Robotropism: Distributed Control of Plants

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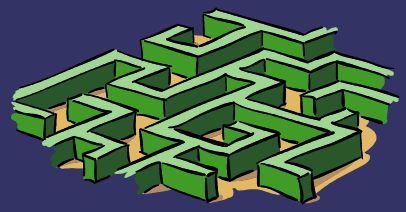
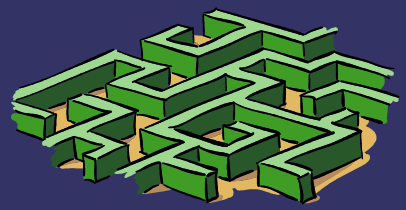


29th September 2010

Overview

- Motivation
- What is Robotropism?
- Aims
- Agent Classification
- Implementation
  - Physics Engine
  - Tropisms and Controller Agents
- Structural Tests
- Conclusions



Motivation

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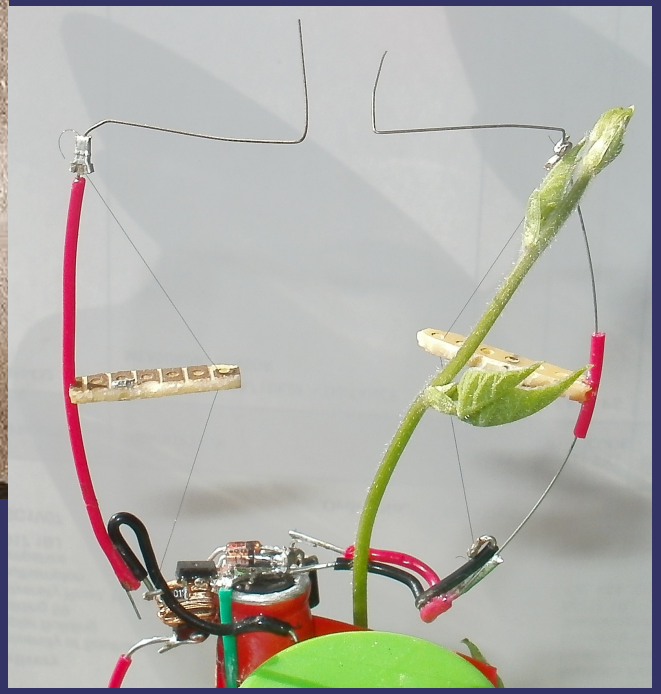
[2]



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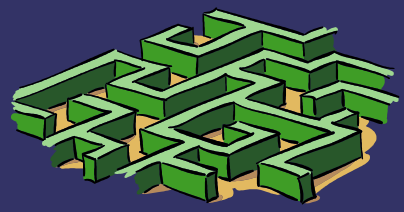
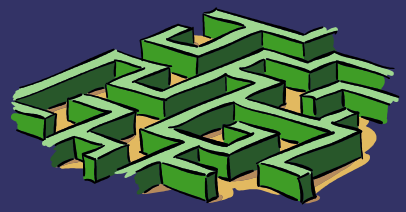


What is Robotropism?

Control of the spatial shape of plants through small artificial controllers attached to the plants

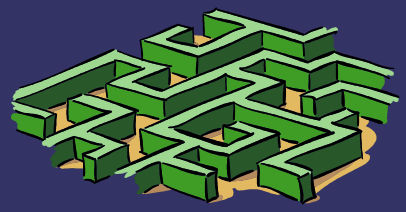
Here:

- Exploits thigmotropism of plants
- Touch stimulates growth in desired direction
- A slow robot:
  - Electronic Brain
  - Plant body



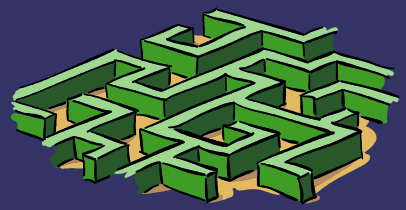
Aims

- Simulate Climbing Plants
- Gravity using a physics engine
- Phototropism etc. using GroIMP
- Robotriopism – controlling agents
- Explore the possibilities of growing structures to order.



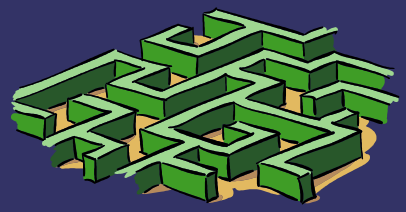
Agent Classification

- Level 0 – No Spatial Awareness
  - Passive, wind or solar powered
  - Fixed relative direction
- Level 1 – Relative Spatial Awareness
  - Microcontroller based
  - Follow a beacon. Light, Sound, Radio
- Level 2 – Absolute Spatial Awareness
  - Knows position of itself and/or others
  - GPS, Radar, Sonar



Physics Engine

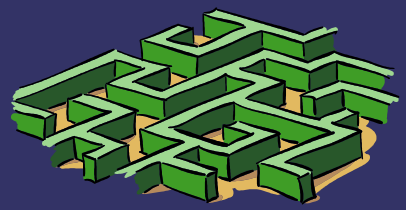
- JBullet chosen
- Plug-in created for GroIMP
- Step 1 – Gravity on free objects
- Step 2 – Create flexible stems



