Evolution of 2D virtual mechanical systems

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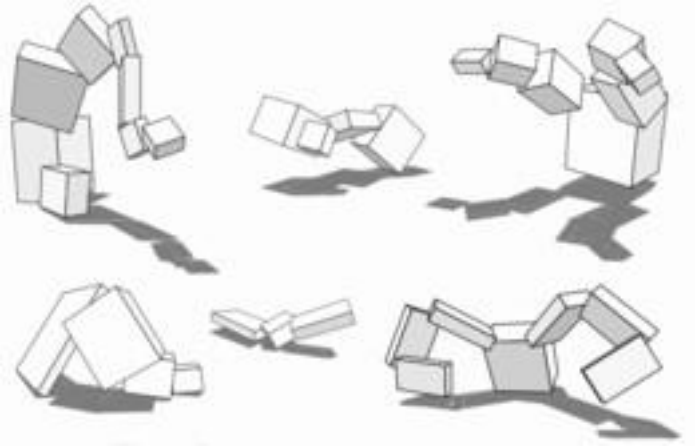
Inspiration

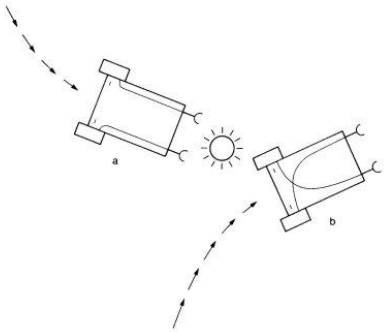
- **Karl Sims:** **Evolved virtual creatures**

digital media artist, computer graphics research scientist,
experiment on evolving flying, walking, jumping
and target tracking virtual agents



- **Valentino Braitenberg:** **Braitenberg vehicles**

Italian Neuroscientist and Cyberneticist,
hypothetical analog vehicles
built using interconnected sensors and actuators



http://www.cc.gatech.edu/~turk/bio_sim/
http://www.ini.uzh.ch/~conradt/research/BraitenbergVehicle/

2D Physics Engine

- Built from scratch (C/C++)
- Articulated rigid body dynamics
- Impulse based solver (Box2D, Chipmunk 2D, Physix, Bullet)
- Springs, motors, linear actuators, impulse engines (jet-like)
- Energy dissipation / energy consumption control
- Aerodynamic drag

Agents - Mobile Units

- Articulated rigid body mechanical systems
- Logics controlled by custom / internal scripting language
- You can build a Mobile Unit with:
  - Construction elements / passive joints
  - Propulsion: motors, actuators, impulse engines
  - Sensors: contact, distance, gyro-pos, proximity
  - Virtual CPU (internal assembly-like language)
- No Neural Networks (to be done)

Scripting Language

- Assembler Interpreter
- Lo-level / Built-in / C++ -> Fast
- Atom instructions
- Runtime execution visualization
- Interrupts from Agent connected devices (sensors)

