HOW NATURE "SOLVES" INVENTIVE PROBLEMS

Stéphane Savelli

MP Solving / stephane.savelli@mpsolving.com

Innovative Solutions from Nature

- From a human being's point of view, Nature has produced a huge amount of innovative solutions, many of them being stunning
- Today's accepted theory of natural evolution is neo-Darwinian: natural evolution is driven by the natural selection of genetic variants of living beings which turn out to be most adapted to the environmental conditions at hand.
- There is no such thing like a conscious "design", nevertheless in this study "innovative solutions" are considered as if Nature had a design thinking
- Therefore:
  - to consider some facts from Nature as "innovative solutions" is a 1st level of (pure) subjectivity
  - additionally, any "innovative solution" requires an interpretation which is the definition of the corresponding inventive problem: this is a 2nd level of subjectivity

Prior Art and Objective of the Study

- Prior art
  - J. Vincent *et al.* [1] state that Nature « uses » the same inventive principles as those from the PRIZM matrix (simplified Altshuller matrix) but with a different statistics of occurrence
  - D. Mann [2] illustrates some inventive principles from the Altshuller matrix with examples from Nature
  - N. Bogatyrev *et al.* [3] show that the different statistics is due to different development strategies in technology and biology
  - V. Timokhov *et al.* [4] illustrate several TRIZ concepts (ideal final result, use of available resources, separation principle, some specific inventive principles) with the help of examples and problems to solve from the biological world (often in relationship with the human society)

- Twofold objective about innovative solutions from Nature:
  - Are the corresponding inventive problems solved by the means of satisfaction, separation or bypass of the contradictory requirements of the underlying physical contradictions?
  - Do some innovative solutions match some trends of engineering systems evolution?

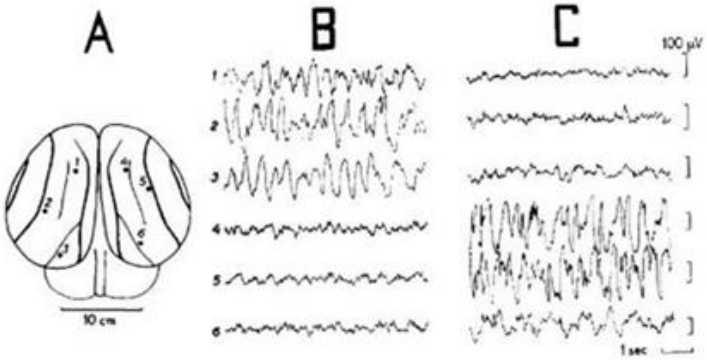
Experimental Procedure

- A set of facts from Nature has been collected (and is still going on), these facts appearing to a TRIZ specialist as innovative solutions
- Each such fact is examined as follows:
  - If possible, similar facts are grouped
  - A corresponding inventive problem is defined
  - If possible, the underlying physical contradiction PC is defined
  - It is examined if PC is solved by the means of satisfaction, separation or bypass
  - Independently it is checked in the inventive solution matches one or several trends of engineering systems evolution

Example #1: Sleep of Aquatic Mammals

PC: Aquatic mammals should sleep in order to restore their energy, but they should not sleep to avoid drowning

- Dolphins solve this PC by **separation in space, then in time** of the contradictory requirements: dolphins have unihemispheric type of sleep, i.e. they rest one half of their brain at a time



Example #1: Sleep of Aquatic Mammals

- Dolphin mother and calf solve the PC by **satisfaction** of the contradictory requirements (first theoretical option): they do not sleep during the first month of the calf's life. It brings also an advantage of increased survival probability against potential predators.

Example #1: Sleep of Aquatic Mammals

- The sea lion solves the PC by **satisfaction** of the contradictory requirements (second theoretical option): it sleeps in a specific position, its head thrown back and its nose pointed upwards, which allows its muzzle to stay outside water

Example #1: Sleep of Aquatic Mammals

- The male walrus also solves the PC by **satisfaction** of the contradictory requirements (second theoretical option): it sleeps in water with the help of pharyngeal pouches which are filled with air and add buoying force

