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Morphogenic Systems Engineering for Self-Configuring Networks

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DSTO,

July 2007

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Problems in Tactical Networks

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- Tactical networks have many impediments to reliable communications
  - Highly dynamic
  - Unreliable transmission & switching
  - Hostile operations
  - Lack of deployed skilled people to maintain service continuity
  - Technical demands of multi-service, converged media networks
    - Voice
    - Video
    - Data

Autonomic Management

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- New movement in network management
- Autonomic Management
  - Continuous closed loop control
  - Self-Configuring
  - Self-Optimising
  - Self-Healing
  - Self-Securing
  - High level policy based specification of behaviours
  - Low level autonomic mechanisms for implementation

Complexity of Networks

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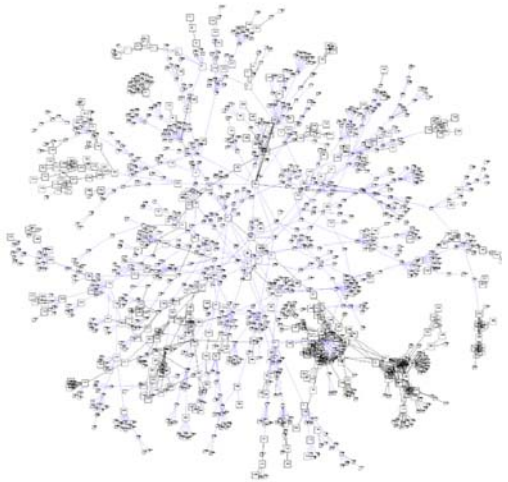
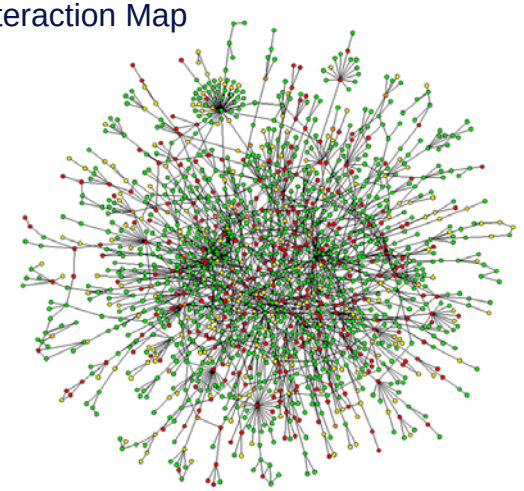
- Premise is that current and future networks have a complexity comparable to biological systems
- Therefore reasonable to consider biological design patterns and mechanisms for the system lifecycle

Internet Topology



Yeast Protein Interaction Map



Concept for Self-Configuration

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- **CHALLENGE QUESTION:**

  Is it possible for a mature, well-configured military communication system to bootstrap itself into existence from a “stem cell” configuration?

- **Well posed questions work at many levels**
  - **Generate novel hypotheses**
  - **Brings focus to the correct issues in a problem**
  - **Provide insights into possible inter-disciplinary opportunities**

Morphogenic Systems Engineering

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- Network Systems have a clear developmental lifecycle
  - Creation,
  - Maturation,
  - Decommissioning
- Analogy is made with embryogenesis and developmental biology
  - Fertilised egg
  - Embryo
  - Functional individual
  - Death
- Design patterns, mechanisms and insights
  - How far can the analogy work?

Configuration Spaces

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- There exists an analogy between
  - the configuration of network services and their operation, and
  - the configuration of a genome and the resulting biological morphology
- This analogy is the basis for what I describe as the genotype ←→ phenotype design pattern.
  - The space of possible genotypes is the configuration space
  - The space of possible phenotypes is the operational space