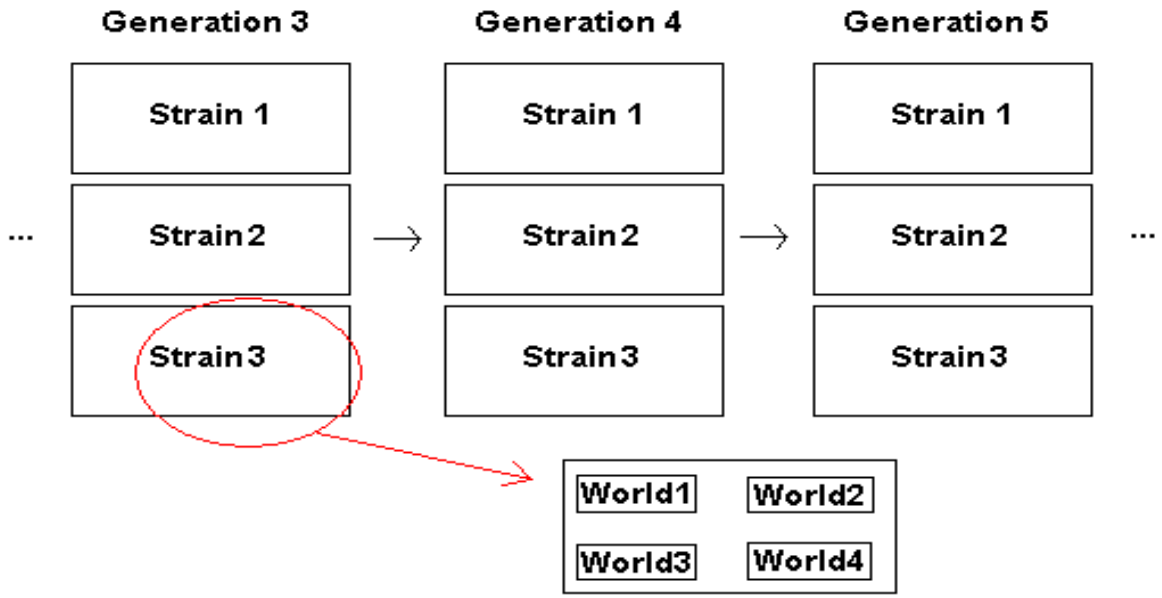
```
        DEVCTL  "GPS1", DEV_CTL_GYROPOS_SENSOR_GET_POSITION, "POS"
        DEVCTL  "GPS1", DEV_CTL_GYROPOS_SENSOR_GET_VELOCITY, "VEL"
        DEVCTL  "GPS1", DEV_CTL_GYROPOS_SENSOR_GET_ANGLE, "ANG"
        DEVCTL  "GPS1", DEV_CTL_GYROPOS_SENSOR_GET_ANGVELOCITY, "ANGV"
P7:     VGETX   "POSX", "POS"
        FMUL    "XLIMIT", -1.0, REG_FC
        JGT     "POSX", "XLIMIT", "P8"
        JLT     "POSX", REG_FC, "P8"
        JMP     "P51"
P8:     MOV     REG_FB, "LOANGOUT"
        JLT     "POSX", REG_FC, "P6"
        FSUB    2*PI, REG_FB, REG_FC
        JLT     "ANG", PI/2, "P3"
        JGT     "ANG", REG_FC, "P3"
        JMP     "P51"
P3:     DEVCTL  "IMP1", DEV_CTL_JET_SET_IMPULSE_FREQ, "LFRQ"
        DEVCTL  "IMP2", DEV_CTL_JET_SET_IMPULSE_FREQ, "HFRQ"
        JMP     "P1"
```

Mobile Unit genotype

- Parametric Mobile Unit definition
- Parametrization of:
  - Construction element dimensions
  - Joint mount points, joint work parameters
  - Propulsion work parameters
  - Sensor work parameters
  - Virtual CPU data variables parametrization
- Defined MU Scheme is used to build a genome
  - Each predefined MU parameter can be turned into a gene

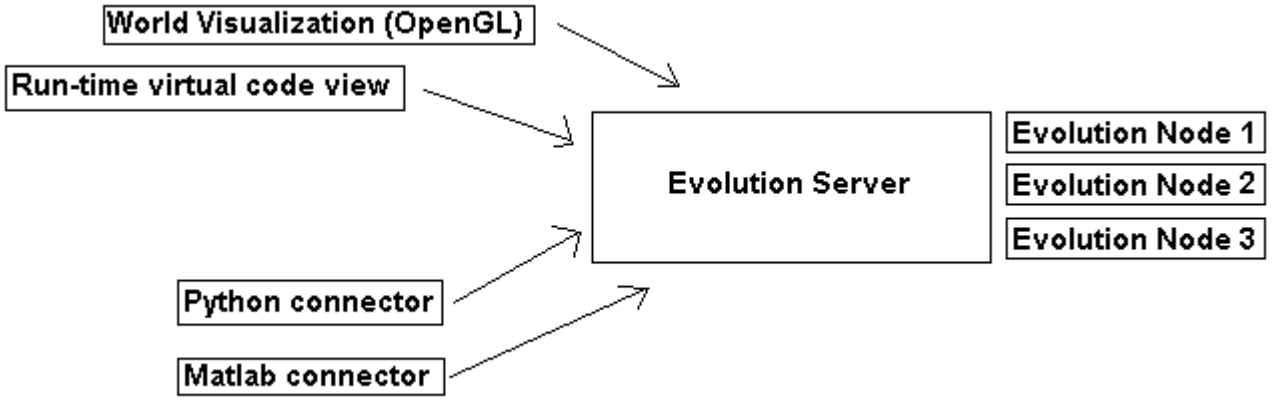
GA Model

- Parallel generations (strains)
- Single / multiple agents per simulation world
- Crossover
- Mutation
- Custom generation-depth during selection