Example #1: Sleep of Aquatic Mammals

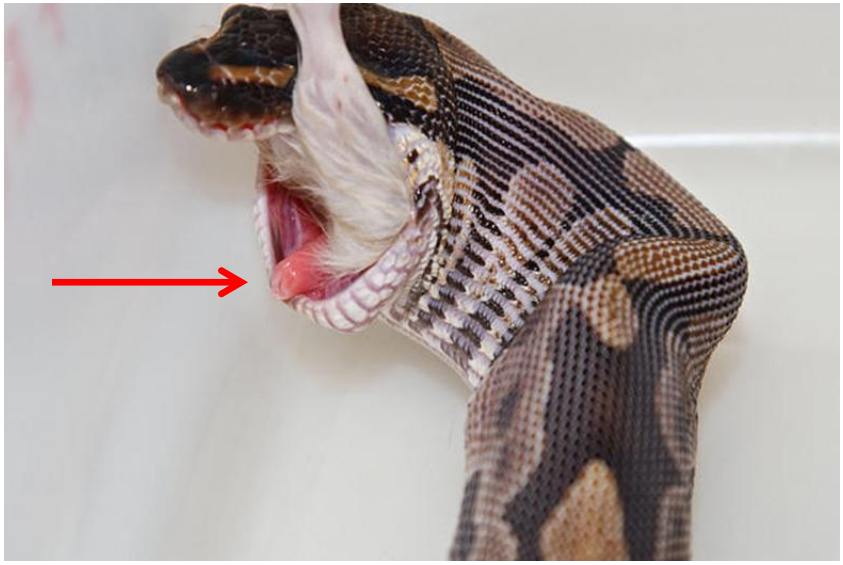
- The sea otter solves the PC by **satisfaction** of contradictory requirements (second theoretical option): it wraps itself in kelp and sleeps in water; kelp contains floats which provide buoying force

Example #1: Sleep of Aquatic Mammals

- This crab-eater seal solves the PC **by bypass** of contradictory requirements. On the below picture, it sleeps on the ice floe. In this case, drowning risk is no more relevant.

Example #2: Snakes Eating Big Preys

- PC: Some snakes should swallow big preys to get energy but they should not swallow big preys because they risk suffocating
  - These snakes solve this PC by means of **satisfaction** of the contradictory requirements: while eating big preys they breathe through a specific organ called glottis which extends out of the mouth and remains open to air flow because it is full of muscles



Ex. #3: Alpine Plants Survival during Glaciation

- Initial problem: How could high altitude alpine plants survive in Europe during glaciation eras?
  - PC: during glaciation, by nature the alpine plant species cannot move and therefore should die from frosting, but it should move to survive
  - Longly recognized solution: by dissemination of seeds (**bypass** of PC) they migrated to southerner areas or areas of lower altitude
  - One recently recognized solution: some plants (like *Eritrichium nanum*) stayed there on « nunataks » (areas without ice, emerged from glaciers) of high altitude, on walls oriented towards south (solar radiation is the same as in intertropical areas) (**satisfaction** of the contradictory requirements)