Experiment

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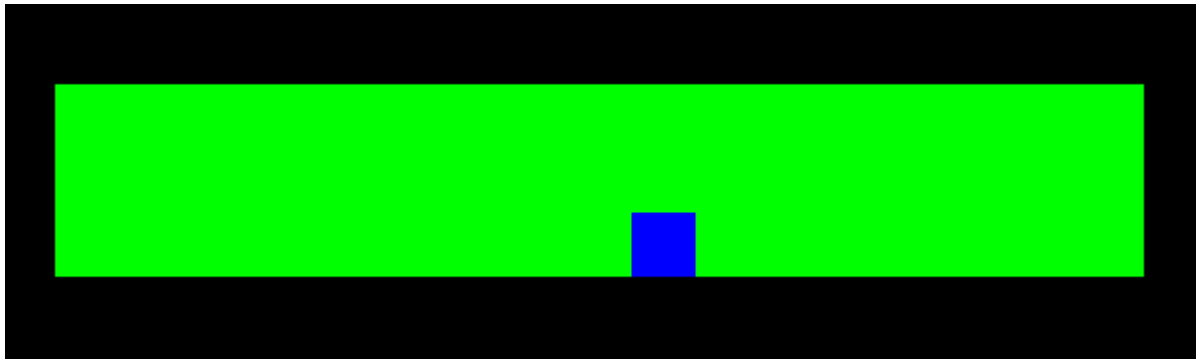
- **Question:**
  Is it possible to automate the evolution of configuration files for networks?
- **Concept Experiment**
  - **Constructed a "Toy Problem" that provides insight into the more difficult and general problem above**
  - **Consists of cellular automata (3x17) whose initial condition is a single "stem cell"**
  - **This is the "space of phenotypes"**



Experiment

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- **The stem cell has a unique genome inserted into it**
- **The genome is a structure consisting of five atomic cellular operators:**
  - **STOP, NOP, KILL, MOVE, SPAWN**
- **The stem cell, and any derived cells, execute operators within the genome**
  - **one operator per cell at each time step**
- **Question:**
  - Can we find a genome data structure that when inserted into stem cell produces the pattern “HELLO” in a reasonable number of time steps?

Experiment

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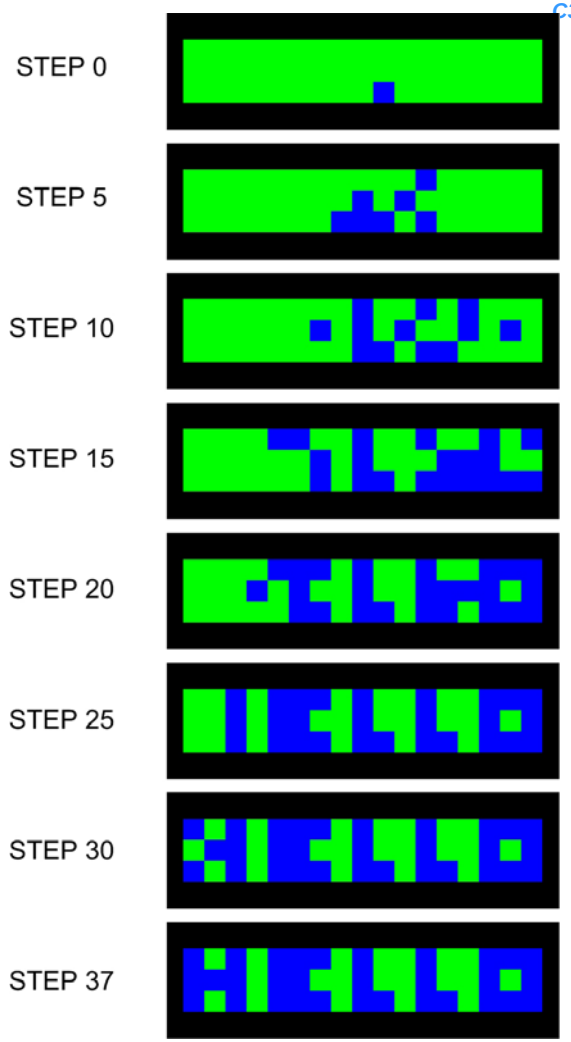
- Yes!
  - Using GP and an appropriate encoding method
- Final genome has 1,996 nodes in a tree whose height is 38
- The phenotype space is 2^{51} possible phenotypes.



