A Compositional Tool for Computer-Aided Musical Orchestration

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PROGRAMA OPERACIONAL REGIONAL DO NORTE

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

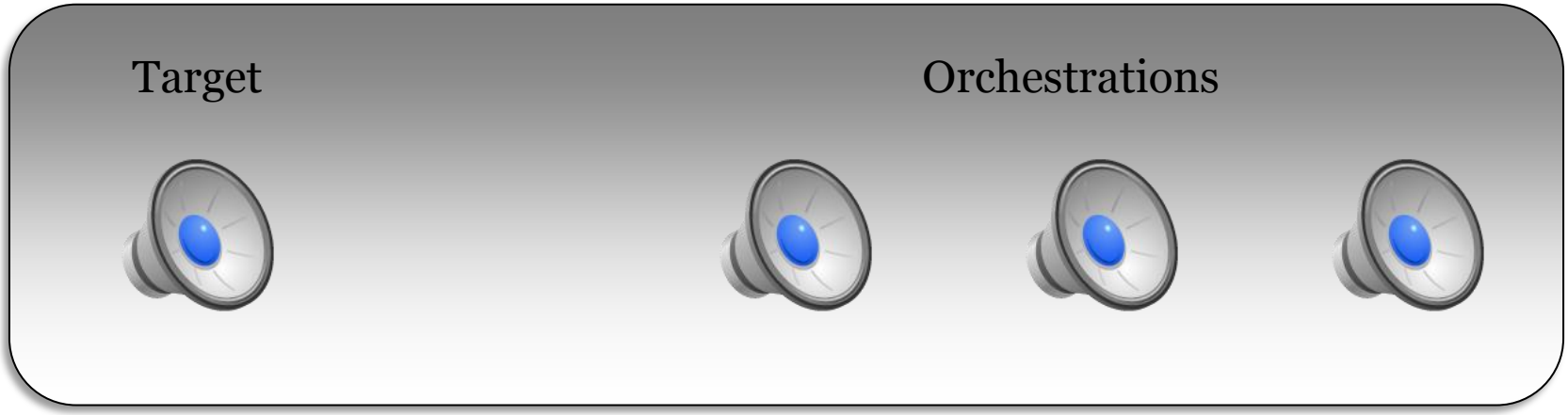
Timbral Combinations

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

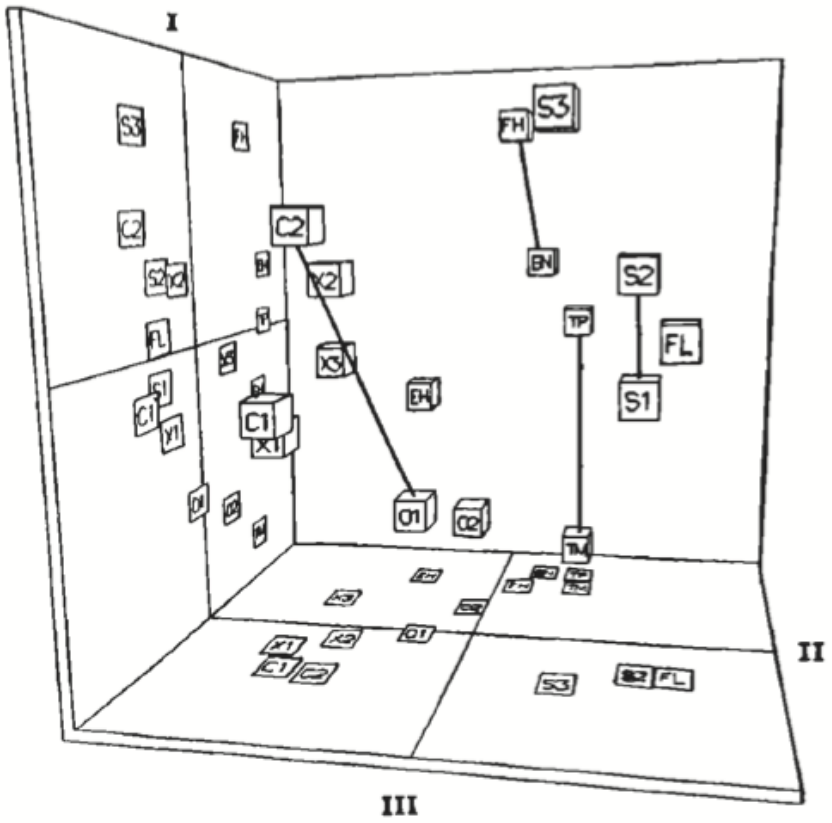
[1] S. McAdams, B. Giordano (2009). The perception of musical timbre. In S. Hallam, I. Cross, & M. Thaut (Eds.), The Oxford handbook of music psychology, 72–80. New York, NY: Oxford University Press.