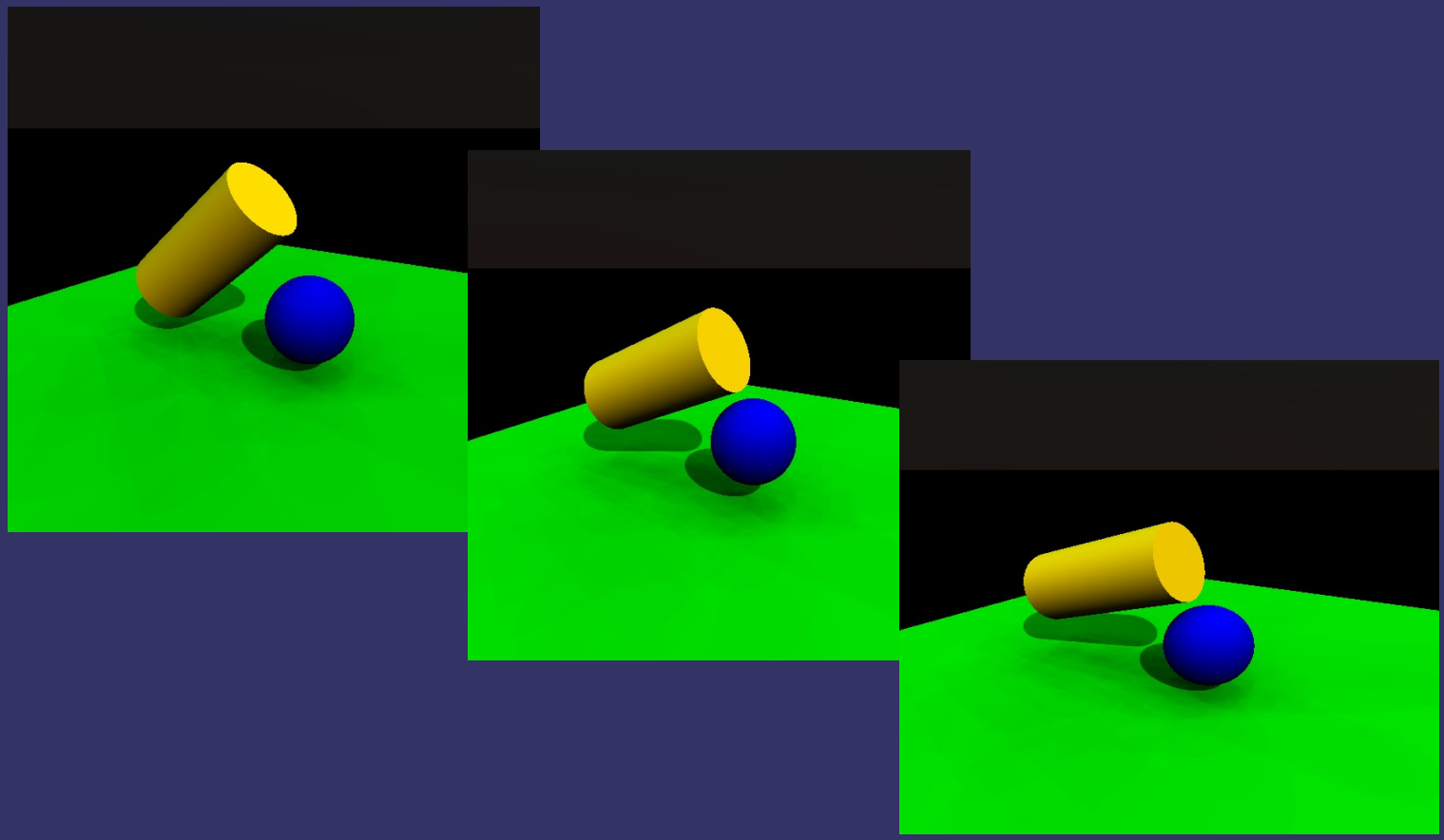
Gravity 1

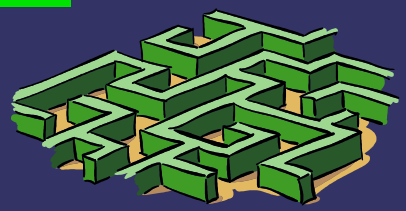
- Physics Engine has separate representation
- Objects from GroIMP are added to it
- Forces are added (Gravity)
- Physics engine
  - Calculates new positions
  - Detects collisions
- Position updated in GroIMP

- Challenge: Different frames of reference
  - GroIMP cylinder origin is at the base
  - JBullet cylinder origin is center of mass



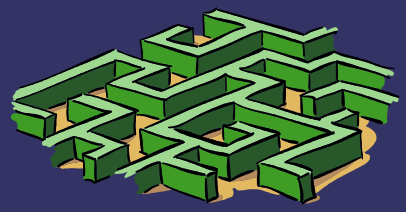
Gravity 2



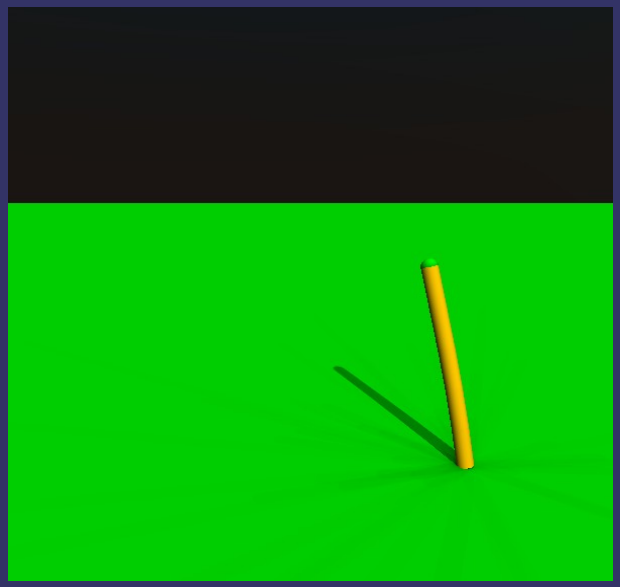


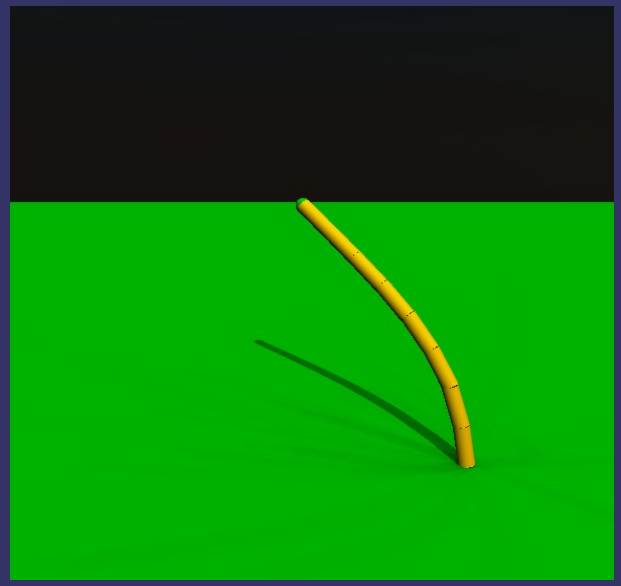
Flexible Stems 1

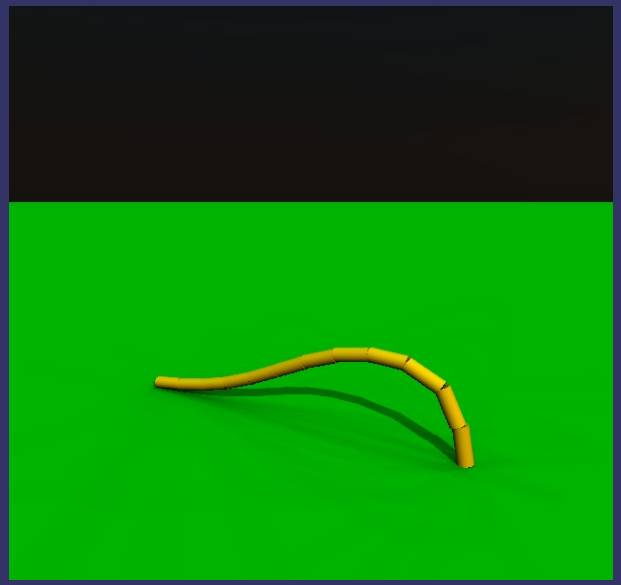
- New Stem object “FlexNode”
  - Cylinder (similar to F in GroIMP)
  - Mass added
  - Joint with 6 degrees of freedom at base
  - Connection point at top
  - Motors oppose bending forces

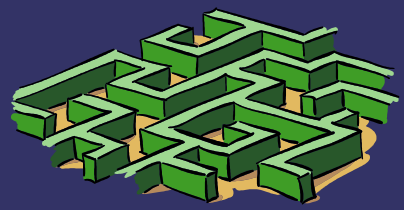


Flexible Stems 2



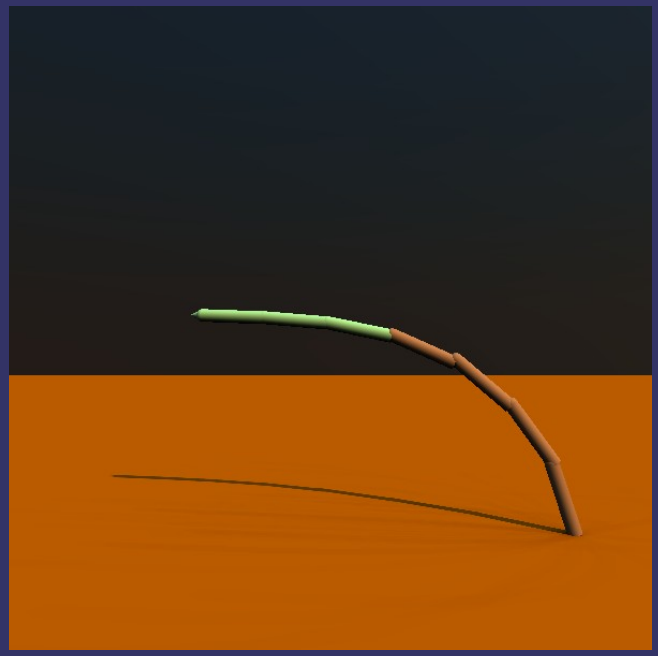




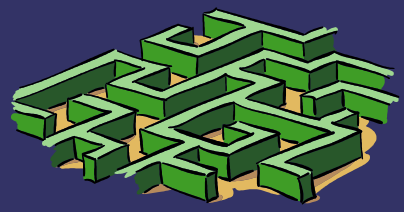


Flexible Stems 3

- Stems can be made to stronger and more dense with age

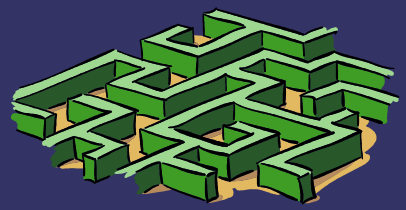


- Problem:
  Joints cannot be made strong enough - too much force and they become unstable



