Interactive Computational Intelligence: A Framework and Applications
Agenda

• Overview
• Methodology
  – IGA
  – Knowledge-based encoding
  – Partial evaluation based on clustering
  – Direct manipulation of evolution
• Applications
  – Media retrieval
  – Media design
• Concluding remarks
Interactive Computational Intelligence

Interaction/Evolution

Human

(Emotion)

Interface

User Modeling

AI

(Soft Computing)

Computer

(Efficiency)

FL  GA  NN
Interactive Evolutionary Computation (IEC)

- Difficulty of optimization problem in interactive system
  - Outputs must be subjectively evaluated (graphics or music)
- Definition
  - Evolutionary computation that optimizes systems based on subjective human evaluation
  - Fitness function is replaced by a human user

![Diagram showing target system, system output, interactive EC, subjective evaluation, and Takagi's comment](image)
Technical Problems in IEC

- Human fatigue problem
  - Common to all human-machine interaction systems
- IEC
  - Acceleration of EC convergence with a small population size and a few generation numbers
  - Usually 10 or 20 search generations
    - Limitation of the individuals simultaneously displayed on a monitor
    - Limitation of the human capacity to memorize the time-sequentially displayed individuals
    - Requirement to minimize human fatigue
Framework

Conventional

IEC

Proposed

IEC

Direct Manipulation

Partial Evaluation

Domain Knowledge

Media Retrieval & Design

IEC

Overview

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Interactive Genetic Algorithm

- Initial Population
- Crossover / Mutation
- Fitness Evaluation
- Reproduction
- GA
- IGA
- Fitness Function
- User Selection
Knowledge-based Encoding

- New Search Space
- Domain Knowledge
- Search Space

- Effective encoding?
- Removing impractical solutions
- Using partially known information about the final solution
- Focusing on a specific search space
- Encoding in a modular manner
Partial Evaluation Based on Clustering

Issues → Clustering algorithm selection, indirect fitness allocation strategy
Direct Manipulation of Evolution

It is very similar to the final solution but a bit different.

Proof of usefulness of the direct manipulation \(\rightarrow\) N-K Landscape
Overview

Humanized Media Retrieval & Design

Media Retrieval
- Image Retrieval
- Video Retrieval
- Music Retrieval

Media Design
- Fashion Design
- Flower Design
- Intrusion Pattern Design
Content-based Image Retrieval

- Keywords-based method
  - Much time and labor to construct indexes in a large databases
  - Performance decrease when index constructor and user have different point of view
  - Inherent difficulty to describe image as a keyword

- Content-based method
  - Image contents as a set of features extracted from image
  - Specifying queries using the features
Motivation

- System for content-based image retrieval
  - QBIC (IBM, 1993)
  - QVE (Hirata and Kato, 1993)
  - Chabot (Berkeley, 1994)

- Needs for image retrieval based on human intuition
  - Difficult to get perfect expression by queries
  - Lack of expression capability
System Structure

Applications: Image Retrieval
Chromosome Construction

Original image  Transformed image  Chromosome
Convergence Test

• The case of gloomy image retrieval

Initial population

The 8th population
Subjective Test by Sheffe’s Method

Applications: Image Retrieval

Confidence interval
95%  99%

Cheerful
Gloomy

-3 -2 -1 0 1 2 3
Motivation

• Evolution of computing technology (Huge computing storage, networking)
  – Necessary for management of video data transfer, processing and retrieval

• Change of view point
  – Query by keyword → Query by content → Difficult to represent human’s semantic information
  – Query by semantics
    • Emotion-based retrieval
Hierarchical Structure of Video

1. Video
   - Scene 1
     - Shot 1
       - Frame 1
   - Scene 2
     - Shot 2
       - Frame 2
   - ... (N scenes)
     - Shot M
       - Frame N
System Architecture

Applications: Video Retrieval
Chromosome Construction

Applications: Video Retrieval

\[
\frac{80 \times 95 + 101 \times 255 + 75 \times 90 + 45 \times 75}{95 + 255 + 90 + 75} = 85.2
\]

\[
\frac{3.17 + 8.5 + 3 + 2.5}{4} = 4.29 \quad \frac{2}{4} = 0.5
\]

average color
histogram

average
brightness

average
edge
histogram

average shot
duration

gradual change
rate

24.2 32.1 ........ 1.6

16.2 2.1 ............ 18.3

4.29 0.5
System Interface

Applications: Video Retrieval
User’s Satisfaction

Applications: Video Retrieval

- Action
- Exitement
- Suspense
- Quietness

Effectiveness vs Generation

- average, best, worst
Emotional Music Retrieval

- Music information retrieval → Immature field
- Query by singing
- Query by content
  - Uploading pre-recording humming via web browser
  - Typing the string to represent the melody contour
- Preprocessing
  - Query by humming → transforms user’s humming into symbolized representation
- Conventional music retrieval system
  - Fast and effective extraction of musical patterns and transformation of user’s humming into systematic notes
- Problem: User cannot remember some parts of melody
Power Spectrum Analysis

\[
\log_{10}[S_z(f)] = \log_{10} f \cdot \log_{10} a \\
\log_{10}(f) = b, c, d: \text{classic, jazz, rock, news channel}
\]
System Architecture

1. Query
2. Retrieval of music by the query
3. Retrieved music
4. User evaluates the music retrieved
5. Generation of new offspring