Genotype ↔ Phenotype Pattern

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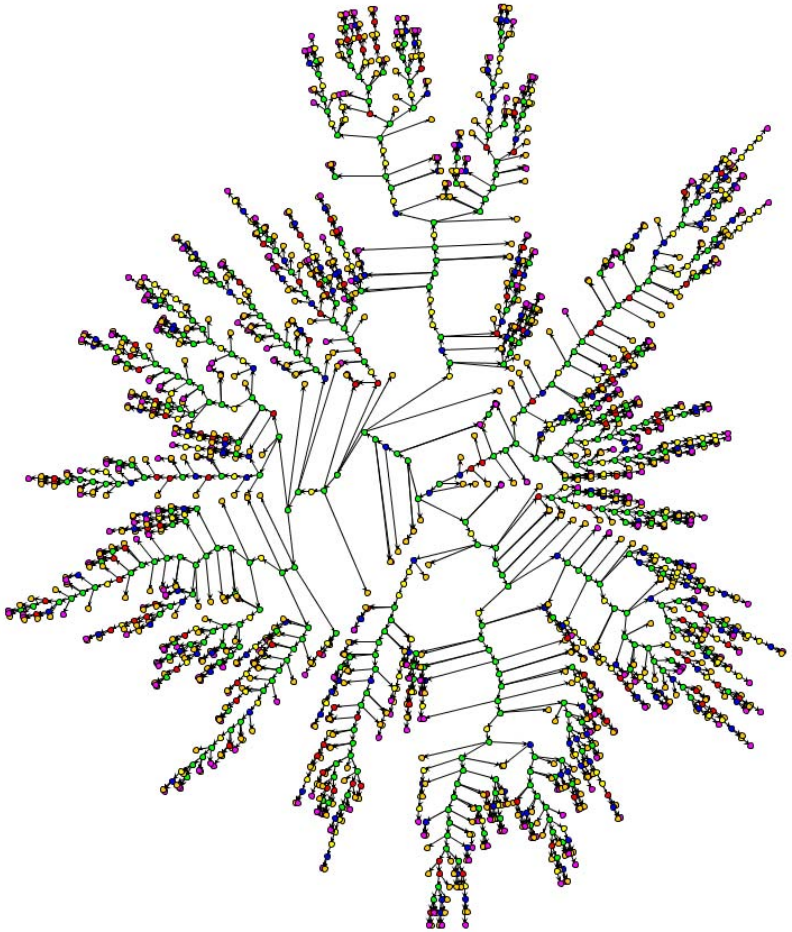
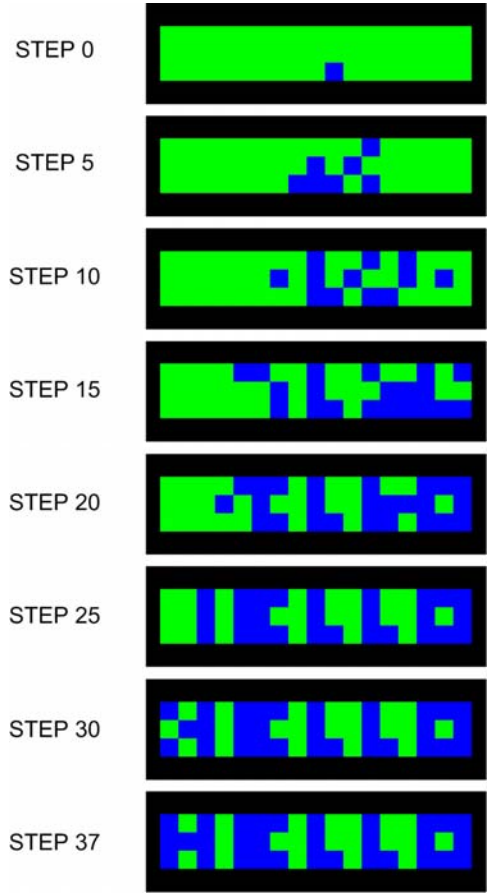


Genotype

system specification



Phenotype

system operation

Experiment

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- Conclusion is that it is possible to use evolutionary processes to find configuration files (genomes) for a desired network function (phenotype).

