PASSIVE RECONFIGURABLE ROBOT

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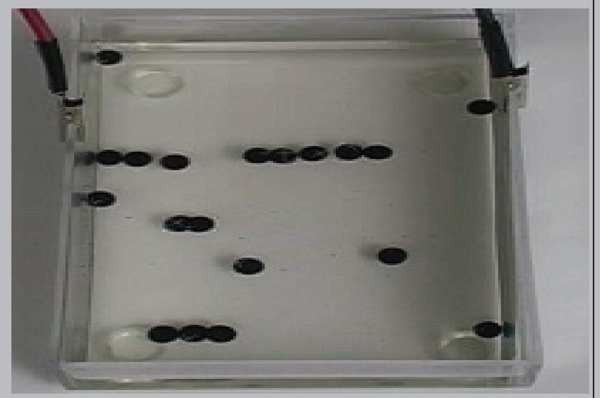
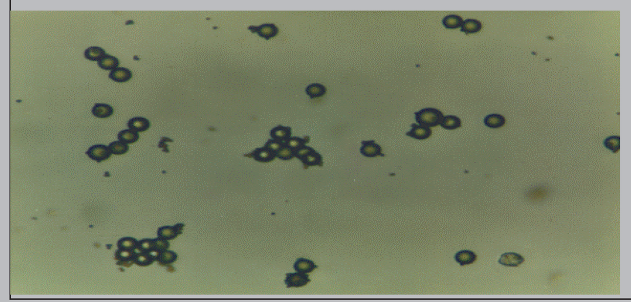
Inspiration

Bimolecular self-assembly, when two single strands of Deoxyribonucleic Acid assembles into a double helix.

Hemoglobin, Ribosome and hybrid stuctured viruses take advantage of 'bottom up approach'. As it is easier to assemble very large complexes and needs less genetic information.

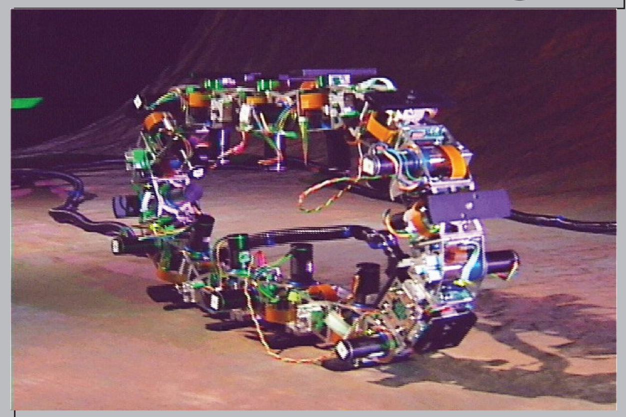
Self-assembly in simple Physical systems. Example, Coins in water self assemble in to a geometry, due to surface tension.





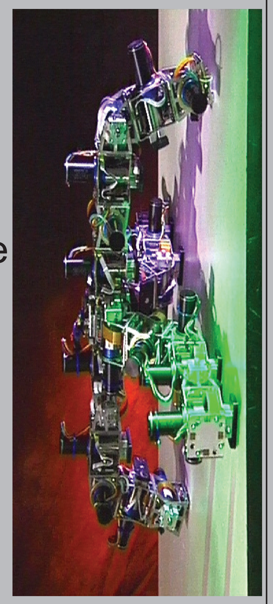
Self-assembly of chemicals, such as streptavidin and biotin beads, to form various conformations.

History



Current Implementation, in **POLYBOT**, uses planned deterministic reconfiguration path. Self-Assembling is accomplished through **Deliberate Active Motions**.

These indiviual units which have onboard power and ability to locomote, places severe power and actuations problems at smaller scales.