Example #4: Bats and Serenading Frogs

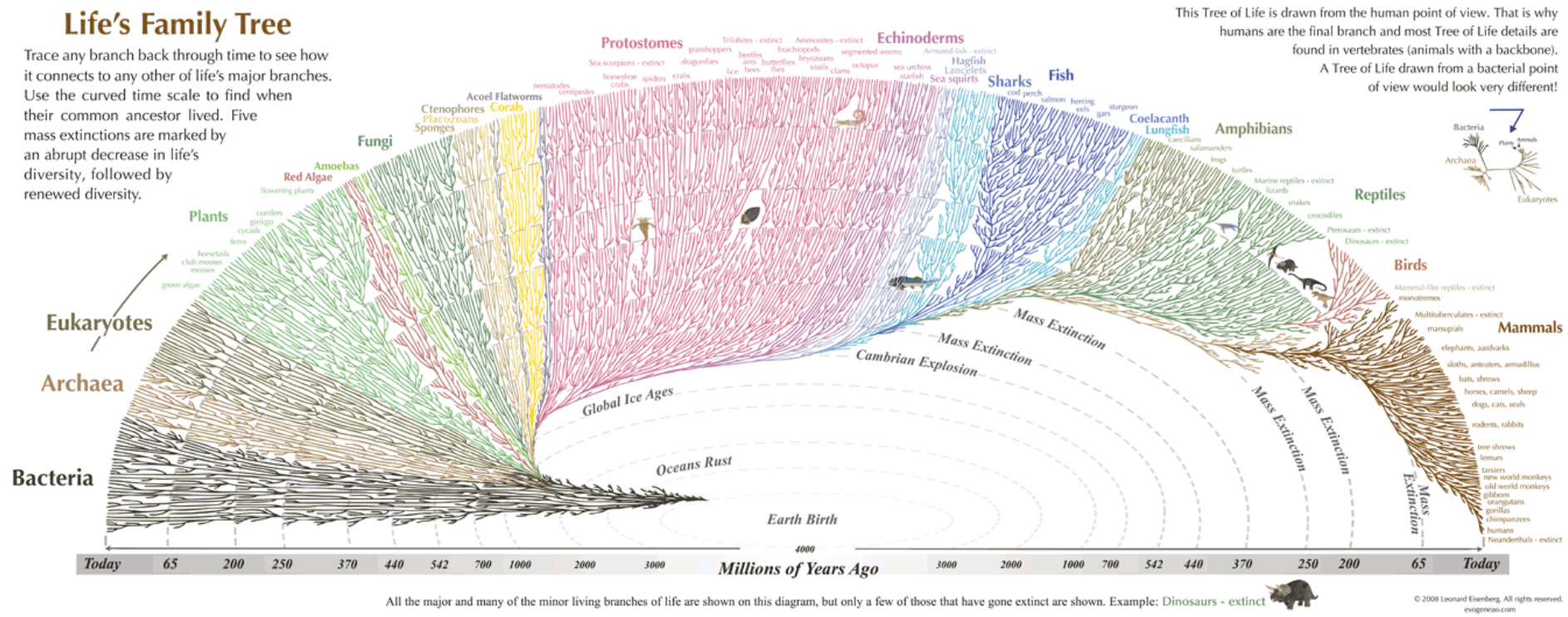
- Context: the male tungura frog serenades female frogs; bats chase the male frog using the serenade sound. As soon as it detects a bat, the male stops serenading.
  - PC: The bat should be far from the frog to detect its sound, but it should be close to catch it
  - Solution: (**satisfaction** of the contradictory requirements): the bat localizes the male frog that has stopped serenading by echolocating the remaining riddles of the frog, and interpolating the frog's position

Conclusion about PCs in Nature

- Some « inventive solutions » from Nature correspond to the resolving of physical contradictions by the means of satisfaction, separation and bypass of the contradictory requirements
- This is no surprise, because physical contradictions and their heuristics have a universal character
- Such examples, as the former examples illustratating the different resolution strategies for a PC, can be used for the sake of:
  - Education (TRIZ beginners, kids)
  - Inspiration, for TRIZ practitioners and specialists, beside illustrative engineering examples

Trends of engineering systems evolution

- **Trend of S-curve evolution / trend of increasing value**
  - Let us compare technological S-curves and the tree of life

