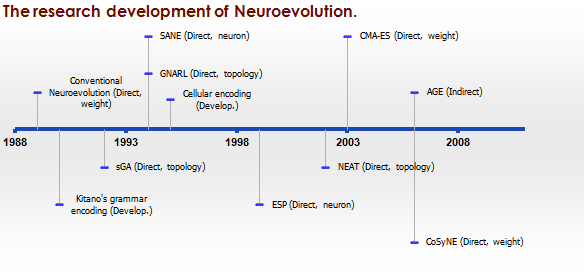
The History of Neuroevolution



The field started with fixed-topology networks, moved to complexifying networks, and then began to focus on indirectly encoded networks

a slew of algorithms developed with outstanding colleagues over the years, such as [NEAT](http://www.mitpressjournals.org/doi/abs/10.1162/106365602320169811), [HyperNEAT](http://eplex.cs.ucf.edu/hyperNEATpage/), and [novelty search](http://eplex.cs.ucf.edu/noveltysearch/userspage/).

* What research question(s) are you asking?
* Why are you asking it/them?
* Has anyone else done anything similar?
* Is your research relevant to research/practice/theory in your field?
* What is already known or understood about this topic?
* How might your research add to this understanding, or challenge existing theories and beliefs?

A literature review or narrative review is a type of review article. A literature review is a scholarly paper, which includes the current knowledge including substantive findings, as well as theoretical and methodological contributions to a particular topic.

# **Review of Literature**

To most effectively explore the work surrounding neuroevolution and genetic algorithms, a subset of literature has been selected based on its relevance to the following questions:

1. Why was there a need for neuroevolution
2. What neuroevolution techniques exist
3. Which of these are effective
4. What does it mean to make progress in neuroevolution
5. What tasks are neuroevolutions most successful at
6. How do we know it’s at good optimisation
7. What are its limitations
8. How does neuroevolution compare to other methods

The review of the literature focuses on the information presented in peer reviewed journals confereces and reports, in hope that these findings are based more on sound research and systematic analysis of the issues.I am going to do my literature review in chronological order.

The first neuroevolution algorithm appeared in the 1980s. At the time, its small group of practitioners thought it might be an alternative to the more conventional ANN training algorithm called backpropagation (a form of stochastic gradient descent).

# **Neuroevolutionary reinforcement learning for generalized helicopter control**

Which neuroevolutionary approach did the helicopter perform best at in order to discover robust controllers for a generalised version of the problem used in the 2007 reinforcement leanring competition in which wind in the helicopter's environment varies from run to run? Our empirical results demonstrate that neuroevolution is effective at optimizing the weights of multi-layer perceptrons, that linear regression is faster and more effective than evolution for learning models, and that model-based approaches can outperform the simple model-free strategy, especially if prior knowledge is used to aid model learning.

# **Efficient evolution of neural network topologies**

An important question in neuroevolution is how to gain an advantage from evolving neural network topologies along with weights. We present a method, NeuroEvolution of Augmenting Topologies (NEAT) that outperforms the best fixed-topology methods on a challenging benchmark reinforcement learning task. We claim that the increased efficiency is due to (1) employing a principled method of crossover of different topologies, (2) protecting structural innovation using speciation, and (3) incrementally growing from minimal structure. We test this claim through a series of ablation studies that demonstrate that each component is necessary to the system as a whole and to each other. What results is significantly faster learning. NEAT is also an important contribution to GAs because it shows how it is possible for evolution to both optimize and complexify solutions simultaneously, making it possible to evolve increasingly complex solutions over time, thereby strengthening the analogy with biological evolution.

1. **Fast Reinforcment Learning through Eugenic NeuroEvolution (want to read but is priority?)**

**This paper focusses on further developing technqiues for evolutionary reinforcement learning. We introduce EuSANE, a method based on a two-level evolution of hidden neurons and network blueprints similar to SANE. However, the blueprint evolution takes place through a eugenic evolution algorithm which is not restricted to local interaction between chromosomes like the standard GA, but utilizes full population stastics about the allele fitnesses to generate offspring.**

