Understanding Coevolution

Theory and Analysis of Coevolutionary Algorithms

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Workshop Schedule

- Introductory Discussion **[2:00pm - 2:45pm]**
  - Introduction to Coevolution
  - Where we are & Where we are headed
  - Survey of CEA Analysis
  - Introduction to Workshop Papers
- Paper Presentations (part I) **[2:45pm - 3:45pm]**
  - Order-Theoretic Analysis of Coevolution Problems
  - When Coevolutionary Algorithms Exhibit Evolutionary Dynamics
- *Break* **[3:45pm - 4:00pm]**

Workshop Schedule (cont')

- Paper Presentations (part II) **[4:00pm - 5:00pm]**
  - The Dominance Tournament Method of Monitoring Progress in Coevolution
  - Coevolutionary Construction of Features for Transformation of Representation in Machine Learning
- Panel Discussion **[5:00pm - 6:00pm]**
  - Introductory Remarks
  - Open Discussion

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  - **Introduction to Coevolution**
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What is Coevolution?

- In Biology
- In Evolutionary Computation (EC)
  - Simulation
  - Problem Solving

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Key Idea: Individuals interact in some way to obtain fitness

What are Coevolutionary Algorithms?

Coevolutionary Algorithms (CEAs)

- Algorithms which implement coevolution (in the EC sense)
- Extensions to Evolutionary Algorithms

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Key Differences: Subjective Fitness versus Objective fitness

Properties of Coevolutionary Algorithms

- Mechanisms for subjective fitness assessment
- Population Structure

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- Mechanisms for subjective fitness assessment
  - Character of Interaction
    - Cooperative
    - Competitive
    - Complex
  - Methods of Interaction
    - Implicit interaction (e.g., fitness sharing)
    - Explicit interaction (how & how many, etc.?)
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- Population Structure
  - Single population models
  - Multiple population models
  - Spatial models

Advantages to CEAs

- Useful when there is no obvious objective measure
- Useful for problem decomposition
- Has the potential for open-endedness

Disadvantages to CEAs

- Complicated & Counter-intuitive dynamics
- Not much theoretical guidance
- Optimization potential is unclear

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Summary of the 2001 Workshop

Basic Concepts of Coevolution (Hugues Juillé & Rik Belew)

- High-level overviews
  - Coevolution & "Adaptive fitness"
  - When coevolution should be used
  - Example applications in coevolution

Summary of the 2001 Workshop

Basic Concepts of Coevolution (Hugues Juillé & Rik Belew)

- High-level overviews
  - Coevolution & "Adaptive fitness"
  - When coevolution should be used
  - Example applications in coevolution
- Central issues in Coevolution:
  - How can CEA mechanisms for fitness assessment guarantee continuous progress with respect to an absolute performance measure?
  - Evolutionary versus coevolutionary search

Summary of the 2001 Workshop (cont')

2001 Workshop Discussion Topics

- Evolutionary versus coevolutionary search
- Challenges of coevolution
- Techniques & architectures for implementation
- Theoretical frameworks of coevolution
- Open-endedness
- Next steps for coevolution community

Motivation for this Year's Workshop

Last year we . . .

- Spent most time discussing *Challenges of Coevolution*
- Spent a little time talking about *Theory*
- Spent very little time identifying *Next Steps*

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There seems to be a clear need for . . .

- Theory & analysis of coevolution
- Continued dialog among coevolutionary computation researchers

Goals for this Year's Workshop

- Promote theory and analysis of CEAs
- Foster discussion about state of the art research in Coevolution
- Identify next steps

Questions for CEA Analysis

- How do CEAs work?
- How do we predict, characterize, and identify observed dynamics in coevolutionary systems?
- What are they good for & how should they be used?
- Do CEAs Optimize?

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- Do CEAs Optimize?

If "yes", then *what* do they optimize?

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Categories of Analysis

- Component Analysis
- Performance & Problem Measures
- Convergence/Asymptotic Analysis

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  - Methods of interaction
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  - Identifying / Tracking CEA behaviors
  - Incorporating measures for improved search
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- Convergence/Asymptotic Analysis
  - PAC Analysis
  - Evolutionary Game Theory (EGT)

Component Analysis

- Methods of Interaction
  - (Angeline and Pollack, 1993) Empirical study of different topologies of competitive tournaments
  - (Bull, 1997) Empirical study of performance of partner selection
  - (Wiegand et al., 2001) Empirical study of properties of collaborator selection
  - (Bull, 2001) Formalism for understanding partner selection
- Problem Decomposition
  - (Potter, 1997) Empirical study of static decomposition
  - (Wiegand et al., 2002) Empirical study of decomposition and problem characteristics
- Standard Genetic Operators
  - (Bull, 1998) Empirical study of effects of mutation on CEAs

