Grammatical Evolution for Gait Retargeting

Problem: Gathering motion data for physics-based animal models is expensive

Solution: Evolutionary based inter-species gait retargeting
- Retarget motion data from one animal to another

Combine quadruped animation, evolutionary algorithms and biomechanical research

James Murphy
james.murphy@ucd.ie
School of Computer Science and Informatics
University College Dublin
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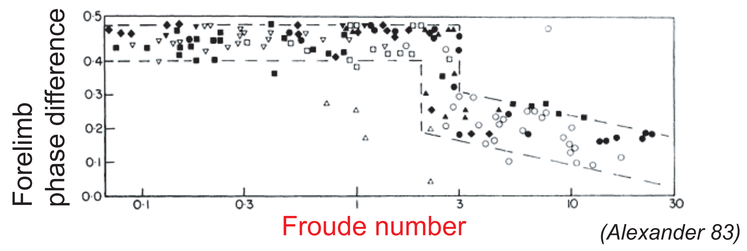
Froude number

F = velocity² / (gravity * hip_height)
= 2 (½ m v²) / (m g h)
∝ kinetic_energy / potential_energy

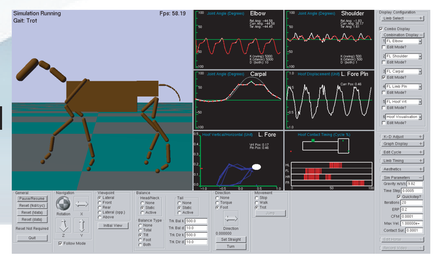
Animals moving at same Froude number have similar gaits



Dog, sheep, camel, rhino, ferret, jird, coypu

Simulation

Simulation application



Quadruped simulation
- Constructs any quadruped model
- Applies torques for movement
-Torques from motion data

Grammatical Evolution

Genotype

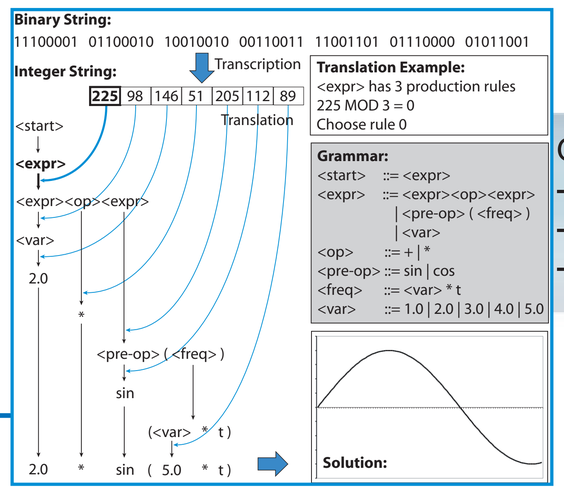
11100001 01100010

Protein — Gait cycle (Grammar)

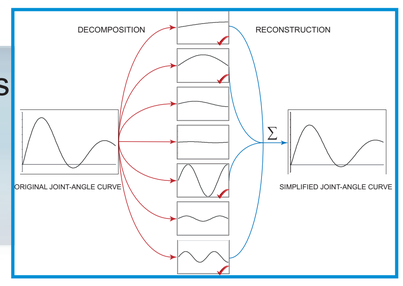
Phenotype

New evolutionary algorithm
- Principles from molecular biology
- Binary string describes solutions
- Analogous to DNA

Derivation of sinusoidal function from grammar

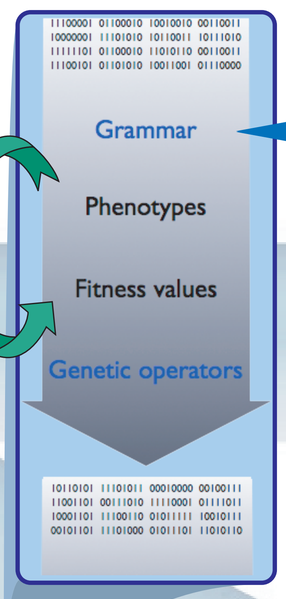


Gait cycle representation

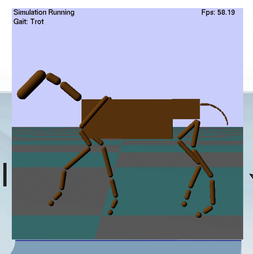


Gait cycle as sum of sinusoidal functions
- Muscles as terms in a Fourier analysis
- Fourier analysis decomposes data
- Simplification reduces parameters

GE process



Simulation/evaluation



Fitness function
- Energy efficiency based
- Most efficient gait optimal
- Constraints enforced

Grammatical Evolution (GE) Process
- Start with initial population of binary strings
- Expand each string to phenotype (gait cycle) through grammar
- Evaluate each phenotype in simulation and return fitness
- Apply genetic operators to create next generation

Genotype to phenotype through grammar
- Grammar adds layer of indirection
- Genetic operators applied to genotype
- Search and solution space separation

Dynamic similarity constraints

Dynamic similarity principles based on Froude number

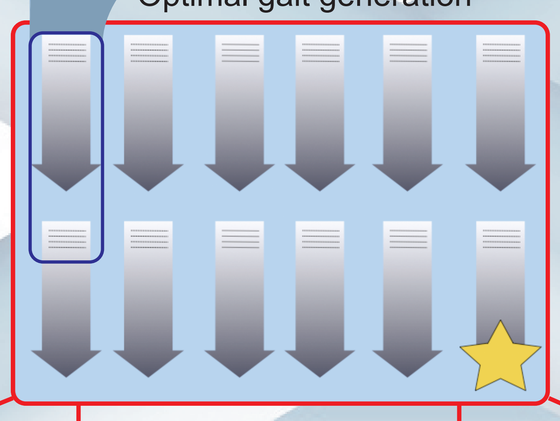
For animals travelling at the same Froude number:
- Legs move in same phase relationship
- Relative stride lengths are equal
- Duty factors are equal

Motion controllers enforce seed data phase differences

Fitness function rejects solutions which do not exhibit...
- relative stride lengths
- duty factors

...equal to those of the seed data

Optimal gait generation



Retargeting theory

- Natural evolution for gait generation
- Skeleton and gaits evolved for efficiency

Retarget through series of hybrid models
- Hybrids are source/target interpolation
- Optimisation close to global minimum

Retargeting process

- Start with measured data
- Generate optimal gait
- Gait becomes seed for first hybrid
- Generate optimal gait
- Gait becomes seed for next hybrid
- Process continues until target reached

Retargeting process