Nanotechnology: opportunities and challenges

GC7 : Journeys in Non-Classical Computation

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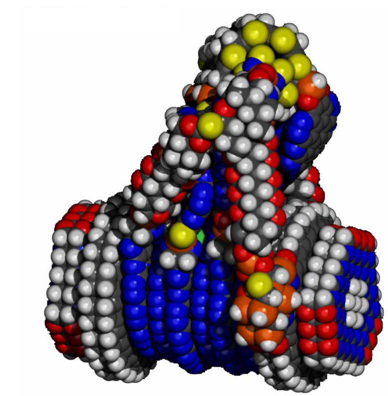
assemblers

- assemblers, nanites, nanobots
    - molecular scale robots
  - making macroscopic artefacts
    - assembling anything, from steaks to spaceships
- assemblers make conventional factories unnecessary



- CS challenges:
  - software, tools, techniques, models, …
    - hardware/wetware up to physicists, engineers, biologists

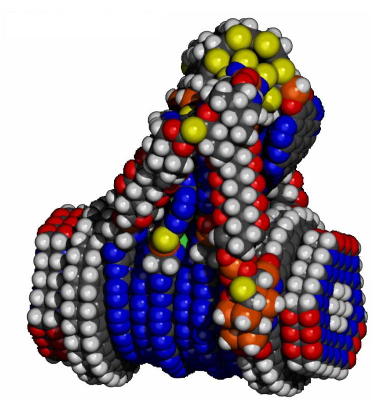
nanoscale fabrication

- “desktop” fabrication plant, comprising
  - many very small devices
    - trillions of molecular scale robot assemblers, conveyors, manipulators, …
  - early concepts used centralised computer control
      - electrical, mechanical, chemical, …
    - assembly instructions broadcast to all the robot assemblers
    - each assembler has some local state to customise the instructions

- universal assembler
  - given the right assembly instructions, and the right raw materials, the plant can assemble *anything*

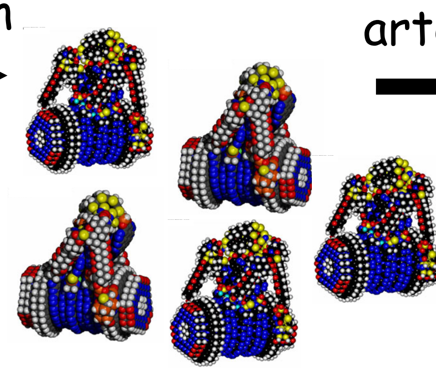
assembling artefacts

- growth and development on two levels
  - bootstrap a small initial assembler population
    - pool of raw material (mainly carbon)
    - assemble trillions of nanites (exponential growth)
  - eg, to build a new nano-fabrication plant
    - which then assembles, or "grows", the artefact



http://www.imm.org/

grow population



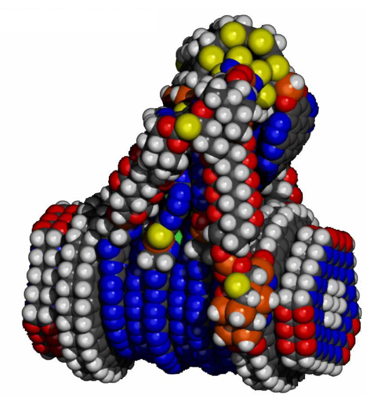
assemble artefact

http:// www.omahasteaks.com/

the MNT design challenge

- assembled artefact is emergent property
  - of actions of vast number of nanites
- design requires "reverse emergence"
  - from desired emergent artefact
  - to behaviour of nanite assemblers

design appropriate assemblers →

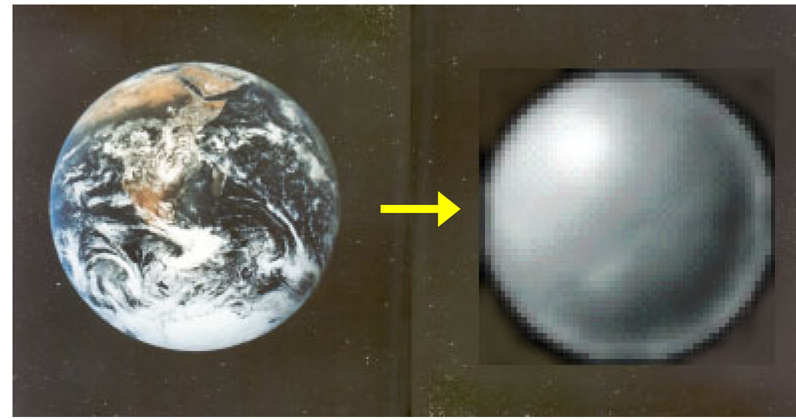


disassemblers

- as part of assembly
  - disassembly of raw materials required for assembly
  - disassembly of “scaffolding” required during assembly
- medical applications
  - scouring cholesterol from arteries
  - filtering blood toxins
  - removing damaged cells
  - repairing damaged nerves
- environmental applications
  - disassembling toxic chemicals into safe constituents
  - concentrating heavy metals
  - disassembling unwanted artefacts

when nanites go bad

- "grey goo" scenario
  - where replicating nanites escape, go rogue, and disassemble the planet



- "Some Limits to Global Ecophagy by Biovorous Nanoreplicators" -- Robert A. Freitas

  http://www.foresight.org/NanoRev/Ecophagy.html

Foresight Institute guidelines (excerpt)

- Artificial replicators must not be capable of replication in a natural, uncontrolled environment.
- Evolution within the context of a self-replicating manufacturing system is discouraged.
- Any replicated information should be error free.
- Any self-replicating device which has sufficient onboard information to describe its own manufacture should encrypt it such that any replication error will randomize its blueprint.
- Mutation (autonomous and otherwise) outside of sealed laboratory conditions, should be discouraged.
- MNT device designs should incorporate provisions for built-in safety mechanisms, such as: 1) absolute dependence on a single artificial fuel source or artificial "vitamins" that don't exist in any natural environment; …

http://www.foresight.org/guidelines/current.html

evolution happens

- given vast numbers of nanites, some will *go wrong*
  - if they are self-replicating, they will evolve
    - evolution is an inevitable consequence of "reproduction, variation, selection"
- safety critical application
  - current approaches totally inadequate
    - "proof of correctness" doesn't help with a mutant
  - new safety techniques and tools required
    - *design* of non-viable "adjacent possible"
      - Foresight Institute guidelines are an excellent start
    - evolution will exploit *anything*
      - even (especially) things outside your abstract model

the proposed journey

- **to solve the MNT design challenge, *safely***
  - designing the desired emergent properties
    - simple rules give complex behaviour
      - but *which* simple rules give the *desired* complex behaviour?
      - thorough understanding of Self-organising Complex Systems
  - designing the *lack* of undesired emergent properties
  - searching for suitable designs
    - large complex search space, bioinspired search algorithms
  - effect of embodied nanites
    - strange physics at very small sizes
      - friction, flow, etc all very different
    - inevitability of evolution
      - evolution exploiting embodied properties