Embodied Artificial Evolution: the Next BIG Thing?

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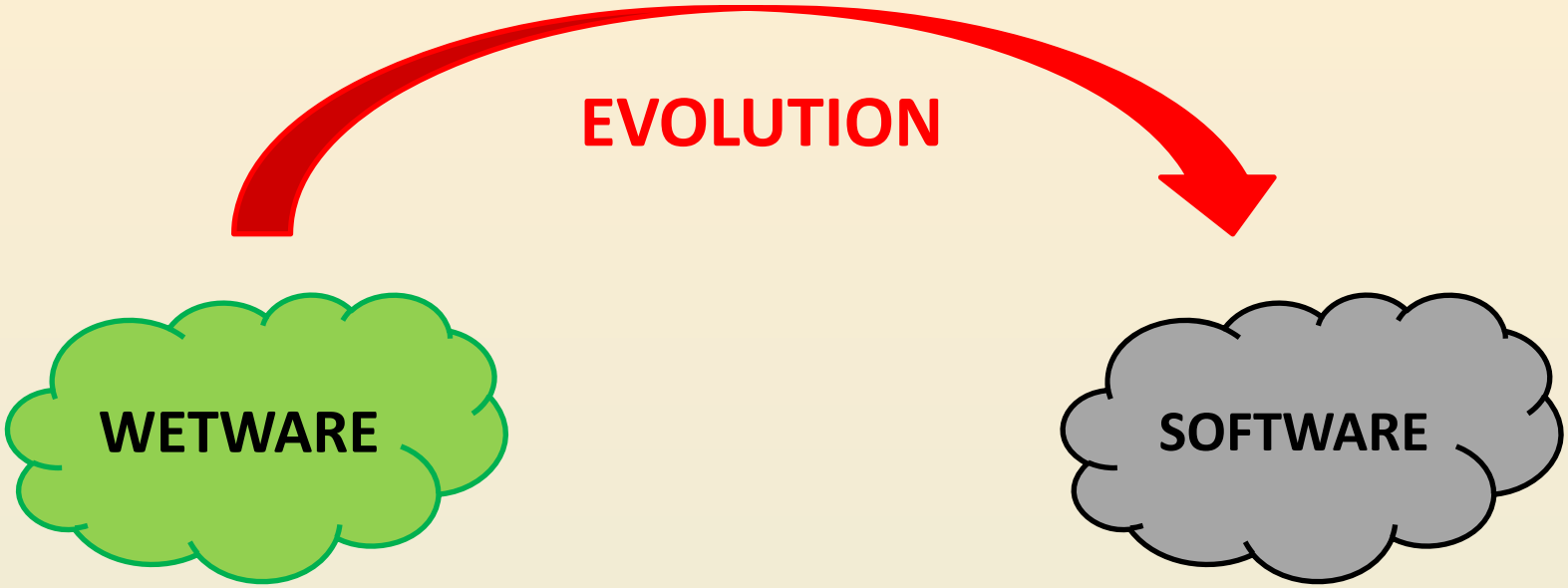
Past, Present

- 19th century:

  evolution is a theory, a passive, explanatory concept that helps us understand things

- 20th century:

  evolution is a tool, an active, creative concept that helps us produce things (solutions for problems) in digital spaces



Biosphere

Evolutionary Computing

Learnt through Evolutionary Computing

Engineering / mastering evolutionary processes

by

- designing evolvable objects (pieces of code, blueprints)
- designing mutation and crossover operators
- designing selection operators
- specifying fitness functions, reward mechanisms
- putting this all together and tuning it (DIVERSITY of alg's !)

for problem solving and simulation

Learnt through Evol Comp (cont'd)

+

- Evolution can solve problems we don't fully understand and cannot clearly specify
- Evolution can cope with changing situations
- Evolution can come up with original, unexpected solutions (that can be reverse-engineered)

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- Designing good EAs can be difficult (representation, parameters)
- No good theory
- Could take too long (can change with new hardware)

Evolutionary computing and embodiment

- Evolution in digital space, result in digital space
  e.g., time tables, consumer models, robot controllers
  evolutionary optimization

- Evolution in digital space, result in physical space
  e.g., jet nozzle, satellite boom, Peter Bentley's coffee table
  evolutionary design / art

- Evolution in physical space, result in physical space
  embodied artificial evolution

Past, Present, Future

- 19th century:

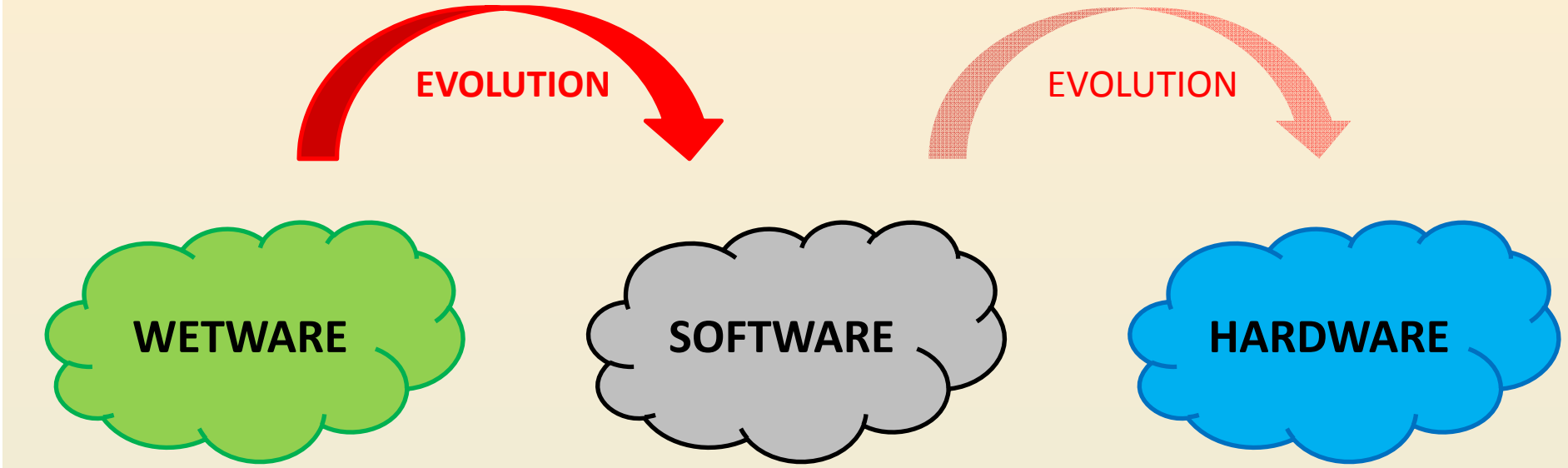
  evolution is a theory, an explanatory concept that helps us understand things

- 20th century:

  evolution is a tool, an active, creative concept that helps us produce things (solutions for problems) in digital spaces

- 21st century:

  evolution is a tool, an active, creative concept that helps us produce things (solutions for problems) in physical spaces



Biosphere

Evolutionary Computing

Embodied Artificial Evolution

Embodied Artificial Evolution

Old: Evolution of code (blueprint)

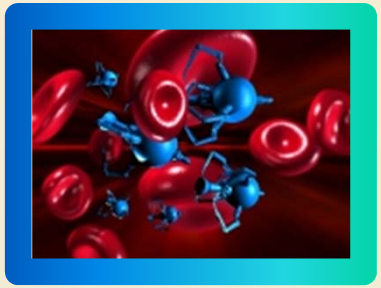
New: Evolution of things

1. Takes place in ***physical objects***
2. Reproduction = ***real birth*** = new object made, survivor selection = ***real death*** = object gone
3. Reproduction and selection are ***autonomous and asynchronous*** (→ population size is inherently variable)
4. Fitness can be ***task-based*** and/or ***open-endend***

Application examples

- Artificial pets, robot companions, servants, explorers, …

- Functional organisms, medical nano-robots, personal virus scanners



- Personal replicators (networked, evolutionary)

Note the difference: artifacts with or without inner controller,
Body vs. Body + mind

Motivation, benefits, impact

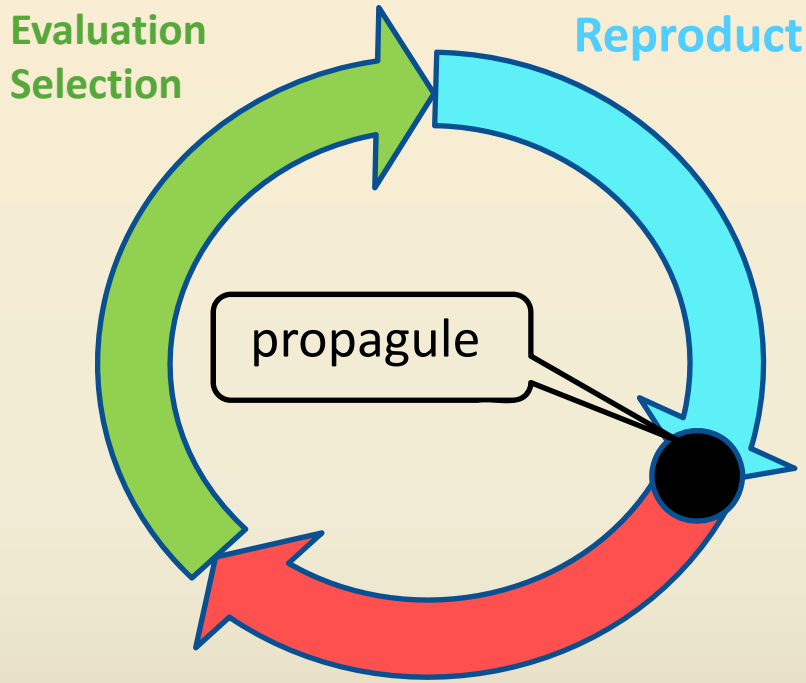
1. EAE / EoT is a ***game changer in design & manufacturing***:
   - Old: design ends with manufacturing
   - New: design & manufacturing are one, intertwined continuous process, evolution → unexpected solutions
2. ***New experimentalism for biology***: study evolution in a different medium by controllable and repeatable experiments → generalization, preconditions for evolution? Taxonomy? …
3. ***Redefines evolutionary computing*** switch from digital to physical changes everything: MATTER MATTERS
4. EAE / EoT is a ***game changer in computing & programming***:
   - Old: van Neumann architecture + computing and software (engineering) as we know it
   - New: HW = morphology, SW = control mechanisms, ???