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]



[2] J Grey. Multidimensional Perceptual Scaling of Musical Timbres. *Journ. Acoust. Soc. Am.*, 61(5):1270–1277, 1977.

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 exciding 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

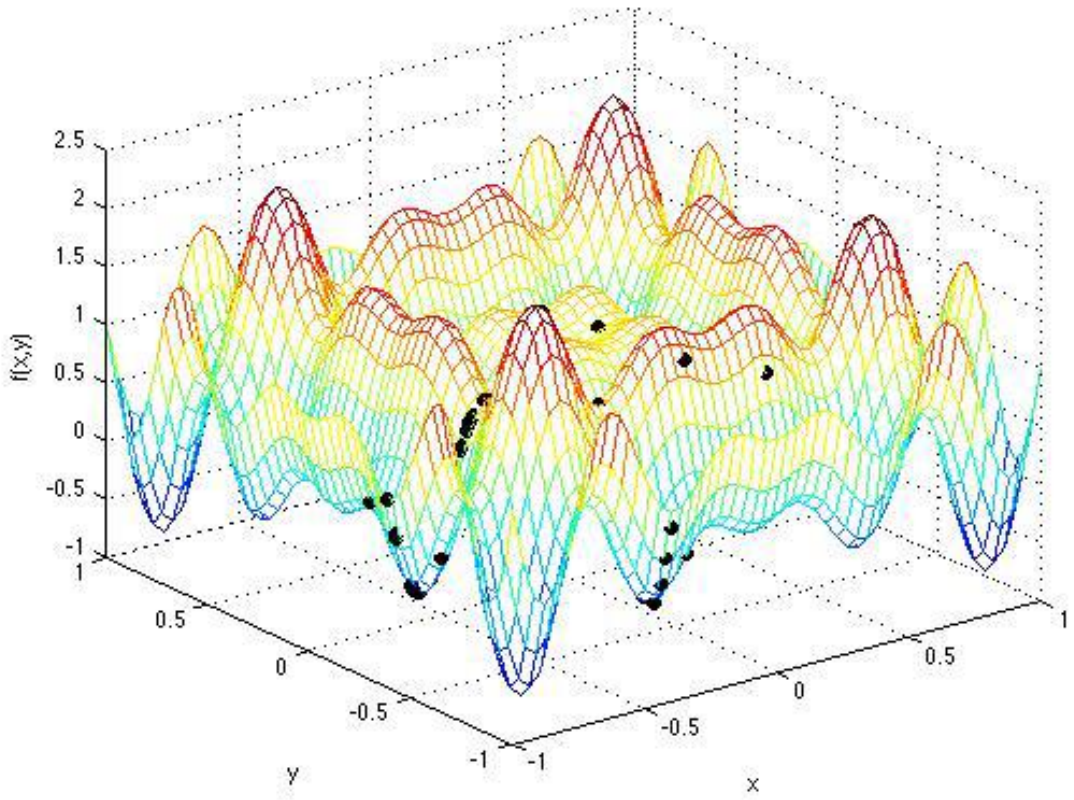
Knapsack Problem is NP Complete

- 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

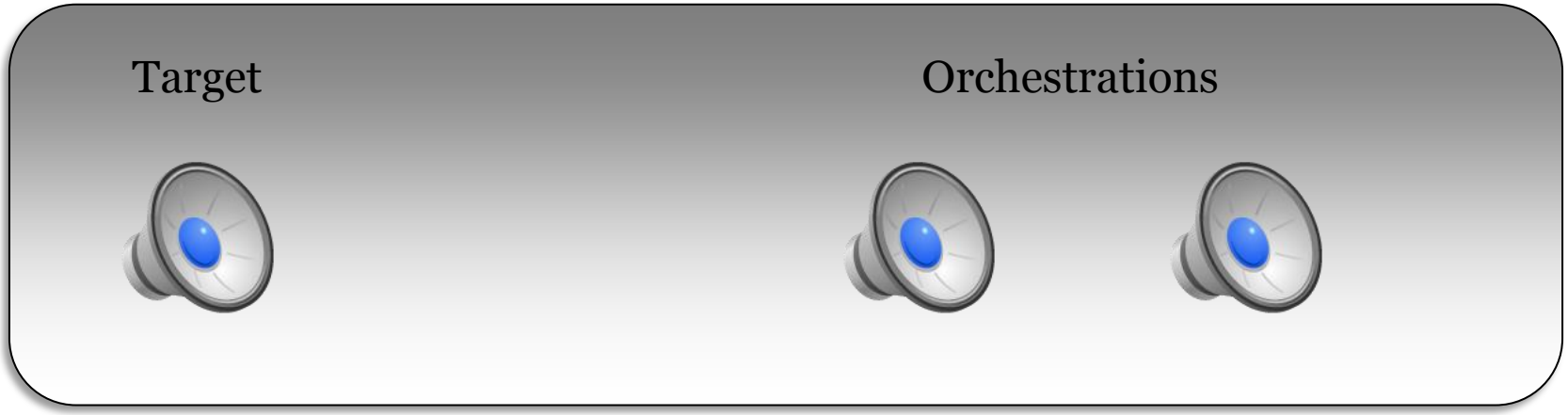
- Meta-heuristics inspired by the process of **natural selection** and the principle of **survival of the fittest**
- Population of candidate solutions evolves toward a local optimum by recursive application of bio-inspired operators **mutation**, **cross-over**, and **selection**