# **Human-Like Combat Behaviour via Multiobjective Neuroevolution (interesting but relevant?)**

Although evolution has proven to be a powerful search method for discovering effective behaviour for sequential decision-making problems, it seems unlikely that evolving for raw performance could result in behaviour that is distinctly human-like. This chapter demonstrates how human-like behaviour can be evolved by restricting a bot’s actions in a way consistent with human limitations and predilections. This approach evolves good behaviour, but assures that it is consistent with how humans behave. The approach is demonstrated in the  bot for the commercial first-person shooter videogame Unreal Tournament 2004. The bot ’s human-like qualities allowed it to take second place in BotPrize 2010, a competition to develop human-like bots for Unreal Tournament 2004. This chapter analyzes, explains how it achieved its current level of humanness, and discusses insights gained from the competition results that should lead to improved human-like bot performance in future competitions and in videogames in general..

1. **Constructing Complex NPC Behavior via Multi-Objective Neuroevolution**

For instance, evolutionary methods can learn so- phisticated behaviors based on a single objective, but realistic game playing requires different behaviors at different times. Such complex behavior is difficult to achieve. What is needed are multi-objective methods that reward different behaviors separately, and allow them to be combined to pro- duce multi-modal behavior. While such methods exist, they have not yet been applied to generating multi-modal behavior for NPCs. This paper presents such an application: In a do- main with noisy evaluations and contradictory fitness objec- tives, evolution based on a scalar fitness function is inferior to multi-objective optimization. The multi-objective approach produces agents that excel at the task and develop complex, interesting behaviors.

# **Evolving artificial neural networks**

Learning and evolution are two fundamental forms of adaptation. There has been a great interest in combining learning and evolution with artificial neural networks (ANNs) in recent years. This paper: 1) reviews different combinations between ANNs and evolutionary algorithms (EAs), including using EAs to evolve ANN connection weights, architectures, learning rules, and input features; 2) discusses different search operators which have been used in various EAs; and 3) points out possible future research directions. It is shown, through a considerably large literature review, that combinations between ANNs and EAs can lead to significantly better intelligent systems than relying on ANNs or EAs alone.

# **Efficient neural network pruning during neuro-evolution**

In this article we present a new method for the pruning of unnecessary connections from neural networks created by an evolutionary algorithm (neuro-evolution). Pruning not only decreases the complexity of the network but also improves the numerical stability of the parameter optimisation process. We show results from experiments where connection pruning is incorporated into EANT2, an evolutionary reinforcement learning algorithm for both the topology and parameters of neural networks. By analysing data from the evolutionary optimisation process that determines the network's parameters, candidate connections for removal are identified without the need for extensive additional calculations.

# **NeuroEvolution of Augmenting Topologies with Learning for Data Classification**

Appropriate topology and connection weight are two very important properties a neural network must have in order to successfully perform data classification. In this paper, we propose a hybrid training scheme Learning-NEAT (L-NEAT) for data classification problem. L-NEAT simplifies evolution by dividing the complete problem domain into sub tasks and learn the sub tasks by incorporating back propagation rule into the NeuroEvolution of Augmenting Topologies (NEAT) algorithm. The new algorithm combines the strength of searching for topology and weights from NEAT and back propagation respectively while overcoming problems associated with direct use of NEAT. We claim that L-NEAT can produce neural network for classification problem effectively and efficiently. Empirical evaluation shows that L-NEAT evolves classifying neural network with good generalization ability. Its accuracy outperforms original NEAT.

1. **Cultural enhancement of neuroevolution**

Any transmission of behavior from one generation to the next via non–genetic means is a process of culture. Culture provides major advantages for survival in the biological world. This dissertation develops four methods that harness the mechanisms of culture to enhance the power of neuroevolution: culling overlarge litters, mate selection by complementary competence, phenotypic diversity maintenance, and teaching offspring to respond like an elder. The methods are efficient because they operate without requiring additional fitness evaluations, and because each method addresses a different aspect of neuroevolution, they also combine smoothly. The combined system balances diversity and selection pressure, and improves performance both in terms of learning speed and solution quality in sequential decision tasks.

