. **10**: p. 147-153.

[2] McKelvey, B., *Complexity Theory in Organizational Science: Seizing the Promise or Becoming a Fad.* Emergence, 1999. **1**(1): p. 5-32.

[3] Nicols, G. and I. Prigogine, *Exploring Complexity*. 1989, New York, N.Y.: W.H. Freeman.

[4] Sutton, R.I., *The Weird Rules of Creativity.* Harvard Business Review, 2001. **79**(8): p. 94-103.