- **Fitness function**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

Genetic Algorithms



CAMO with Genetic Algorithms

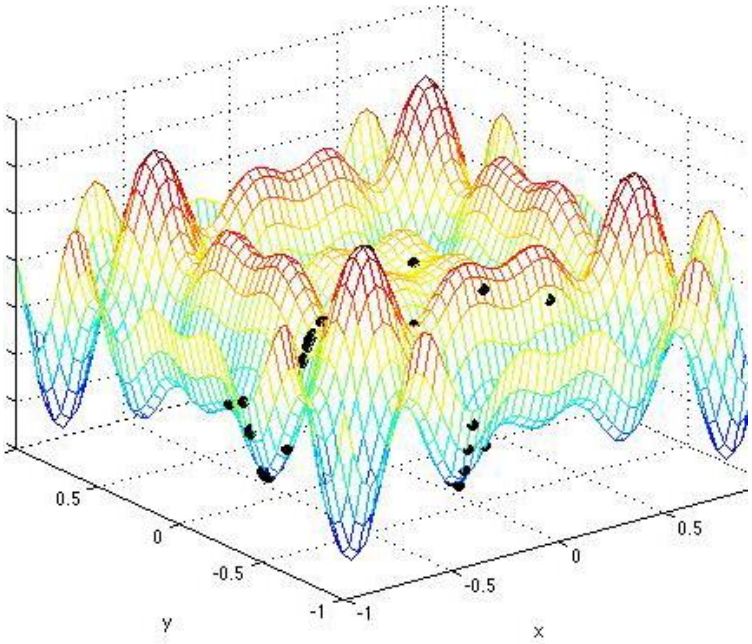
- Orchidée [3] is the state of the art for CAMO
- Orchidée performs constrained optimization
- Orchidée uses Genetic Algorithms and local search
- Local search explores the neighborhood of a solution



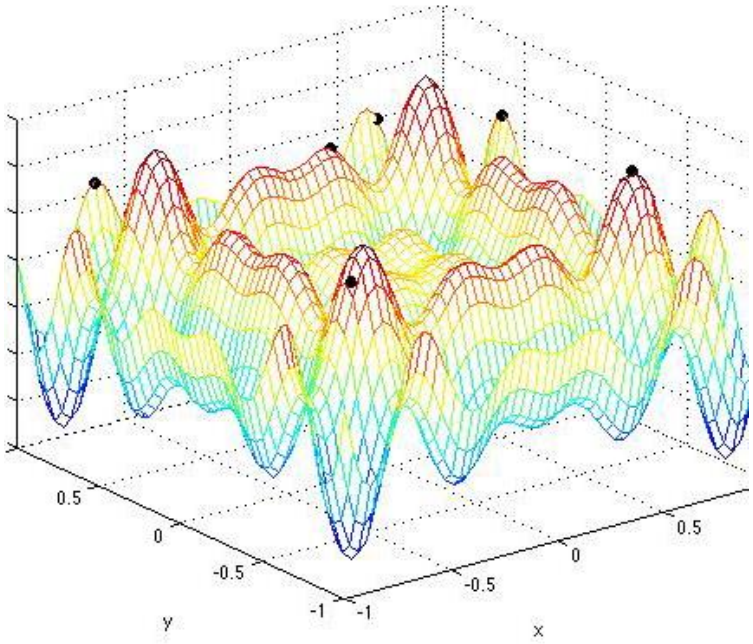
[3] G. Carpentier, G. Assayag, and E. Saint-James. Solving the Musical Orchestration Problem using Multiobjective Constrained Optimization with a Genetic Local Search Approach. *Journ. Heuristics*, 16(5), pp. 681–714 (2010).