Physical medium ?

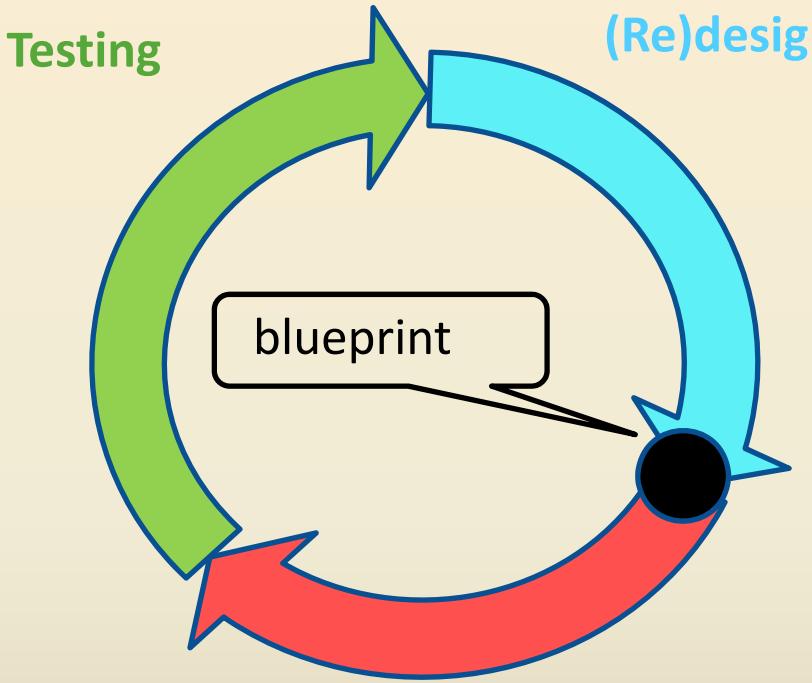
Huge diversity of approaches, under different umbrellas

- Hardware, mechatronics, plastics,
- Wetware bottom-up, chemistry
- Wetware top-down, biology
- Hybrids
- Functional fluids, programmable matter, microfluidics,
- …. ???

A new game for “passive” stuff



Embryonic development



Manufacturing

A new game for “active” stuff

WETWARE

HARDWARE

Cells

- very small
- self-replicating
- self-repairing
- self- …

Robots

- very small to big
- programmable
- controllable
- sensors/actuators/controllers

Sweet spot

Grand challenges

- Body type

Combine wetware with hardware (+software): self-* and programmable

- Reproduction - how to start

Implement “birth” for human engineered physical devices (robots), artifacts (and “death” too, under selection)

- Kill switch - how to stop

Guarantee that human supervisors can shut down the system, if needed.

Grand challenges cont'd

- On-line in vivo design - UI & control
  - On-the-fly monitoring and steering by user preferences - selection
  - Combination of autonomous and directed evolution. Freeze switch?

- Evolvability & evolution speed

Essential assessment criterion for the feasibility of potential applications.

- Co-evolution of morphology & control ("body & mind")
  - We cannot program these new guys the way we used to
  - New HW, new SW, thus new computer, computing, etc. →
  - New principles & methodology for development, testing, validation…
  - Lifetime adaptation, learning, development , Lamarckism, …

~~Conclusions~~ Closing remarks

- Evolution in the real world is different
- Computation in this new paradigm is different
  - new architecture for information processing / computing
  - redefines “program”, “programming”, software engineering, testing, validation, ect.
- Big Q’s are implied:
  - Scientific (fundamental issues regarding evolution, notion of Life)
  - Technological (feasibility)
  - Applicability (remember IBM in the 1940ies)
  - Desirability (ethics, think of GMOs)
- Different communities → unifying vision / umbrella needed
- Next BIG thing ?