Modeling Innovation with Fitness Landscapes: The Star Network Motif

New England Complex Systems Institute
One-Week Intensive Course: Complex Physical, Biological and Social Systems
MIT, January 6-10, 2003
Supervisor: Prof. Yaneer Bar-Yam

Submitted by:
Laurent Mirabeau
Igor Feldman
Murat Cokol
Ezra Goodnoe

NECSI One Week Intensive Course
January 6-10, 2003
Supervisor: Prof. Yaneer Bar-Yam

Laurent Mirabeau
Igor Feldman
Murat Cokol
Ezra Goodnoe

Modeling Innovation with Fitness Landscapes:
The Star Network Motif

Abstract:

The objective of this project is to build a model for studying a class of problems inspired by innovation theory and complexity. The concepts of fitness landscapes will be used to model an agent looking to optimize its utility function.

Innovation theory proposes that the architecture of a product being developed by a team is in fact closely mirrored by an organization. This paper will explore one type of commonly used topology for organizing research teams at a high level. A central hub represents an architecture team interacting with a number of component teams that are modeled by the remaining nodes of the network motif.

The simulation models 100 walks on 10 landscapes with 500 iterations each.

Hypothesis/Motivation:

Fitness or success of a product (agent) is dependent upon its ability to find innovations. These innovations improve overall utility of the product. Furthermore, large-scale success is dependent upon the ability to see beyond the immediate environment.

The objective of the project is to build a ‘machine’ which has goal-seeking behavior to evaluate various strategies for reaching higher fitness by making component decisions. The agent can choose to switch any of the components in an effort to improve the overall product.

The simulation will test the overall fitness of the product as the product architecture and the components change. The fields include:

- Innovation theory
- Dominant design
- Mapping of product architecture
- Organization of firm(s)

- Overall fitness of the agent exhibits exponential behavior. This is consistent with innovation learning curves.
- The hub or node changes happen early in process, which implies that overall architecture changes will precede individual component changes.
- Increasing the number of components by a factor of 2 will impact the search in the form of a power law.
- Increasing ruggedness of the landscape lowers average fitness, suggesting a need for a switch of strategies.

Model:

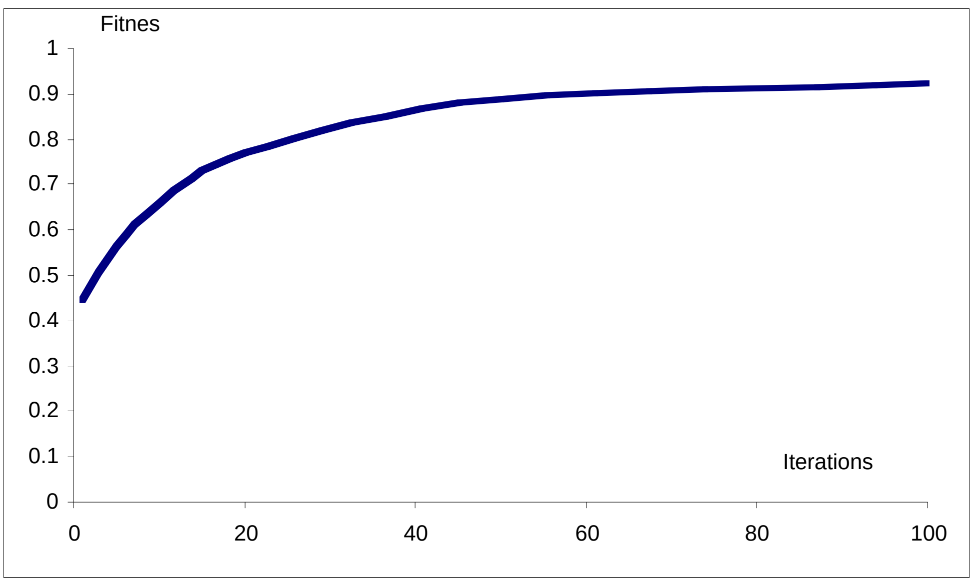
- The simulation is designed according to the hub and spoke model where information from the branch nodes aggregates to a center node. This theoretical structure can be mapped to an architecture team and its interrelationships. Furthermore, these relationships and their overall structure are representative of the architecture of the product itself.
- A change of design impacts all components positively or negative to model synergies and constraints when changing design.

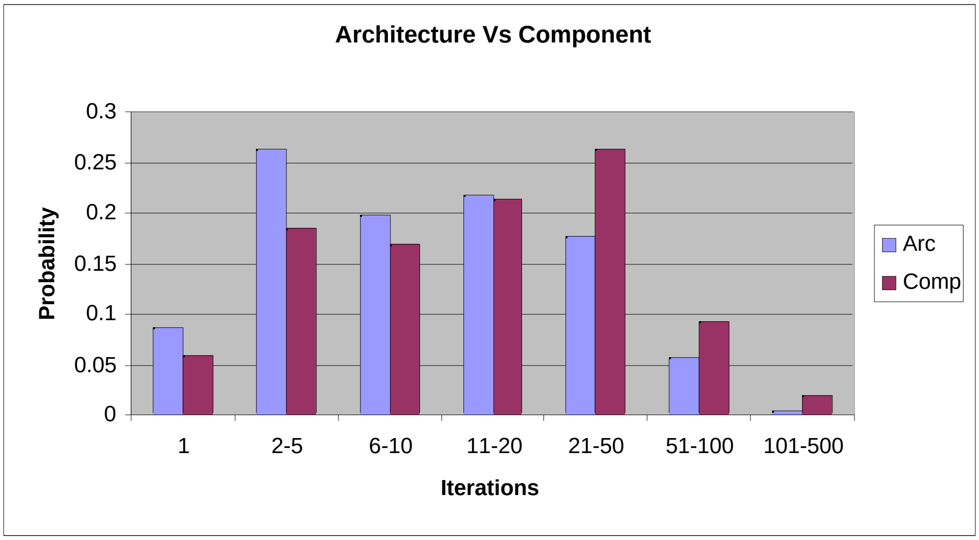
- On the other hand a change of components affects only a component and its relationship to the current overall design.
- Generic network motif
  - this model illustrates on the pure topology of the network

Psuedo code:

- Create n nodes, initialize values 1-5 utility
- Create n*(n-1)*s*s links, initialize random –1<l<1
- Calculate fitness for points in landscape
- Random drop on landscape
- Select one-mutant neighbor
- Calculate fitness and move to neighbor if that neighbor is higher
- Iterate, repeat for many agents over several landscapes

Results:





- The simulation was able to reproduce expected behavior in line with Kaufmann's nk model.
- The simulation demonstrates that, with this type of topology, you should typically make global design changes before you will make individual component changes

Next Steps:

- Increase complexity of model by adding dependencies
- Try various strategies – Stochastic process to melt off peaks, Concurrent agents, Increase hamming distance
- Combine several motifs to create new class of problems