Proposed Approach

Genetic Algorithms



Artificial Immune System [4]



[4] L. N. de Castro and J. Timmis. An Artificial Immune Network for Multimodal Function Optimization. In *Proc. Congress on Evolutionary Computation*, vol. 1, pp. 699–704 (2002).

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

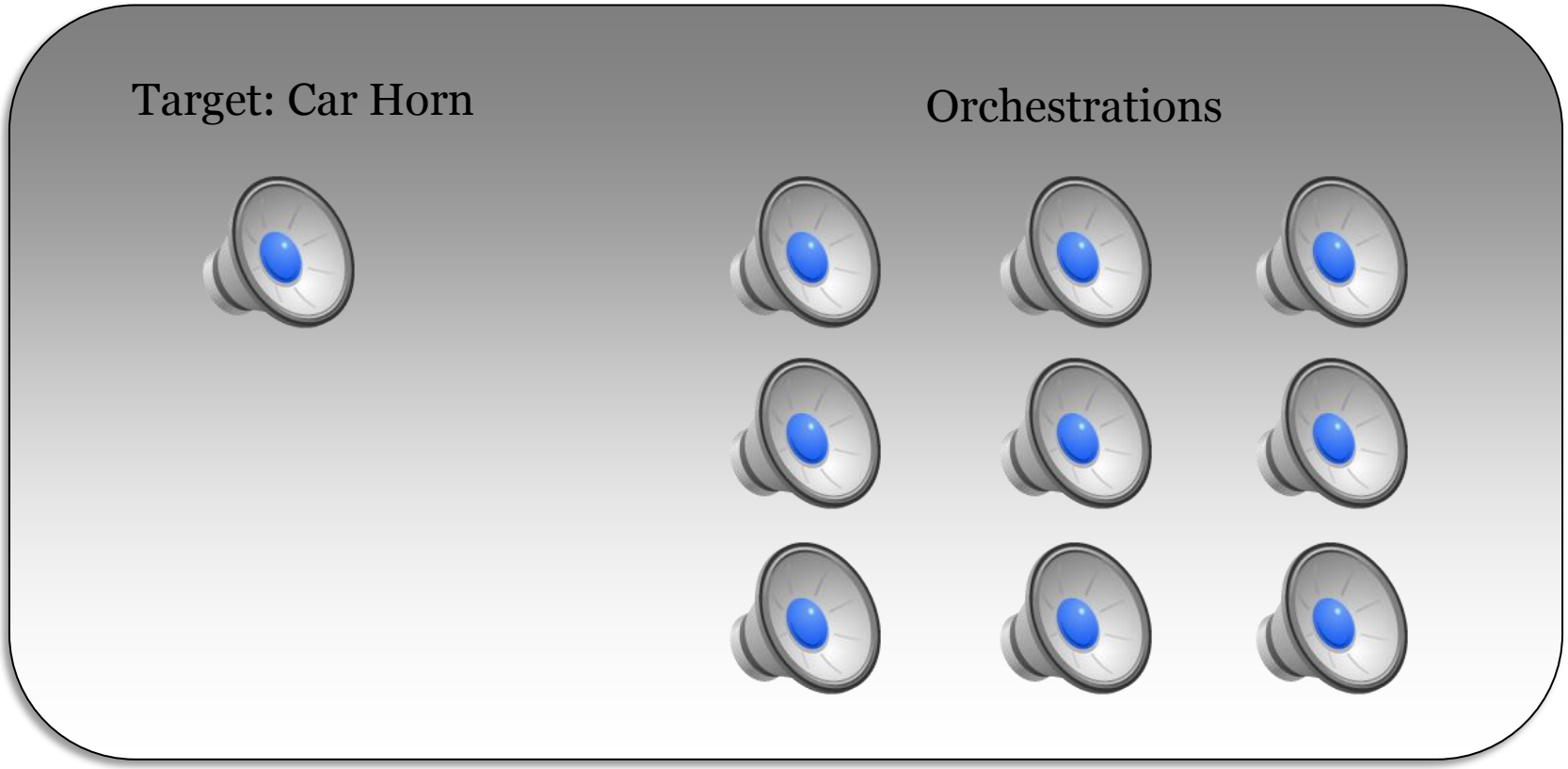
Artificial Immune System [4]