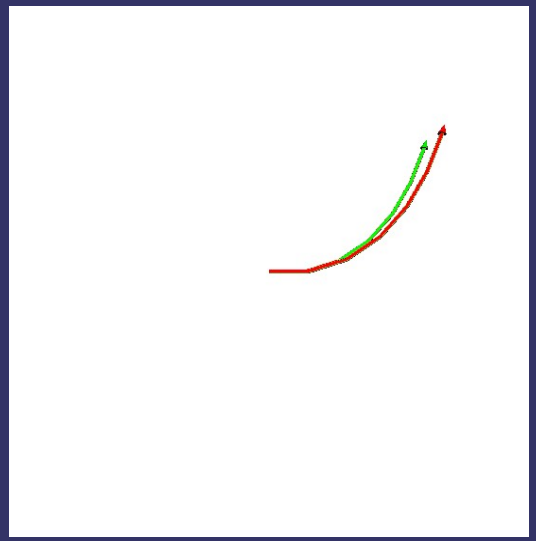
Effects Implemented in GroIMP

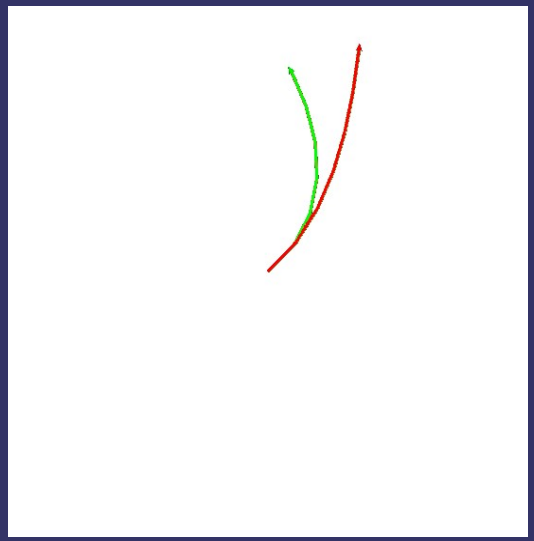
- Gravitropism
  - Directional Tropism from a vector
- Phototropism
  - Light sensitive tip plus directional Tropism
- Thigmotropism
  - Cone projected from tip
  - Intersection of volumes
  - Directional tropism
- Collision avoidance
  - Cone projected from tip

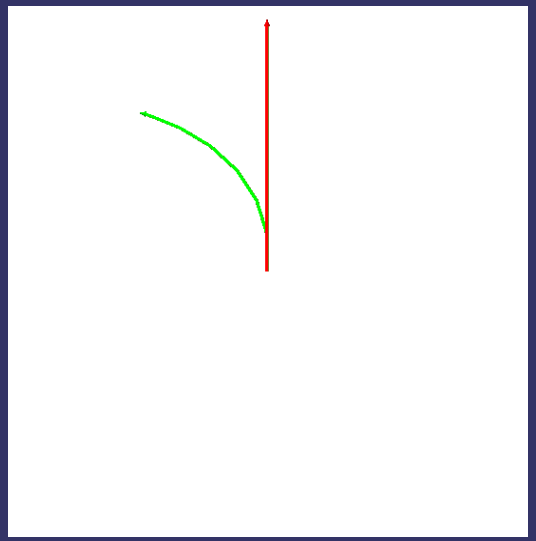


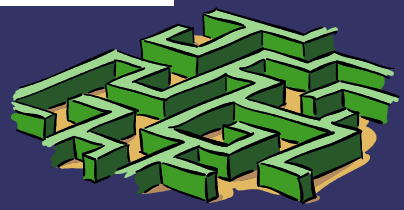
Problem with Tropisms

- Effect of RD is dynamic:
  Move the stem with something else
  (eg physics engine) and the effect changes
- Solution: Calculate a Transform instead