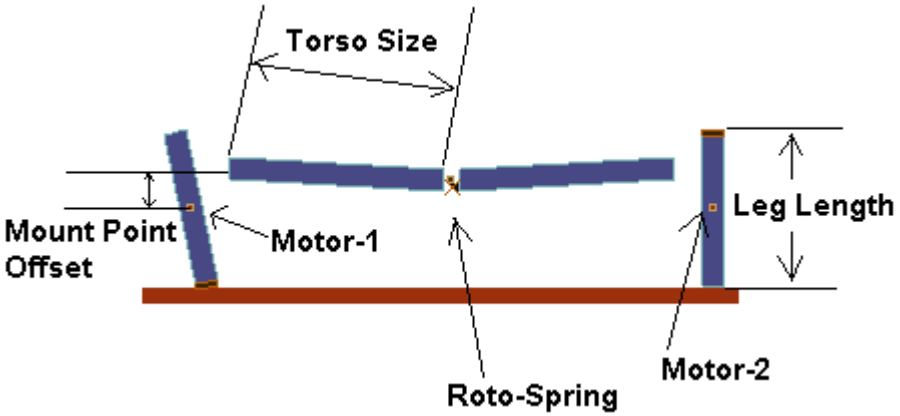
Evolution Server

- Distributed client-server system
- Paralell computation enabled Evolution Server (for supercomputing)
- One CPU / Core per one simulation world
- Different species evolutions on same server simultanously
- Local/remote client connections (using TCP/IP networking)



First Tests: „Walkers”

