A Compositional Tool for Computer-Aided Musical Orchestration

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Musical Orchestration

• Refers to composing music for an orchestra
• **Initially** orchestration was simply the assignment of instruments to pre-composed parts of the score
• **Gradually** orchestration has become part of the compositional process
• **Nowadays** musical orchestration involves *timbral combinations*
• Timbral combinations involve playing multiple instruments simultaneously to achieve desired effects
Timbral Combinations

• I ask you ‘Can you play the instruments of an orchestra to resemble a person screaming?’
• ‘Why would anyone want to do that?’ You ask me back
• Well...
Timbral Combinations
Computer-Aided Musical Orchestration (CAMO)

- Large databases of musical instrument sounds
- Find combination of notes from musical instruments that best approximates a given target sound **perceptually**
Applications of CAMO

• Music Composition
  o Autonomous exploration of instrument combinations
• Music education and training
  o Orchestration classes
• Sound design and synthesis
  o Exploration of timbral combinations of synthetic sounds
• Computer music
  o Control of sound combinations via perceptual features
• Cinema and video
  o Generation of orchestral pieces for movie scores
• Post production
  o Re-orchestrate existing pieces
• Scientific research and development
  o Musical instrument timbre perception
Formalization of CAMO

• **Autonomous** exploration of instrument combinations
• Complexity of timbre perception [1]
  - Multidimensional perceptual phenomenon
  - Composers use non formalized knowledge
  - Codify perceptual similarity between sounds
• Combinatorial optimization problem
  - Combinatorial explosion
  - Knapsack problem
  - NP-complete
• Constraints
  - What instruments are available
  - How many of each instrument

Musical Instrument Timbre

Timbre Perception

- The ways in which sounds are perceived to differ
- Perceptual difference not accounted for by pitch, loudness, spatial position, duration, and environmental characteristics
- **Categorical view:** sound source recognition, identification, tracking in time
- **Sensory view:** multidimensional set of attributes associated with timbre spaces

Timbre Space [2]

Knapsack Problem

- Resource allocation
- Knapsack has limited capacity $W$
- $N$ items with weight (oz) and benefit ($$
- Pack $n \in N$ items to maximize total benefit $B$ without exceeding total capacity of the knapsack $W$
CAMO as a Knapsack Problem

- Allocation of musical instruments to an orchestration
- Orchestration accommodates a limited number of instrumental sounds
- The spectral energy is the counterpart to weight
- The similarity with the target is the benefit of adding a sound
- Add sounds to maximize similarity without exciding the capacity of the orchestration
Knapsack Problem is NP Complete

- Brute force solution requires evaluation of $2^n$ candidate solutions
- Exponential time complexity: $O(nW)$
- NP complete (non deterministic polynomial time)
  - No proof that NP complete problems can be solved in polynomial time
  - No known polynomial complexity algorithm to determine whether solution is optimal
- Solving NP complete problems
  - Approximation
  - Parameterization
  - Restriction
  - Heuristics: Genetic algorithms
Genetic Algorithms

- Meta-heuristics inspired by the process of natural selection and the principle of survival of the fittest
- Population of candidate solutions evolves toward a local optimum by recursive application of bio-inspired operators mutation, crossover, and selection
- **Fitness function** evaluates the quality of candidate solutions
Genetic Algorithms
CAMO with Genetic Algorithms

- Orchidée [3] is the state of the art for CAMO
- Orchidée performs constrained optimization
- Orchidée uses Genetic Algorithms and local search
- Local search explores the neighborhood of a solution

Proposed Approach

Genetic Algorithms

Artificial Immune System [4]

CAMO with Artificial Immune Systems

**Genetic Algorithms**
- Loss of diversity
- Converges to a single solution
- Solution usually corresponds to a local optimum
- Constraints on database to obtain different solutions

**Artificial Immune System [4]**
- Maintenance of diversity
- Converges to multiple solutions in parallel
- Capable of returning all optima upon convergence
- Allows greater autonomy on database

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CAMO with Artificial Immune Systems

• Immune Orchestra
CAMO with Artificial Immune Systems

- Immune Orchestra

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<th>Orchestrations</th>
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CAMO with Artificial Immune Systems

- Immune Orchestra

Target: Scream

Orchestrations
Acknowledgments

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