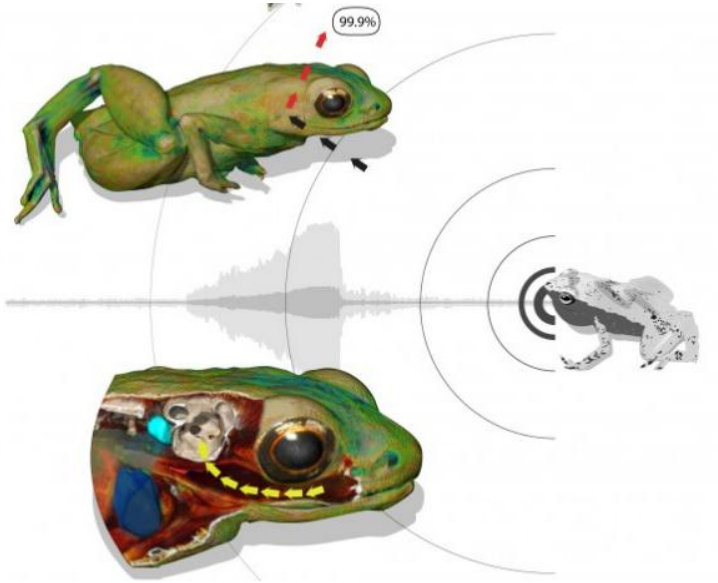


Trends of engineering systems evolution

- **Trend of S-curve evolution / trend of increasing value**
  - The tree of life shows:
    - Species diversification within the same branch of life
    - Species extinction with impossibility of being replaced by a « better » version of this species
    - Appearance of new branches of life without relation to the extinction of other forms of life
  - An S-curve is characterized by a increasing performance over time; at the level of a species, there is no meaning of considering a specific performance or a value: a species exists because it is adapted to its ecosystem; if a value would exist, it would be binary (a species exists or not at some given time of life history) most of the time
  - In this context, « natural inventive solutions » are only opportunistic solutions that have been selected by natural evolution because they bring some survival advantage to the considered species
  - Anyway there is no privileged direction for natural evolution [5], therefore living beings themselves do not follow any trend; however some « innovative solutions » from Nature can be interpreted according to some trends of engineering systems evolution

Trends of engineering systems evolution

- **Trend of increasing degree of trimming**
  - Inventive problem: How can Gardiner's Seychelles frog (formerly believed deaf) hear whereas it has no eardrum, no middle ear cavity?
  - Inventive solution:
    - The bones in its mouth amplify sound waves
    - The sound waves further travel to the inner ear easily, for fewer and thinner tissue layers lay between mouth and inner ear

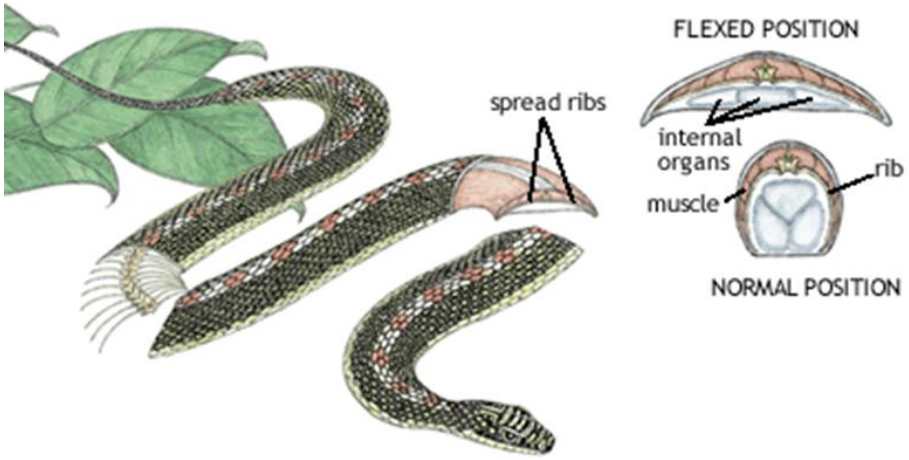


Trends of engineering systems evolution

- **Trend of increasing degree of trimming**
  - Starting point: not considering birds or bats, some vertebrates glide in air with the help of membranes:
    - Draco lizard
    - Flying phalanger
    - Wallace's flying frog

Trends of engineering systems evolution

- **Trend of increasing degree of trimming**
  - Paradise tree snakes (e.g. *Chrysopelea paradisi*), are excellent air gliders, but they have no membranes at all. How to they achieve this performance? They follow the **Trend of increasing dynamization**:
    - Once in air, it sucks its stomach and enlarges its ribs; as a result its body cross section looks like that of a Frisbee
    - They ondulate in air



Trends of engineering systems evolution

- **Trend of increasing coordination**
  - Problem: When a prey is caught in a spider web, it tries to move and generates mechanical waves that allow the spider to locate it precisely, and catch it. Social spiders live in gigantic webs. The prey localization is potentially impossible because of the simultaneous movements of spiders.
  - Solution: Spiders coordinate their movements: they run together towards the prey, and stop together to localize the prey, and again, and again…: this is the **coordination of rhythms**

Trends of engineering systems evolution

- **Trend of increasing coordination**
  - Problem: Being a predator (resp. a prey), how to hide in the environment, so as to increase the probability of catching a prey (resp. of survival)
  - Solution: Camouflage, which is a **coordination between the visual appearance** (colors, shape, patterns) **of the predator** (resp. prey) **and its environment, for the visual channel of the prey** (resp. predator).
  - Nature provides a huge amount of examples (tiger, owl, butterfly …)