1. **Culling and Teaching in Neuroevolution**

The evolving population of neural nets contains information not only in terms of genes, but also in the collection of behaviors of the population members. Such information can be thought of as a kind of “culture” of the population. Two ways of exploiting that culture are explored in this paper: (1) Culling overlarge litters: Generate a large number of offspring with different crossovers, quickly evaluate them by comparing their performance to the population, and throw away those that appear poor. (2) Teaching: Use backpropagation to train offspring toward the performance of the population. Both techniques result in faster, more effective neuro-evolution, and they can be effectively combined, as is demonstrated on the inverted pendulum problem. Additional methods of cultural exploitation are possible and will be studied in future work. These results suggest that cultural exploitation is a powerful idea that allows leveraging several aspects of the genetic algorithm

# **Eugenic neuro-evolution for reinforcement learning**

In this paper we introduce EuSANE, a novel reinforcement learning algorithm based on the SANE neuro-evolution method. It uses a global genetic search algorithm, the *Eugenic Algorithm*, to optimize the selection of neurons to the hidden layer of SANE networks. The performance of EuSANE is evaluated in the 2-pole-balancing benchmark task. EuSANE is several times faster than SANE in this task, showing that it is a highly efficient method of reinforcement learning in challenging domains

1. **Optimizing Visual Properties of Game Content Through Neuroevolution**

This paper presents a search-based approach to generat- ing game content that satisfies both gameplay requirements and user-expressed aesthetic criteria. Using evolution- ary constraint satisfaction, we search for spaceships (for a space combat game) represented as compositional pattern- producing networks. While the gameplay requirements are satisfied by ad-hoc defined constraints, the aesthetic evalua- tion function can also be informed by human aesthetic judge- ment. This is achieved using indirect interactive evolution, where an evaluation function re-weights an array of aesthetic criteria based on the choices of a human player. Early results show that we can create aesthetically diverse and interesting spaceships while retaining in-game functionality

# **NeuroEvolution: Evolving Heterogeneous Artificial Neural Networks**

NeuroEvolution is the application of Evolutionary Algorithms to the training of Artificial Neural Networks. Currently the vast majority of NeuroEvolutionary methods create homogeneous networks of user defined transfer functions. This is despite NeuroEvolution being capable of creating heterogeneous networks where each neuron’s transfer function is not chosen by the user, but selected or optimised during evolution. This paper demonstrates how NeuroEvolution can be used to select or optimise each neuron’s transfer function and empirically shows that doing so significantly aids training. This result is important as the majority of NeuroEvolutionary methods are capable of creating heterogeneous networks using the methods described.

# **The application of improved NeuroEvolution of Augmenting Topologies neural network in Marcellus Shale lithofacies prediction**

The organic-rich Marcellus Shale was deposited in a foreland basin during Middle Devonian. In terms of mineral composition and organic matter richness, we define seven mudrock lithofacies: three organic-rich lithofacies and four organic-poor lithofacies. The 3D lithofacies model is very helpful to determine geologic and engineering sweet spots, and consequently useful for designing horizontal well trajectories and stimulation strategies. The NeuroEvolution of Augmenting Topologies (NEAT) is relatively new idea in the design of neural networks, and shed light on classification (i.e., Marcellus Shale lithofacies prediction). We have successfully enhanced the capability and efficiency of NEAT in three aspects. First, we introduced two new attributes of node gene, the node location and recurrent connection (RCC), to increase the calculation efficiency. Second, we evolved the population size from an initial small value to big, instead of using the constant value, which saves time and computer memory, especially for complex learning tasks. Third, in multiclass pattern recognition problems, we combined feature selection of input variables and modular neural network to automatically select input variables and optimize network topology for each binary classifier. These improvements were tested and verified by true if an odd number of its arguments are true and false otherwise (XOR) experiments, and were powerful for classification.

### **Highlights**

► Introduce NEAT neural network into shale lithofacies prediction. ► Improve the efficiency of NEAT by proposing two new attributes: node location and flag of recurrent connection. ► Incorporate growth of population size to NEAT. ► Predict Marcellus Shale lithofacies by conventional logs using NEAT network.