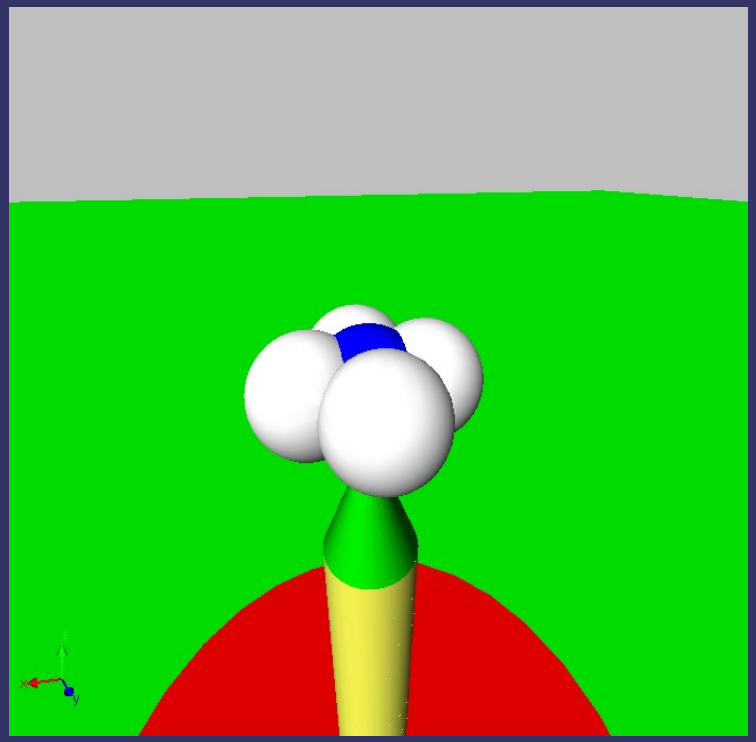


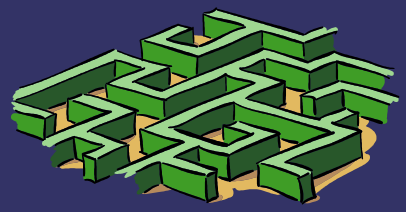




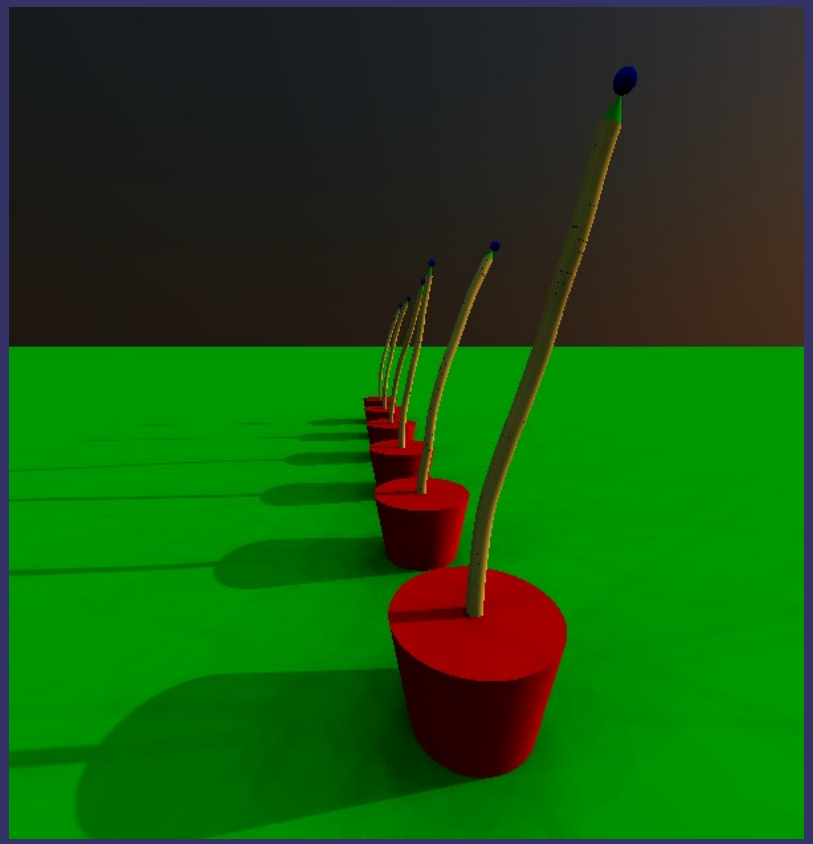
Photosensitive growth tip

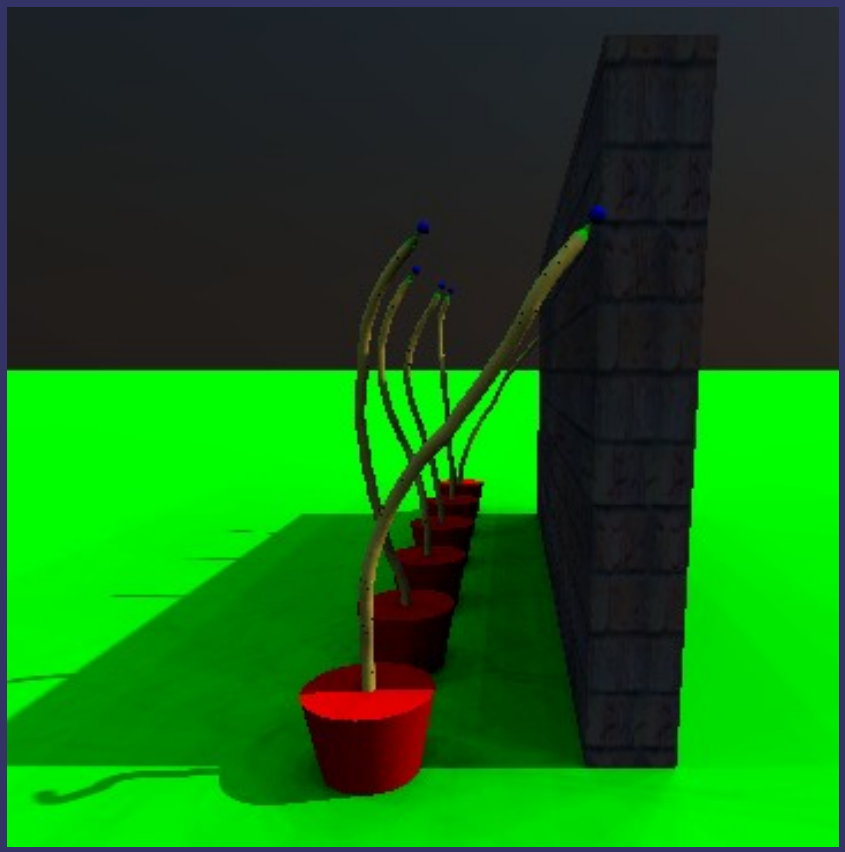
- Used four SensorNode objects
- Estimate angle from opposing sensors

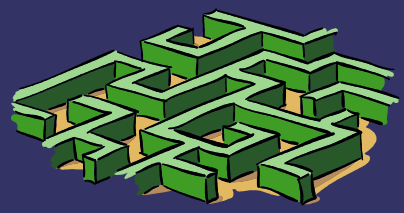




Phototropism

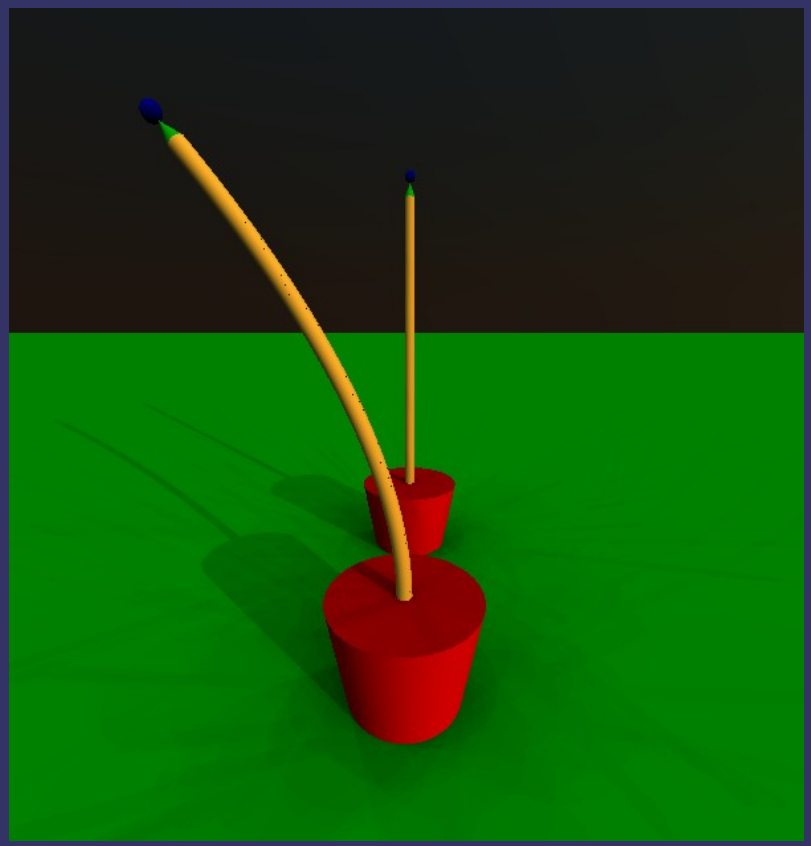


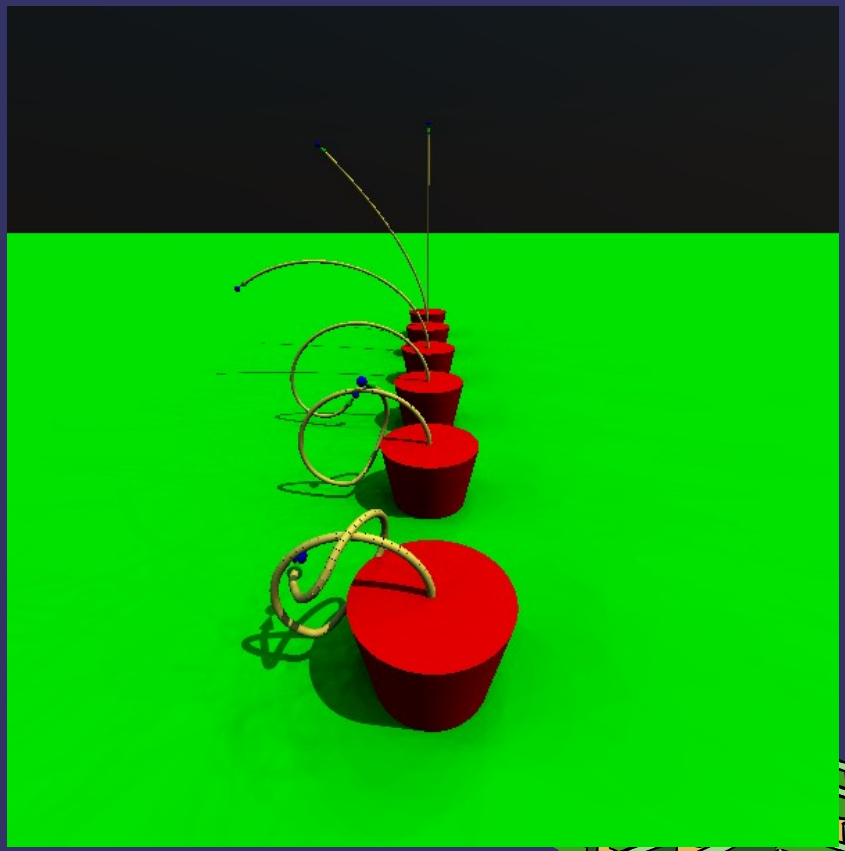




Level 0 controller

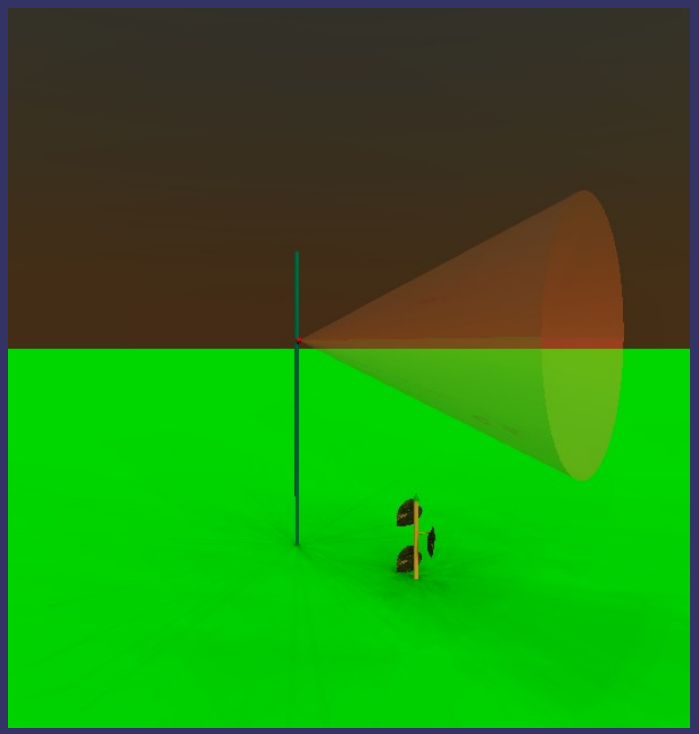
- Directional Tropism
- Relative to tip orientation
- Increased effect = smaller bend radius