Future Work

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- Insights into the more deeper questions:
  - What are the atomic operational primitives in network services?
  - How do we organise these operators?
  - How do we specify the fitness of tactical network services?
  - How far can we automate the development of network configuration files by using computational evolutionary processes?
  - Can we automate the deployment of management services morphogenically?

Questions

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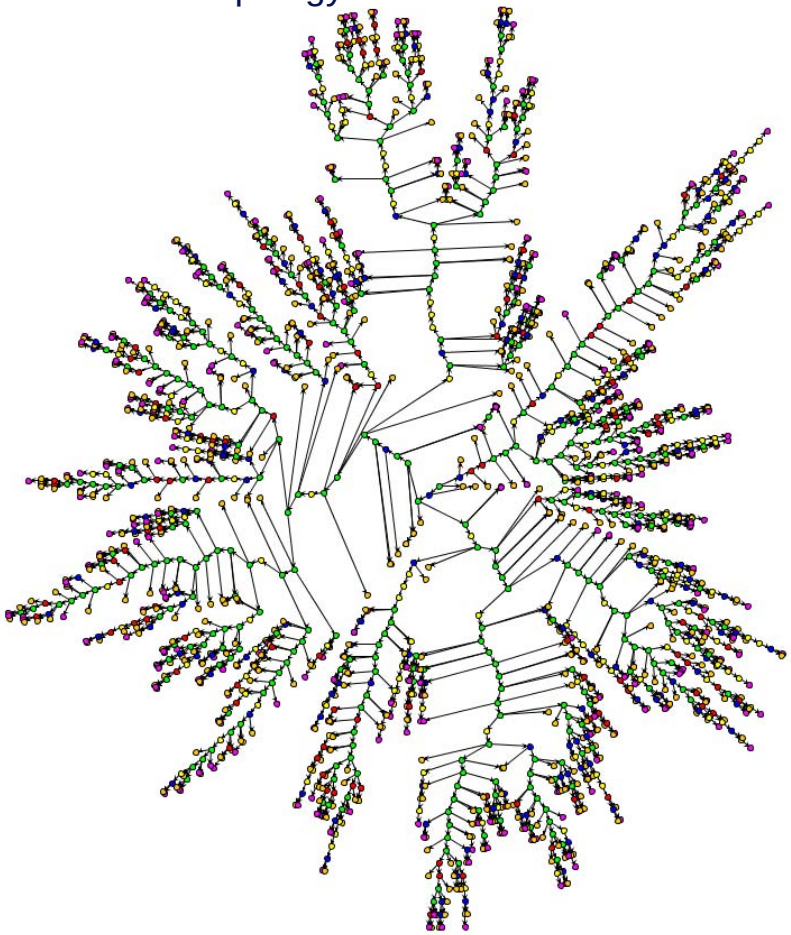
Genome Topology



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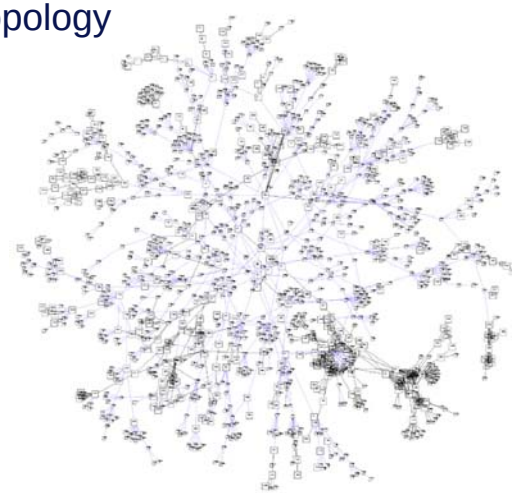

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