- Maintenance of diversity
- Converges to multiple solutions in parallel
- Capable of returning all optima upon convergence
- Allows greater autonomy on database

[4] J. Abreu, M. Caetano, R. Penha. Computer-Aided Musical Orchestration Using an Artificial Immune System. In: C. Johnson, V. Ciecielski, J. Correia, P. Machado (Eds.) Evolutionary and Biologically Inspired Music, Sound, Art and Design. Springer International Publishing, vol. 9596, pp. 1-16 (2016)

CAMO with Artificial Immune Systems

- Immune Orchestra



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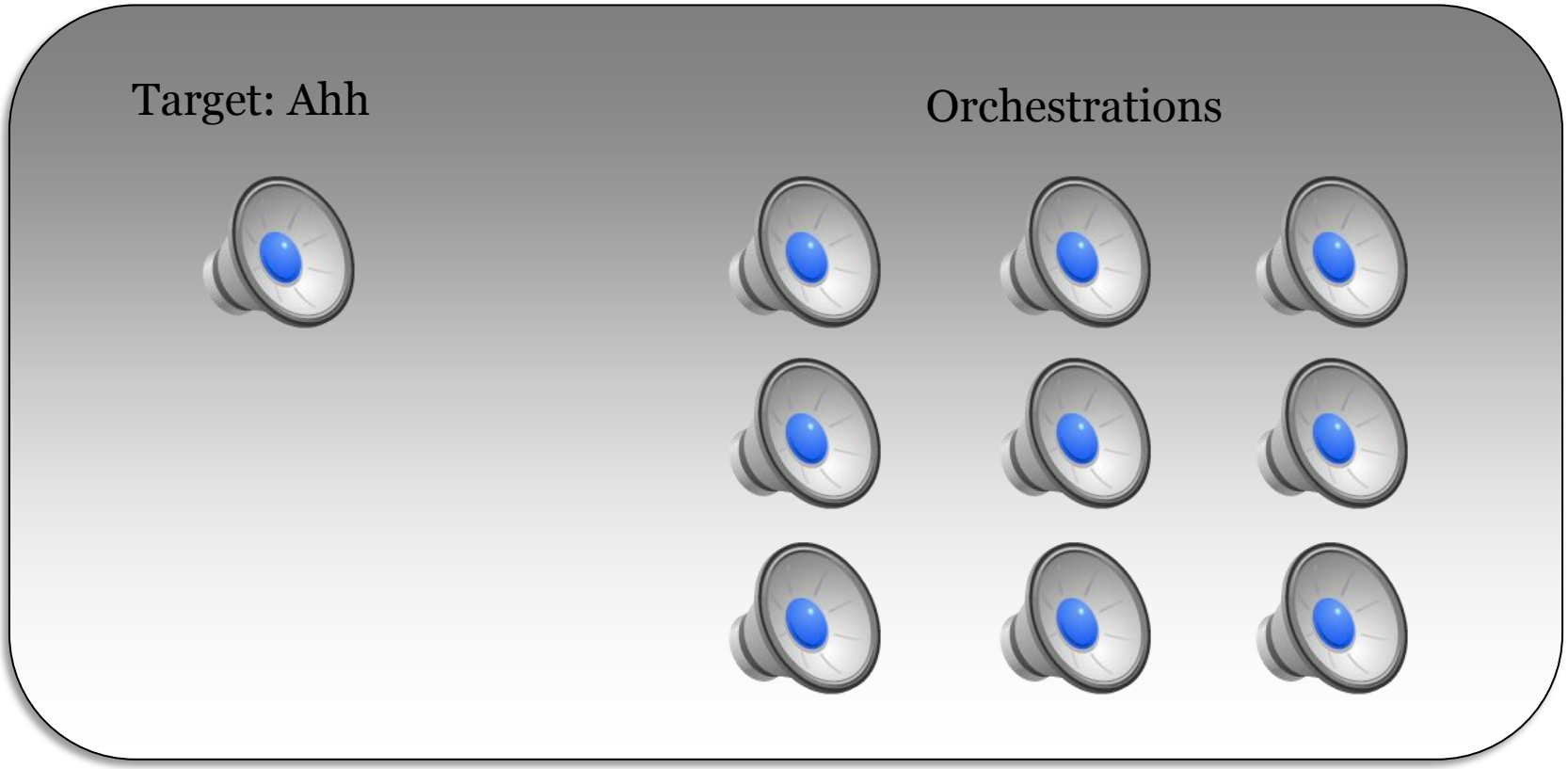