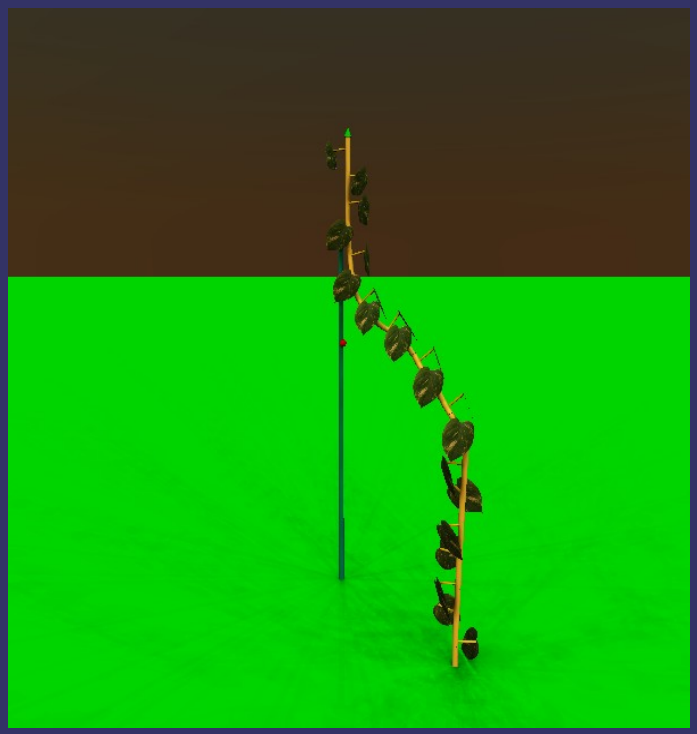


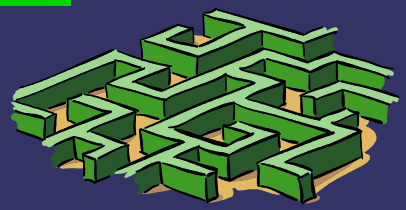


Level 1 controller

- Beacon attractor
- Cone of influence
- Tropism direction towards beacon

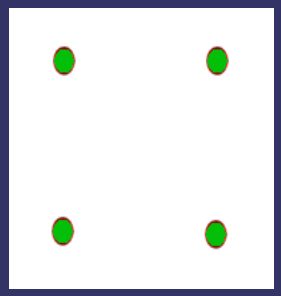


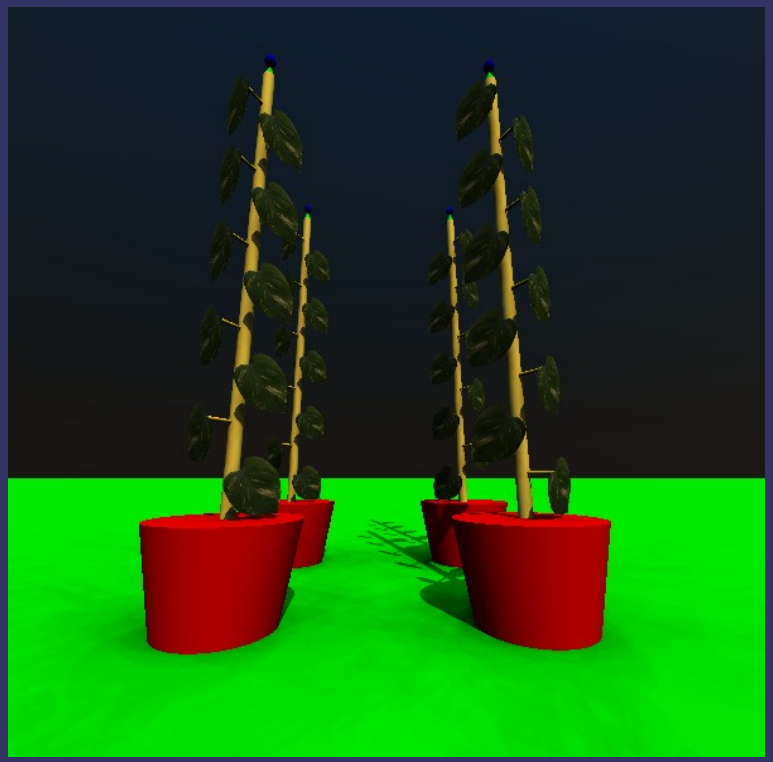




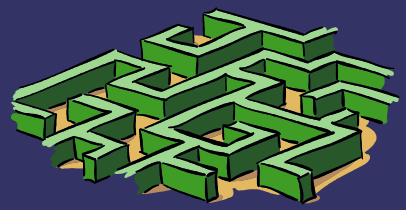
Structural tests - 1

- Level 0 controllers
- Square Patterns





Control – strength=0



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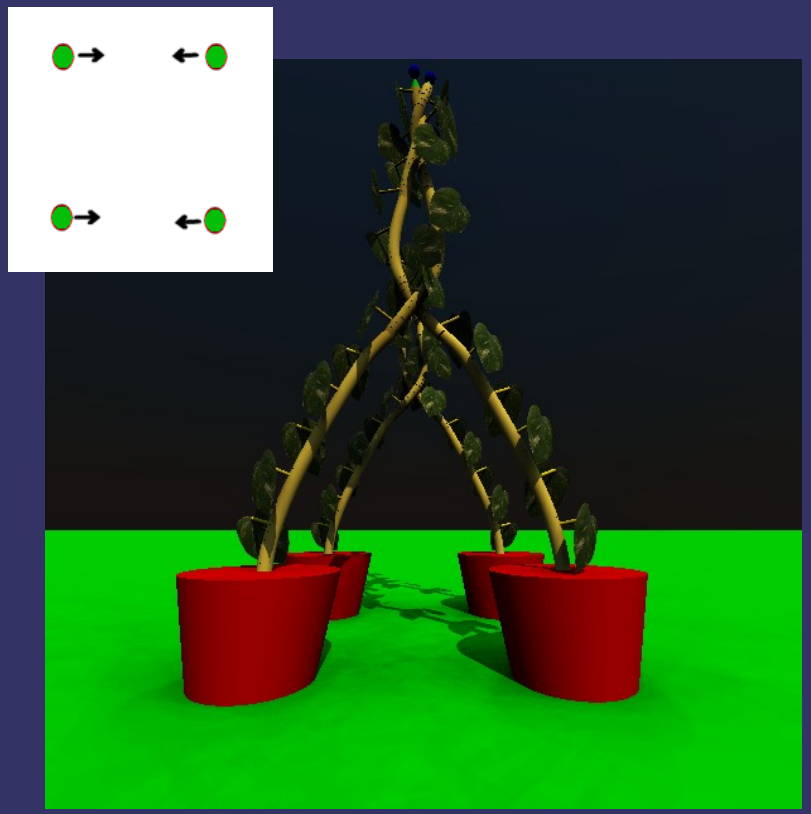
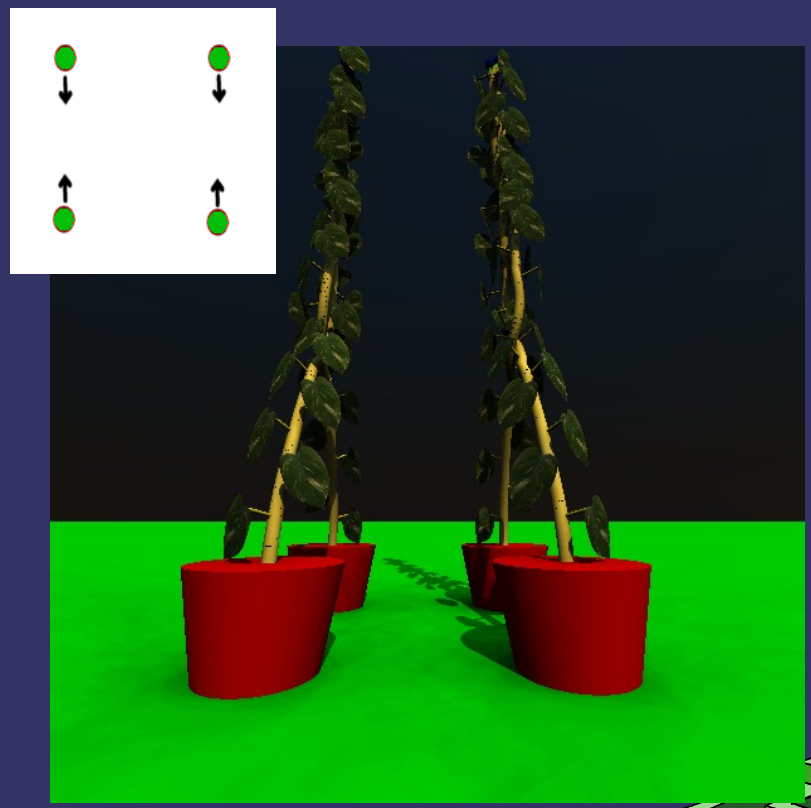
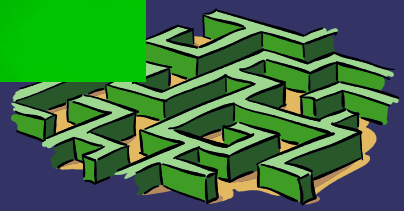
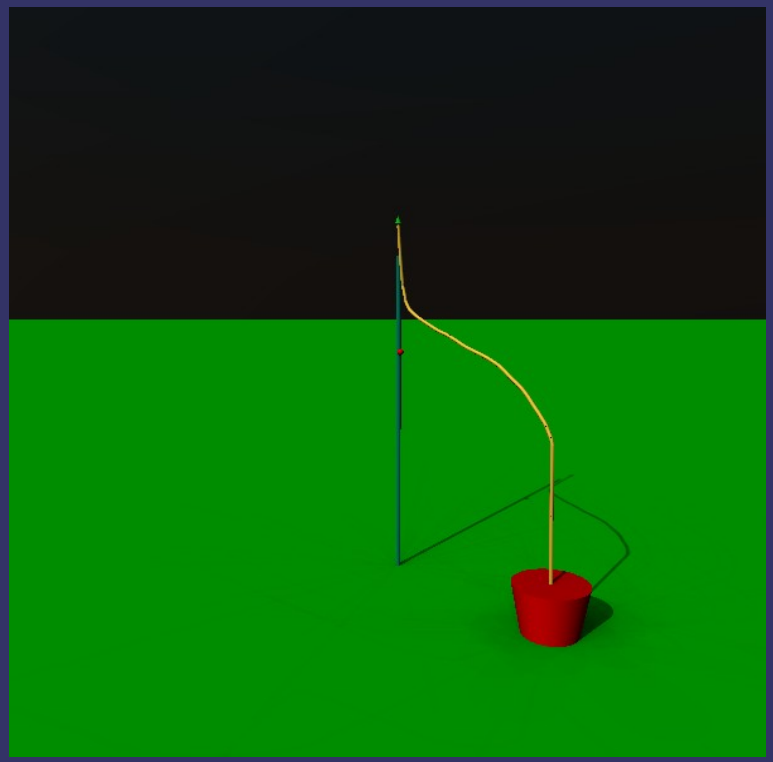


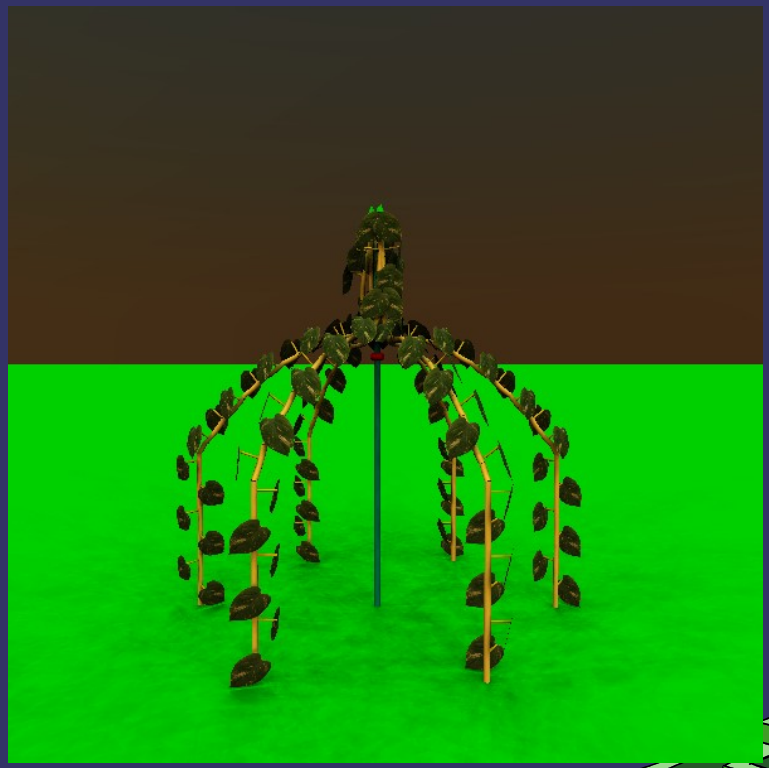


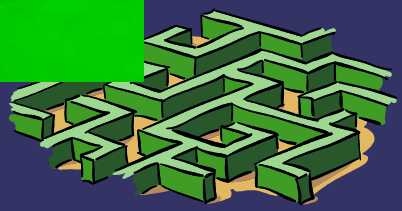


Structural tests - 2

- Level 1 controllers
- Beacon on a pole with cone of attraction
- Result – a hut