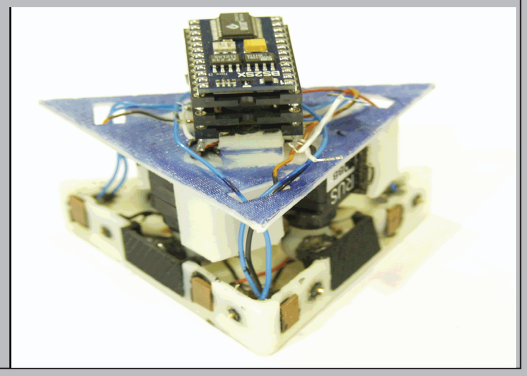
We Propose macro-scale programmable modules which exploit Brownian Motion in the environment to form parallel local structures. This then aggregates to reconfigure in to a required geometry.

Advantages include:

economic mass production of units.

graceful degradation of functions, also called Self-Repair.

Ability to transform into topologies suitable to the task at hand

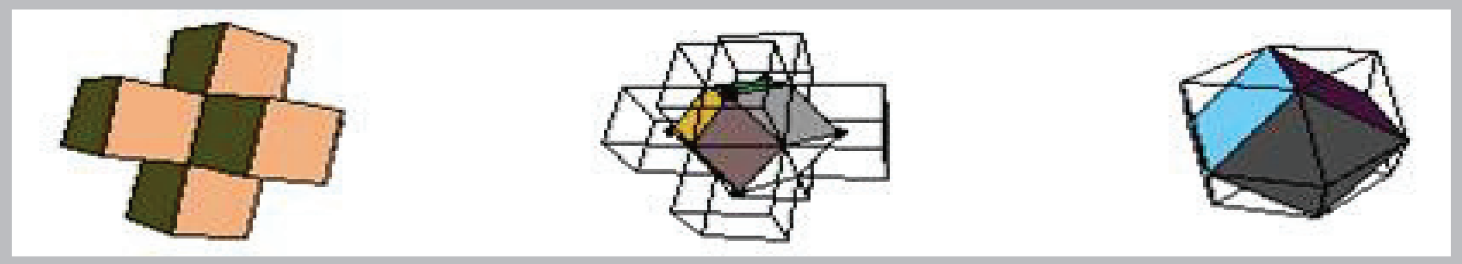


Concept

Imagine Rhombic Dodecahedron shaped robotic modules moving in Browninan Motion. When they come in close proximity they attach or detach depending on the graph grammar rules.

Brownian Motion: irregular, composed of translation and rotation, and the trajectory appears to have no tangent. Every particle move independently. The motion more active, less viscous the fluid and higher the temperature.

Rhombic Dodecahedron: Space filling polyhedron which can be used to generate tesellation of space.
A Zonohedron. Advantage is that the combinatorics of the faces is equivalent to those line arrangements in space.



Graph Grammar: A simple labeled graph over an alphabet Σ= {a, b, c, . . .} is a triple G = (V,E, l) where V is a set of vertices, E is a set of unordered pairs or edges from V and l is a labeling function.