CAMO with Artificial Immune Systems

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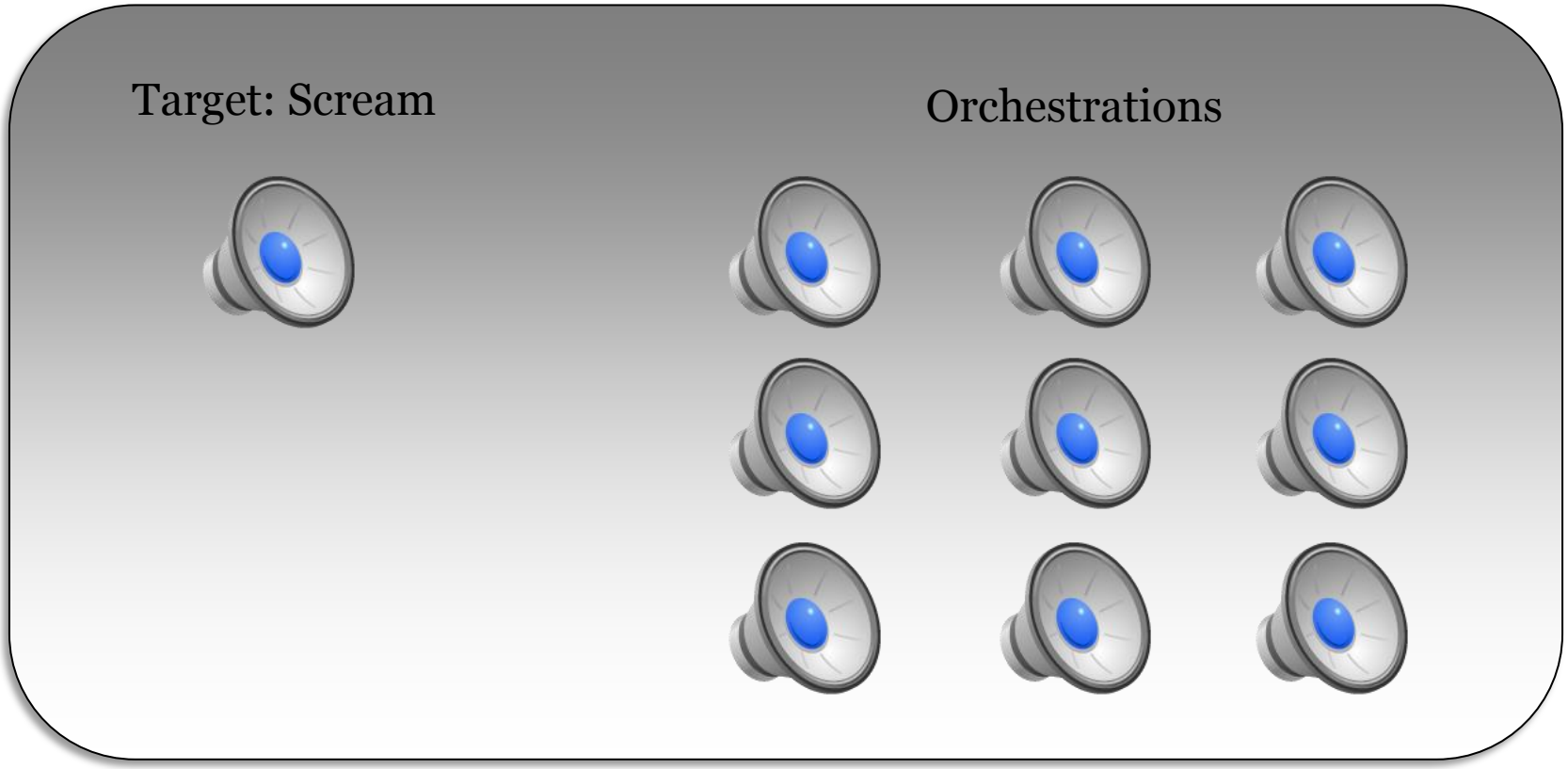

Acknowledgments

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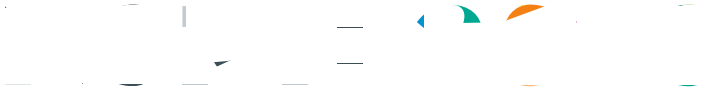

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