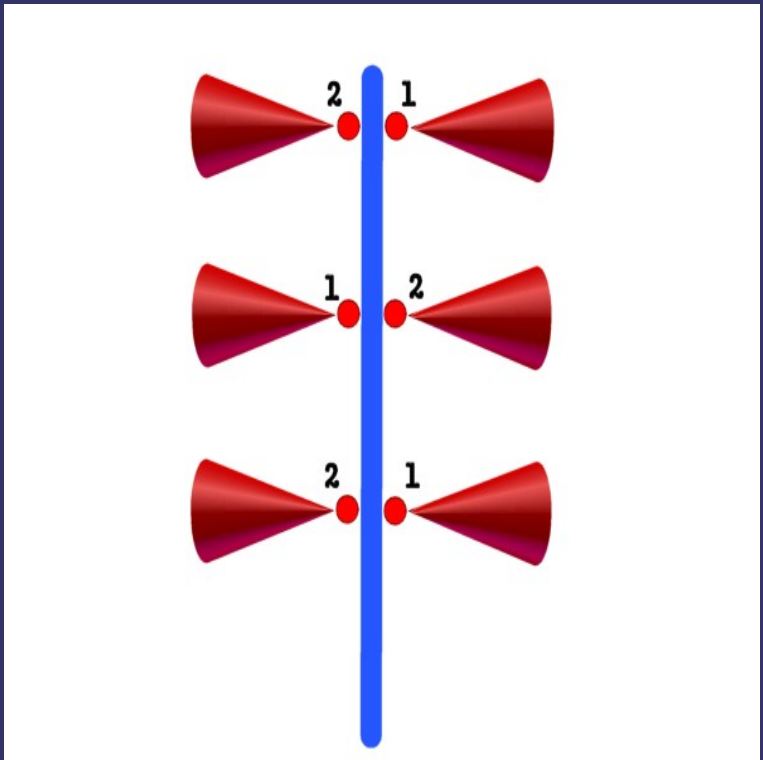


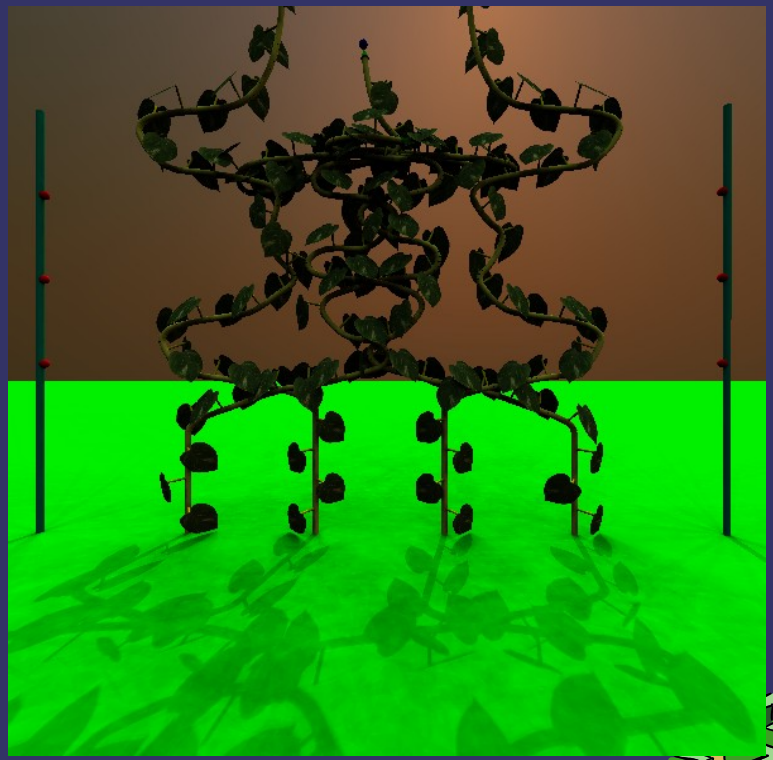


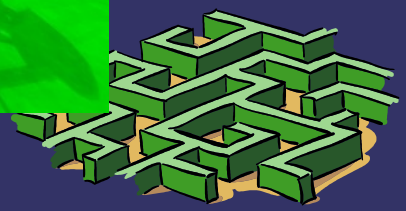


Structural tests - 3

- Beacons on a pole with ID numbers
- Level 1 controllers attracted to one ID
- Timers Switch ID attractions
- Result Fence patterns