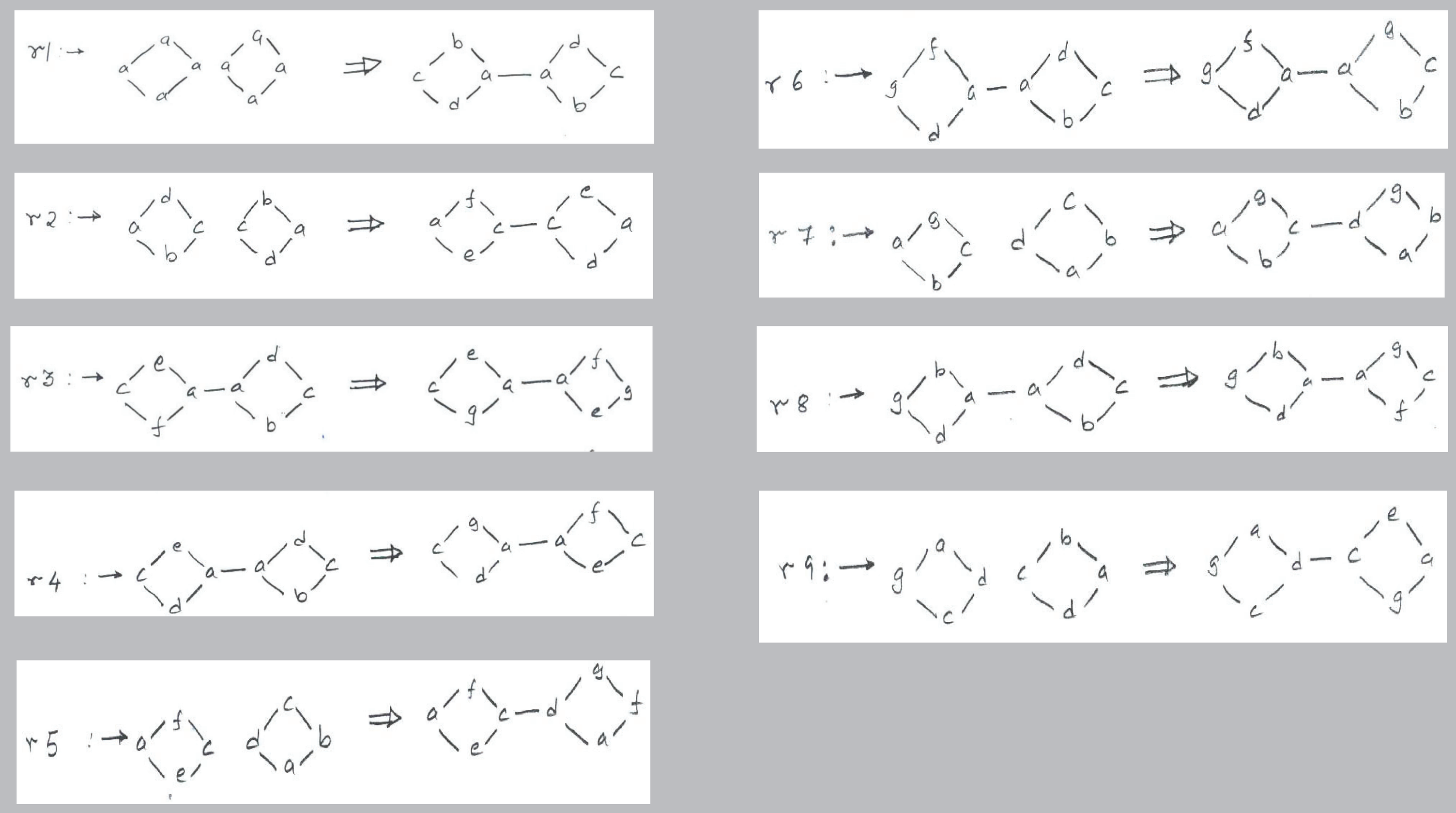
A rule is a pair of graphs r = (L,R) where $V_L = V_R$.

Given a graph G = (V,E, l) and an action (r, h) on G with r = (L,R), the application of (r, h) to G yields a new graph G' = (V,E', l')

A system is a pair (G' Φ) where G' is the initial graph of the system and Φ is a set of rules

Implementation

We Implement the graph grammar ruleset Φ, to Reconfigure in to the shape of '**P**'. With size of Φ 9 and lables {a,b,...g} of size 6, we were able to construct our final configuration from 10 square shaped units Hence embedding a purely topological object C_4 (a cycle of four vertices) in to R^2 (2D space).