Performance & Problem Measures

- Identifying/Tracking CEA behaviors
  - (Cliff and Miller, 1995) External, subjective measurement for tracking Red Queen dynamics
  - (Ficici and Pollack, 1998) External, obj msr (order stats) for understanding Arms Races (& other dyn)
  - (Juillé and Pollack, 1998; Pagie and Mitchell, 2001) Empirical studies comparing dynamics of search in EAs and CEAs
  - (Watson and Pollack, 2001) Simple medium for measuring and understanding coevolutionary dynamics
  - (Luke and Wiegand, 2002) Formal methods for equating CEA dynamics with EA dynamics
  - (Stanley and Miikkulainen, 2002) Application of dominance notions for improved selection

Performance & Problem Measures (cont')

- Incorporating measures for improved search
  - (Rosin and Belew, 1995) Methods for improving competition
  - (Ficici and Pollack, 2001) Pareto Optimality
- Problem Analysis
  - (Olsson, 2001)Analysis of asymmetric coevolutionary problems
  - (Bucci and Pollack, 2002) Order-Theoretic framework for identifying coevolutionary problems.

Convergence/Asymptotic Analysis

- PAC Analysis
  - (Rosin and Belew, 1997) Analysis of competitive learning, including proof of convergence to perfect game strategies
- Evolutionary Game Theory
  - (Ficici and Pollack, 2000; **?**; **?**) Introduction to evolutionary game theory as an analysis tool for coevolution. Theoretical analysis of the selection method for single population, competitive coevolutionary algorithms
  - (Wiegand et al., 2002) EGT formalism for multiple population, cooperative coevolutionary algorithms

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Workshop Paper Topics

- Order-Theoretic Analysis of Coevolution Problems
- When Coevolutionary Algorithms Exhibit Evolutionary Dynamics
- The Dominance Tournament Method of Monitoring Progress in Coevolution
- Coevolutionary Construction of Features for Transformation of Representation in Machine Learning

Workshop Theme

- Attempt to address similar sorts of questions
  - What kind of problems are intrinsically coevolutionary?
  - When is an algorithm exhibiting coevolutionary dynamics, and when is progress measurement possible?
  - How can we use dominance and ranking information to assist coevolutionary search?

Workshop Theme

- Attempt to address similar sorts of questions
  - What kind of problems are intrinsically coevolutionary?
  - When is an algorithm exhibiting coevolutionary dynamics, and when is progress measurement possible?
  - How can we use dominance and ranking information to assist coevolutionary search?
- Common threads
  - Attempts to understand how to characterize and analyze coevolution
  - Use game theoretic notions of ranking and dominance
  - Fit into Progress & Problem Measures category

Part I

- Order-Theoretic Analysis of Coevolution Problems
  Anthony Bucci
  Jordan B. Pollack

- When Coevolutionary Algorithms Exhibit Evolutionary Dynamics
  Sean Luke
  R. Paul Wiegand

Break

There will be a 15 minute break...

Part II

- The Dominance Tournament Method of Monitoring Progress in Coevolution
  Kenneth O. Stanley
  Risto Miikkulainen

- Coevolutionary Construction of Features for Transformation of Representation in Machine Learning
  Bir Bhanu
  Krzysztof Krawiec

Introductory Remarks: Overview

- Goals of the Coevolution Workshop
- Challenges for the Coevolution Computation community
- Challenges for Coevolutionary Computation research
- Action Items for the Future

Introductory Remarks: Overview

- Goals of the Coevolution Workshop
- Challenges for the Coevolution Computation community (≈15 min)
- Challenges for Coevolutionary Computation research (≈30 min)
- Action Items for the Future (≈15 min)

We will spend some time independently on each of these.

Introductory Remarks: Workshop Goals

- Promote theory and analysis of CEAs
- Foster discussion about state of the art research in Coevolution
- Identify next steps

But also. . .

Introductory Remarks: Workshop Goals

- Promote theory and analysis of CEAs
- Foster discussion about state of the art research in Coevolution
- Identify next steps

But also. . .

- Raise awareness of Coevolutionary Computation in general
- Bring together the community to focus on challenges
- Discuss a potential game plan for the future

Panel Discussion

Challenges for Co-EC community (15 min)

- Is there interest in Coevolution?
- Is there enough interaction among Coevolution researchers?
- Does Coevolution have enough presence in the EC community at large?

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Last GECCO: 4 full papers, 4 posters, 4 workshop papers = 12 publications on coevolution, but there is no coevolution *Deme* or session.

Panel Discussion

Challenges for Co-EC research (30 min)

Particularly:

- What, if anything, do CEAs optimize?
- Properties of a problem affecting methods of interaction
- Cooperative versus competitive coevolution
- Single population versus multi-population coevolution

More generally:

- Do practitioners currently apply CEAs appropriately?
- How can we assist practitioners applying CEAs?

Action Items for the Future (15 min)

- Identify goals for our community?
  - Short term goals
  - Long term goals
- How do we Increase collegial interaction?
  - Rik Belew's BBS
  - Discussions on EC mail lists
- How do we increase presence of Coevolutionary Computation?
  - How do we encourage greater participation in events such as the workshop?
  - Should there be another workshop next year? If so, who should do it?

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