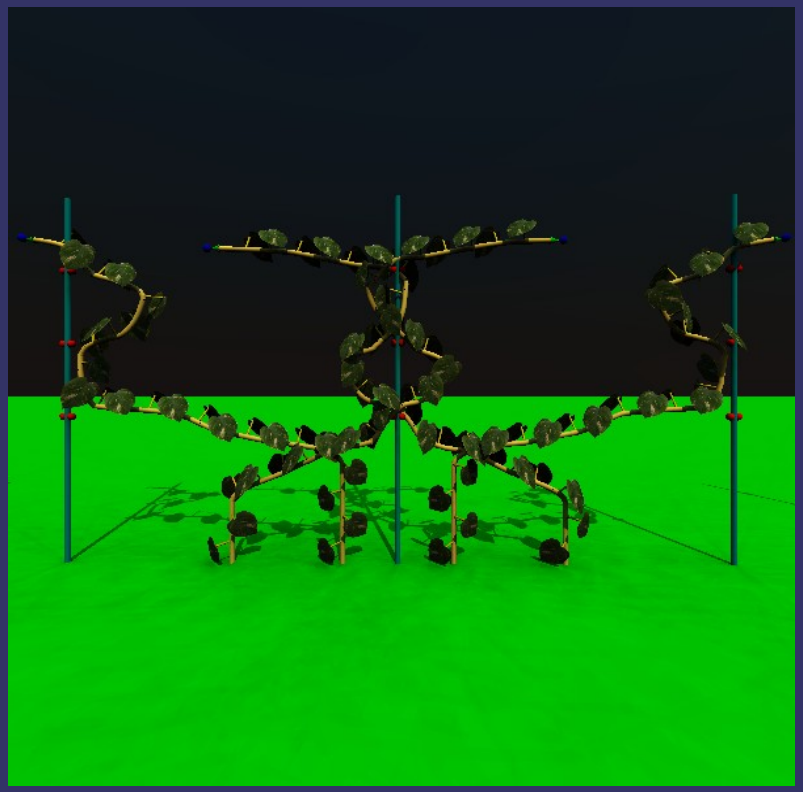


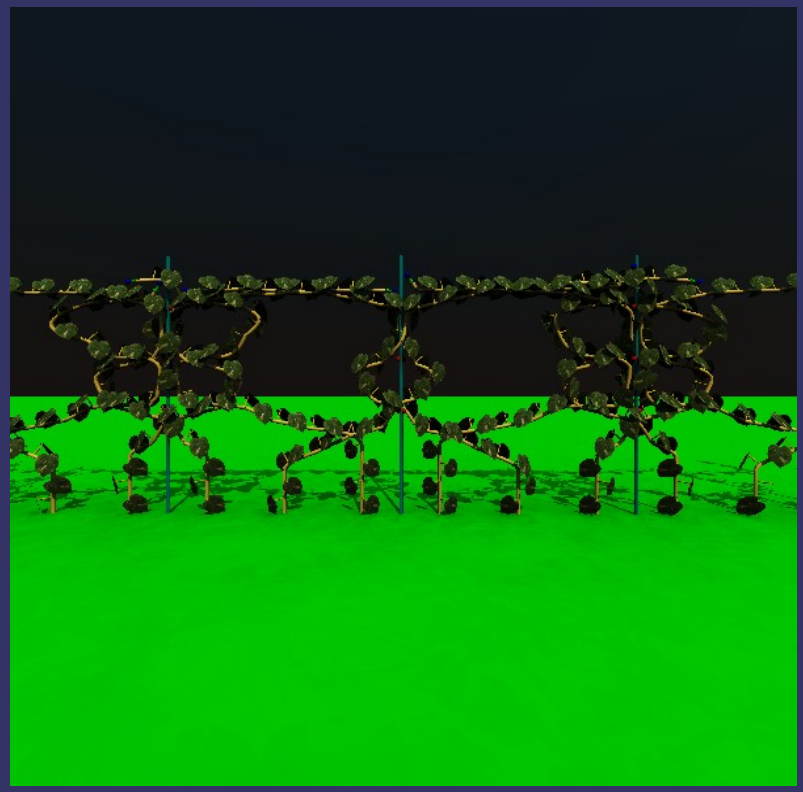


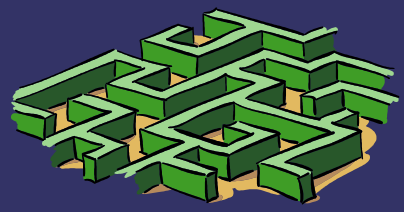


Structural Tests - 4

- More Poles = Longer Fences

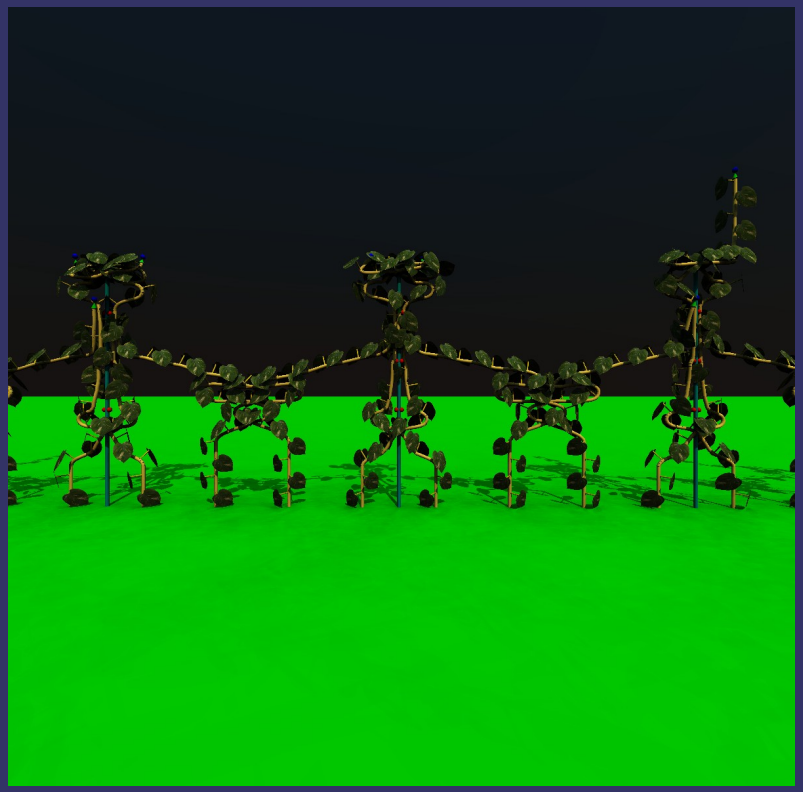


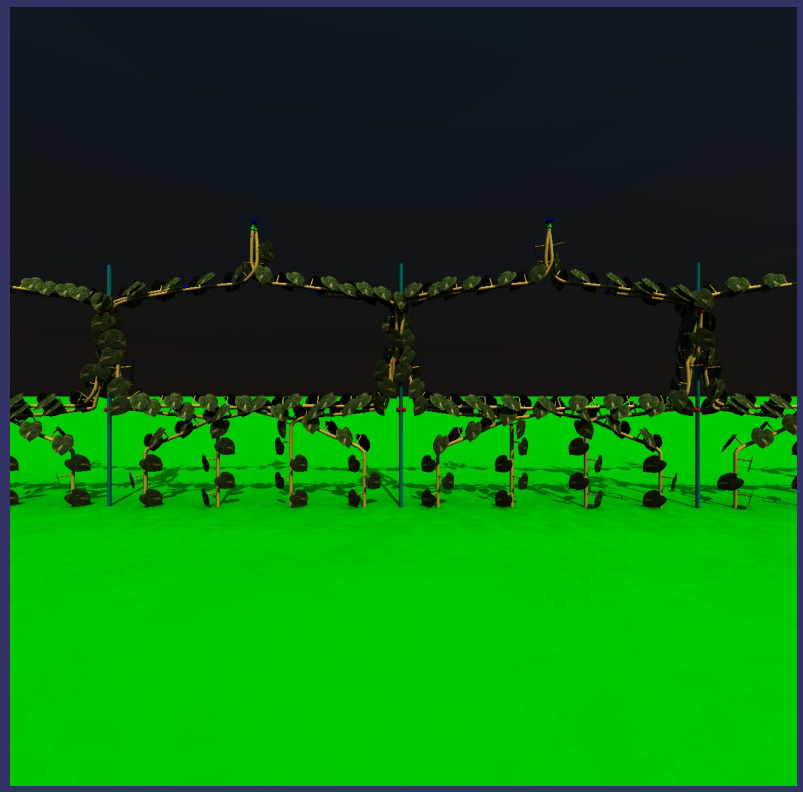


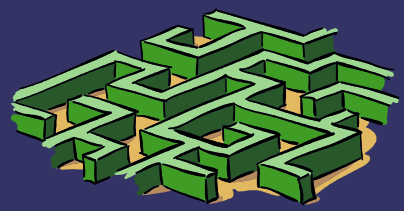


Structural Tests - 5

- Change timer period – more patterns

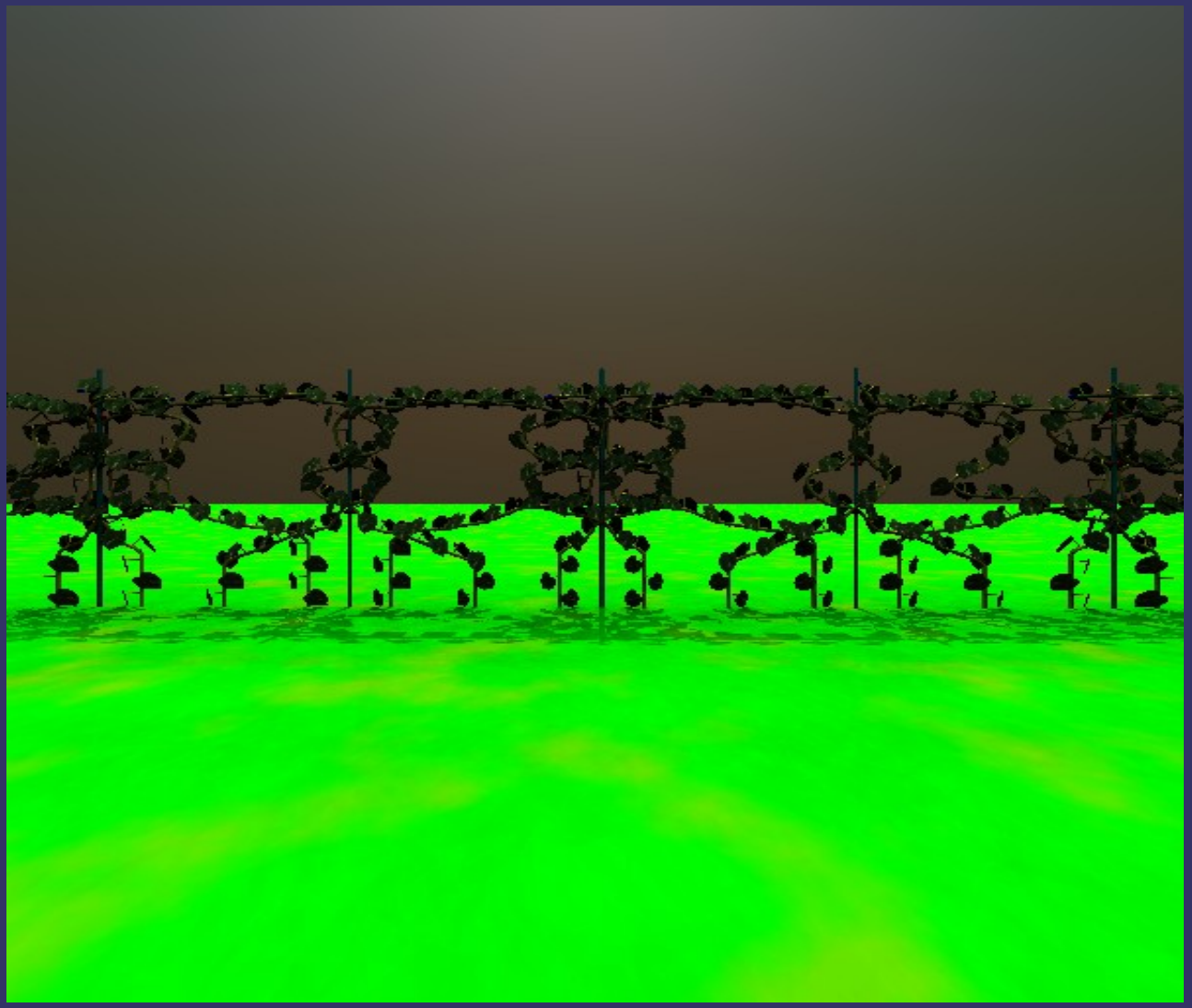


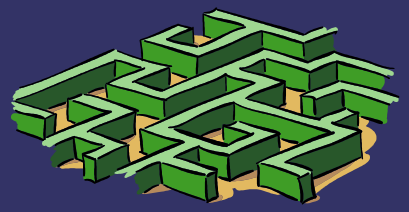




Structural Tests - 6

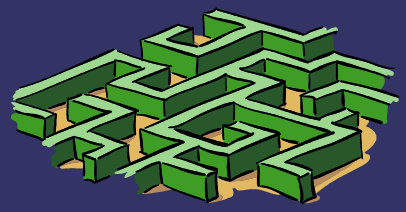
- Gaussian Noise added to parameters





Conclusions

- Interesting structures can be grown to order
- JBullet joints too weak or unstable
- Level 0 Controllers easily diverted
- Level 1 Controllers give robust control
- Further investigation worthwhile



References

- [1] Kerrigan, C., 2009. The 200 year continuum. Leonardo 42 (4), 314{323
- [2] Anonymous. Aperos de labranza y otras cosas del pueblo. Accessed 17th September 2010. URL http://ollerosdetera.iespana.es/aperosdelabranza_1.htm
- [3] Montgomerie, C., 2010. Robotropism. A Part III project report, University of Southampton, UK.