Applications: Music Retrieval
Chromosome Construction

Query Chromosome

<table>
<thead>
<tr>
<th>Variation of sound</th>
<th>0~1</th>
<th>2~3</th>
<th>4~5</th>
<th>6~7</th>
<th>8~9</th>
<th>10~11</th>
<th>12~13</th>
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<td>4</td>
<td>12</td>
<td>5</td>
<td>13</td>
<td>1</td>
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Retrieval of music
Applications: Music Retrieval

Convergence Test

- Case 1: $m=0.5$, $c=0.5$
- Case 2: $m=0.2$, $c=0.5$
- Case 3: $m=0.5$, $c=0.2$
- Case 4: $m=0.2$, $c=0.2$

Distance vs. generation graph.
Convergence Test (2)

Target music

<table>
<thead>
<tr>
<th>Variation of sound</th>
<th>0~1</th>
<th>2~3</th>
<th>4~5</th>
<th>6~7</th>
<th>8~9</th>
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<td>5</td>
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<table>
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<th>Variation of Sound</th>
<th>0~1</th>
<th>2~3</th>
<th>4~5</th>
<th>6~7</th>
<th>8~9</th>
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<td>14</td>
<td>5</td>
<td>11</td>
<td>38.13</td>
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</tbody>
</table>
Change of Consumer Economy

Before the Industrial Revolution:
Customers have few choices on buying their clothes

After the Industrial Revolution:
Customers can make their choices with very large variety

Near Future:
Customers can order and get clothes of their favorite design

Manufacturer Oriented

Consumer Oriented

Applications: Fashion Design
Need for Interaction-based System

- Almost all consumers are non-professional at design
- To make designers contact all consumers is not effective

- Need for the design system that can be used by non-professionals
Fashion Design

• Definition
  – To make a choice within various styles that clothes can take
• Three shape part of fashion design
  – Silhouette
  – Detail
  – Trimming
System Architecture

OpenGL Program

Models of each part → Combine → Display

Decode

Interactive Genetic Algorithm

GA operation → Reproduce → User Fitness

Applications: Fashion Design
Knowledge-based Encoding

A : Neck and body style (34)
B : Color (8)
C : Arm and sleeve style (11)
D : Color (8)
E : Skirt and waistline style (9)
F : Color (8)

Total 23 bits

Search space size
= 34 \times 8 \times 11 \times 8 \times 9 \times 8
= 1,880,064

Applications: Fashion Design
Direct Manipulation Interface

Applications: Fashion Design
Fitness Changes for Each Encoding Scheme

- Knowledge-based Encoding
- Sequential Encoding

Applications: Fashion Design
Hypercube Analysis

One-Mutant Neighbors using Genetic Operator

Shortest Path Using DM Method

Applications: Fashion Design
Motivation

- Proposed Method
  - Representation of knowledge-based genotype using the structure of real flower
  - Automatic generation of creatures
- Process
  - Directed graph: Define the genotype of flower structure
  - IGA: Evaluation of created individuals and automatic creation
  - Math Engine: Representation of phenotype
- Objective
  - Creation of character morphology similar to reality
  - Find optimal solution in small solution space using knowledge-based genotype representation such as directed graph
  - Automatic creation of character using IGA
Related Works

- Tree, flower and feather modeling
  - L-System
- Box-based artificial characters (Karl Sims) evolution
  - Graph model representation
- Golem
  - Robotic form and controller evolution
  - Graph-based data structure

Applications: Flower Design
Overall Procedure

1. Create initial edges between nodes
2. Set dimension and color of each part
3. Set parameters of parts and edges
4. Create 3D world in simulation
5. Create rigid parts in genotype
6. Perform 3D rendering
7. Evaluate fitness of each individual

- Satisfied individual?
  - Yes: Stop
  - No: Selection
    - Crossover/Mutation
    - Create individuals of next generation
Chromosome Construction

\[ V(DG) = \{\text{stem, twig, sepal, petal, leaf}\} \]

\[ E(DG) = \{<\text{stem, stem}>, <\text{stem, twig}>, <\text{stem, sepal}>, <\text{twig, twig}>, <\text{twig, leaf}>, <\text{sepal, petal}>\} \]

<table>
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<th>sepal</th>
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<th>leaf</th>
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<td>leaf</td>
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</tbody>
</table>
Applications: Flower Design

Convergence Test
Analysis Using Sheffe’s Method

Applications: Flower Design
Motivation

• Various intrusion detection system
  – For evaluating, IDS uses known intrusions
    • Possibility of having different patterns within identical intrusion type
    • Difficult to detect transformed intrusions

• Problems
  – For better evaluation, intrusion patterns are needed more
    • Difficult to generate all possible proper intrusion patterns manually
  – Automatic generation is needed
Motivation (2)

- Evolutionary pattern generation
  - Needs a variety of intrusion patterns
    - It is possible to generate new patterns by combining primitives
    - Generation of transformed intrusion patterns using simple genetic algorithm

- IGA-based intrusion pattern generation
  - Difficult to estimate the fitness of patterns automatically
  - Using interactive genetic algorithm for the estimation
Method

- Intrusive behavior can be divided into 5 steps
  - Proposed by DARPA
  - Possible path of U2R attack
System Architecture

- Known Intrusion Patterns
- Initial Population
- IGA
  - GA
  - Fitness Evaluation
  - Generate Audit Data
- Intrusion Patterns
  - 000100.....
  - 001100.....
- Exploit Code

Applications: Intrusion Pattern Design
Concluding Remarks

• Humanized computing framework using IEC
  – Knowledge-based encoding
  – Partial evaluation based on clustering
  – Direct manipulation of evolution

• Applications in media retrieval & design
  – Image, video and music retrieval
  – Fashion, flower and intrusion pattern design