# **Novelty of behaviour as a basis for the neuro-evolution of operant reward learning**

An agent that deviates from a usual or previous course of action can be said to display novel or varying behaviour. Novelty of behaviour can be seen as the result of real or apparent randomness in decision making, which prevents an agent from repeating exactly past choices. In this paper, novelty of behaviour is considered as an evolutionary precursor of the exploring skill in reward learning, and conservative behaviour as the precursor of exploitation. Novelty of behaviour in neural control is hypothesised to be an important factor in the neuro-evolution of operant reward learning. Agents capable of varying behaviour, as opposed to conservative, when exposed to reward stimuli appear to acquire on a faster evolutionary scale the meaning and use of such reward information. The hypothesis is validated by comparing the performance during evolution in two environments that either favour or are neutral to novelty. Following these findings, we suggest that neuro-evolution of operant reward learning is fostered by environments where behavioural novelty is intrinsically beneficial, i.e. where varying or exploring behaviour is associated with low risk.

# **Improving reinforcement learning function approximators via neuroevolution**

Reinforcement learning problems are commonly tackled with *temporal difference methods,* which estimate the long-term value of taking each action in each state. In most problems of real-world interest, learning this value function requires a *function approximator.* However, the feasibility of using function approximators depends on the ability of the human designer to select an appropriate representation for the value function. My thesis presents a new approach to function approximation that automates some of these difficult design choices by coupling temporal difference methods with policy search methods such as evolutionary computation. It also presents a particular implementation which combines NEAT, a neuroevolutionary policy search method, and Q-learning, a popular temporal difference method, to yield a new method called NEAT+Q that automatically learns effective representations for neural network function approximators. Empirical results in a server job scheduling task demonstrate that NEAT+Q can outperform both NEAT and Q-learning with manually designed neural networks.

# **Neuroevolution with manifold learning for playing Mario**

Evolutionary learning of neural networks, i.e., neuroevolution, has shown to play an important role in agent constitutions. It has the robustness property for dynamic, practical problems. In the case of a large number of input neurons, however, the search space of neuroevolution becomes much larger so that it is difficult to find out better policies. In this paper, Isomap, one of the manifold learning algorithms, is employed to reduce the dimensionality of the input space. The Isomap tries to reduce the dimensionality based on manifold structures in high dimensional space and to preserve local topological relationships among data. Mario AI is used as a test bed for the proposed method. Video games such as Mario, Ms. Pac-Man, and car racing have been recognised as ideal benchmark problems for computational intelligence, where they require a variety of inputs, real-time strategy, and so on, and they provide good simulators which are capable to apply CI techniques. A large number of scenes in Mario are applied by the Isomap in order to constitute a map from scene information to low dimensional data. Experimental results on the Mario AI show the effectiveness of the proposed method.

# **2-D Pole Balancing with Recurrent Evolutionary Networks**

The success of evolutionary methods on standard control learning tasks has created a need for new benchmarks. The classic pole balancing problem is no longer difficult enough to serve as a viable yardstick for measuring the learning efficiency of these systems. In this paper we present a more difficult version to the classic problem where the cart and pole can move in a plane. We demonstrate a neuroevolution system (Enforced Sub-Populations, or ESP) that can solve this difficult problem without velocity information.

**A review of the Neuroevolution**

**Abstract**

1) the overall purpose of the study and the research problem(s) you investigated; **to get an overview of successful neuroevolution techniques and how and why it began**. 2) the basic design of the study; **I reviewed a range of literature that employed neuroevolution in various scenarios and I want to see what appears the most effective**. 3) major findings or trends found as a result of your analysis; and, 4) a brief summary of your interpretations and conclusions.

An example of a good abstract is the following

“*Learning and evolution are two fundamental forms of adaptation. There has been a great interest in combining learning and evolution with artificial neural networks (ANN’s) in recent years. This paper: 1) reviews different combinations between ANN’s and evolutionary algorithms (EA’s), including using EA’s to evolve ANN connection weights, architectures, learning rules, and input features; 2) discusses different search operators which have been used in various EA’s; and 3) points out possible future research directions. It is shown, through a considerably large literature review, that combinations between ANN’s and EA’s can lead to significantly better intelligent systems than relying on ANN’s or EA’s alone.*”

**Introduction**

**-**what is neuroevolution. With references.

-what is artificial neural networks

-what are evolutionary algorithms

-organisation of the article

*the literature review is organised as follows. Section 1 is devoted to the comparisons between evolutionary algorithms and back progragration and other memthods to find a good performing neural network. Section 2 discusses the appliations of various evolutionary algorithms and the success. Section 3 discusses the evolution*

**Section 1**