Simulation

1. Constructive grammer rules ($E_L \subset E_R$) are stored in the robotics modules.

2. Boundaries are defined in which robots move in Brownian Motion.

3. Initialized all robots all labels.

4. Initialize OpenGL.

5. Check proximity between robots edges.

6. If close enough, then check if any of the rule set matches.

7. If rule match, then attach and relabel with r_R .

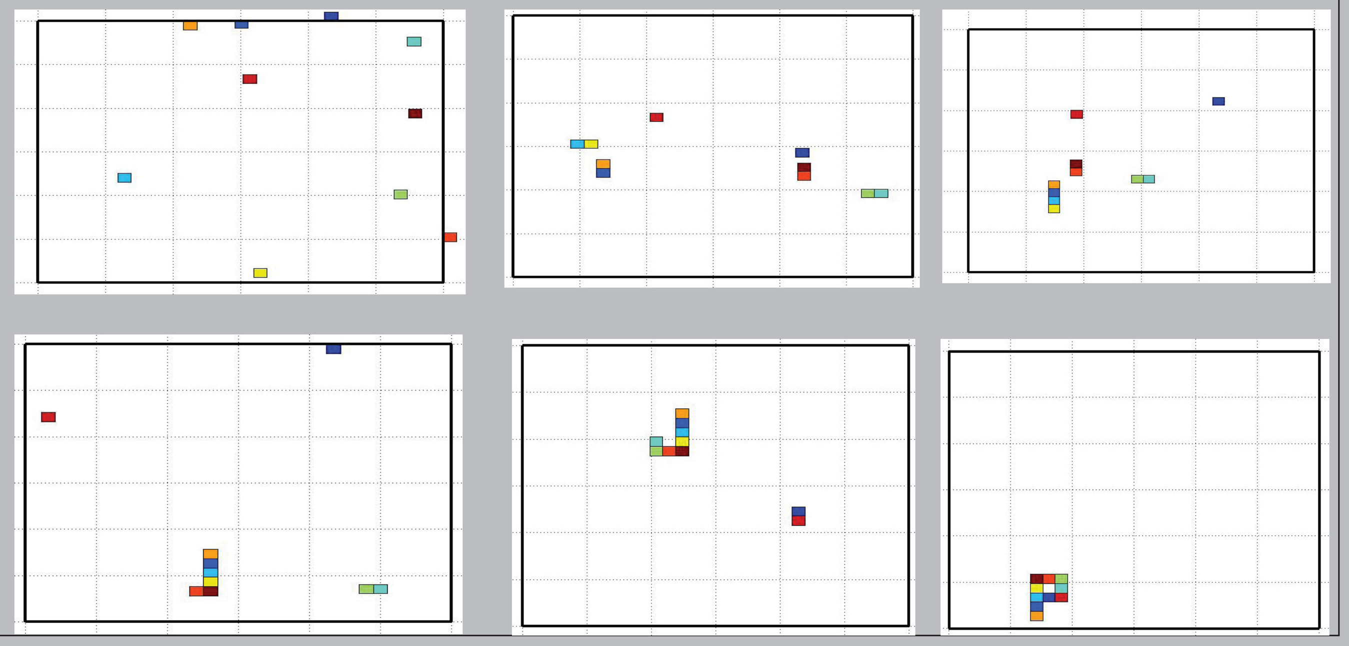
8. Else, repel.

9. When the final shape is formed (This happens when all the rules are implemented) STOP.

Results

Various formation of subassemblies in Simulation.

(a) initialized arbitrary position (b)dimer formation (c)fourmer formation (d) sixmer subassembly (e) eightmer and dimer subassemblies and (f) formation of 'P'.



Discussion

Inherent problems in passive reconfigurable robotic system.

1. **Optimization of rules**: least time to asssemble or least set of rules.
2. **Stochastic Model**: Generation of uncontrollable rule set Φ_U, Attraction basin of each units, retension of bonds, Orientation rule set in 3D Φ_O .
3. **Geometry**: Which geometrical structures can be reached. Topological problems like deadlock and concavity. Further extending the graph grammar technique with embedding C_{12}(for RD) in R^3 (in 3D).

In Future, we plan to pursue (a) a graph grammar generating algorithm, which gives the rule set Φ when provided with the parameters of geometrical structure,(b)define explicit notion of time, for deterministic self reconfiguration (c) formalize the theory of self organization at all levels and (d) based on this theory build a working prototype.