„Walker” species test results

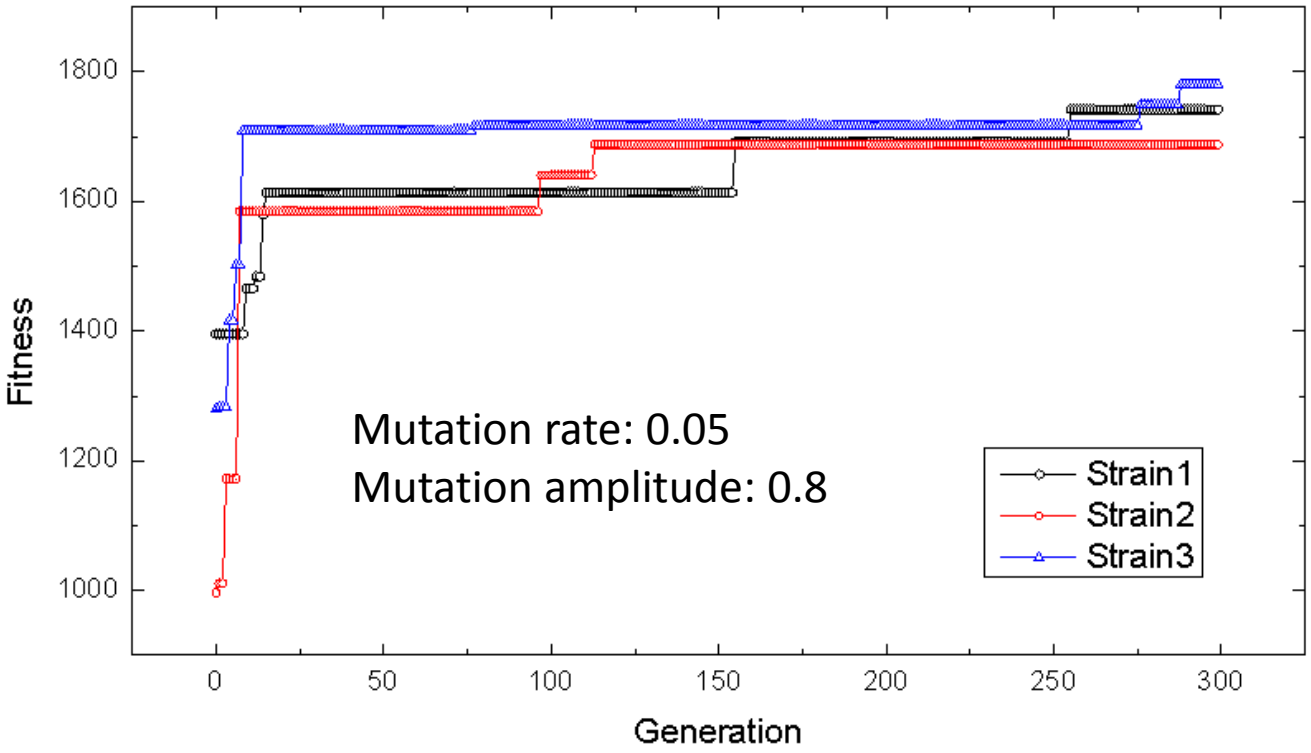


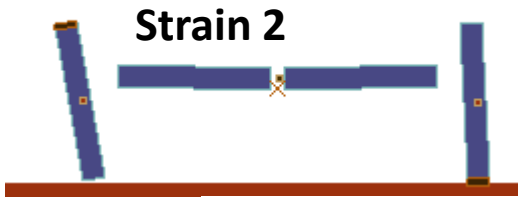
Walker Genotype:

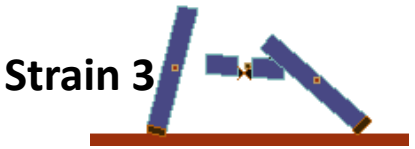
Gene1: TorsoSize

Gene2: MountPointOffset

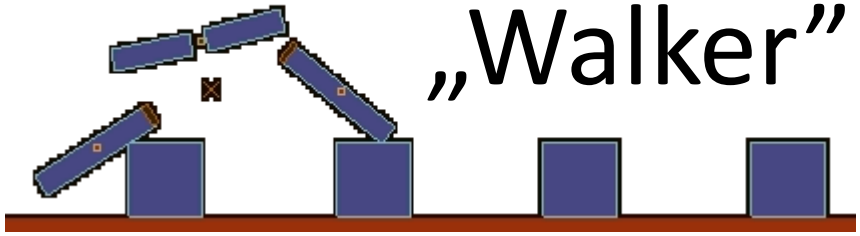
Gene3: LegLength

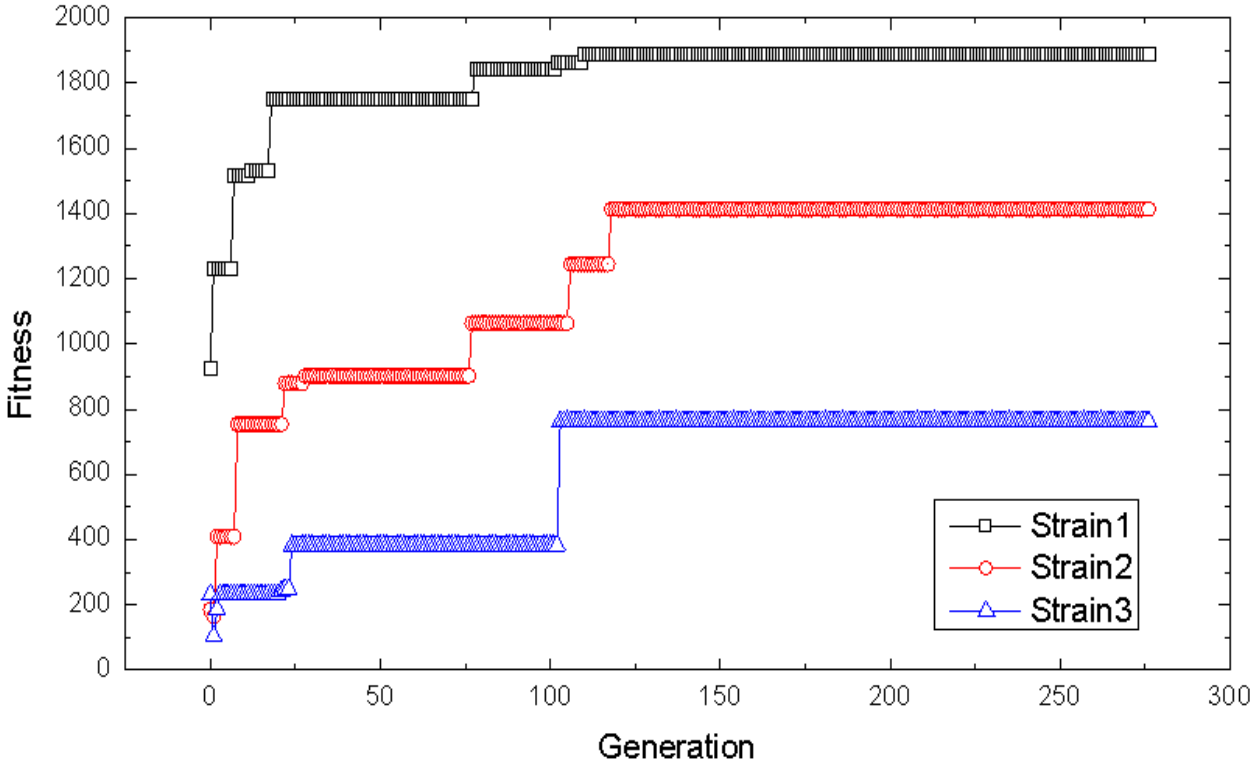




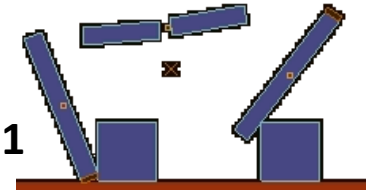


„Walker” + obstacles

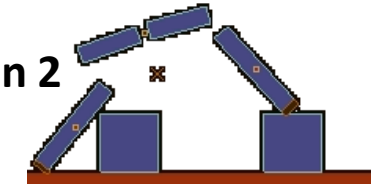




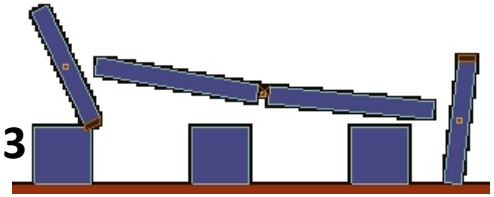
Strain 1



Strain 2



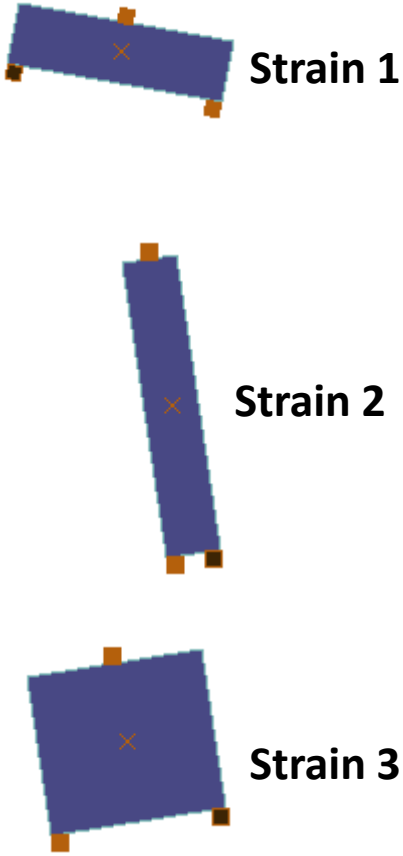
Strain 3



„Drone” species test

Drone Genotype:

Gene1: Impulse magnitude
Gene2: High impulse frequency
Gene3: Low impulse frequency
Gene4: Fly-Limit-X
Gene5: Thrust-Limit-Y
Gene6: Critical angle
Gene7: Body width
Gene8: Body height



Ok...What did just happened... ?

- „Walker" species using motor-torque vibration bug for faster movement
- „Drone" species using non-continous collission detection bug to cheat on flying ability
- They are all cheating !
- ... or are they not ....

Future work

- 2D -> 3D
- Mechanisms for new morphology emergence
- Implementation of NN as a Mobile Unit device
- More sophisticated propulsion devices
- Inter-motor synchronization (gestures)
- New sensor types
- Phenotype / Genotype Database
- Phenotype Explorer
- Evolve creatures !