Trends of engineering systems evolution

- **Trend of increasing coordination**
  - PC: A plant cannot move, but a plant should move to disseminate its seeds
  - Many inventive solutions (**satisfaction**) based on **coordination of some parameters of seeds with some parameters of resources of their environment**; examples of such parameters are:
    - Buoyancy / ocean currents: a coconut can travel on the ocean several years before reaching a shore
    - Aerodynamic shape / wind: paper-thin wings of Alomitra vine seeds allow them to glide (possibly) across hundreds of meters in the forest

Trends of engineering systems evolution

- **Trend of increasing coordination**
  - Other inventive solutions based on **coordination of some parameters of seeds with some parameters of resources of their environment**; examples of other parameters are:
    - Hook and open shape / fur of mammals: the burdock fruit holds on to a mammal fur; the seeds are progressively disseminated when transported
    - Fruit tastefulness & richness / preference of some birds for some fruits: the quetzal swallows the fruit of wild avocado tree, and regurgitates the seed some minutes later, at some other place, favoring dissemination; this « treatment » in the bird's throat eases its further germination

Conclusion about TESE in Nature

- During their natural evolution, living beings do not follow themselves any trend, and therefore do not follow any trend of engineering system evolution
- However, interestingly, many « innovative solutions » from Nature can illustrate different trends of engineering systems evolution, in particular:
  - Trend of increasing degree of trimming
  - Trend of increasing dynamization
  - Trend of increasing coordination
- These examples, again like for solving strategies of PCs, are for the sake of education or inspiration
- The present work is going on, it should be extended (more trends, more examples) and refined (regarding sub-trends)

References

- [1] Vincent, J.F.V.; Bogatyreva, O.A. ; Bogatyrev, N.R.; Bowyer, A.; Pahl A.-K.: Biomimetics: its practice and theory. In: J. R. Soc. Interface (2006) 3, 471-482
- [2] Mann, D. Matrix 2010. Re-updating the TRIZ contradiction matrix. IFR Press, Clevedon (UK), 2009
- [3] Bogatyrev, N.R.; Bogatyreva O.A.: TRIZ evolution trends in biological and technological design strategies. In: Proceeding of the 19th CIRP Design conference – Competitive Design, Cranfield University, 30-31 March 2009, pp 293
- [4] Timokhov, V.; the TRIZ-SHANS community. Natural innovation. Examples of creative problem solving in biology, ecology and TRIZ. Creax, 2002.
- [5] Dawkins, R.; Qu'est-ce que l'évolution? Le fleuve de la vie. Hachette Littératures (1995)

Credits and References for the Photographs and Drawings

- Sleeping dolphin: http://vierleeuwenjacira.weebly.com/slapen.html
- Dolphin sleep patterns: Rattenborg NC, Amlaner CJ, Lima SL. (2000) Behavioral, neurophysiological and evolutionary perspectives on unihemispheric sleep. Neurosci. Biobehav. Rev. 24:817-842.
- Dolphin mother and calf: http://www.zooborns.com/zooborns/2013/10/dolphin-brookfield-zoo.html
- Walrus: Norbert Rosing/National Geographic/Getty Images (http://animals.howstuffworks.com/mammals/walrus-sleep-without-drowing1.htm)
- Sea otter: http://m.inmagine.com/image-ptg00155441-Male-sea-otter-sleeping-in-kelp-endangered-species-enhydra-lutris-this-photo-was-taken-of-a-wild-sea-otter-on-monterey-bay%20-california-in-july.-An-extensive-file-of-sea-otter-and-other-marine-mammals-are-available..html
- Kelp float: Festival International de l'Image Sous-Marine et de l'Aventure, Antibes Juan-les-Pins, 24-28 février 2010, http://blog.aquatilia.com/?cat=9
- Crabeater seal: http://antarcticmicrobes.edublogs.org/2012/01/11/lets-go-boating/
- Snake glottis: http://fire-eyes.org/gal/index.php/ob/n/rep/sn/o/m/j/fr/_N9H4879
- Nunatak: http://commons.wikimedia.org/wiki/File:Janke_Nunatak,_Antarctica.jpg
- Eritrichium nanum: Dipartimento di Scienze della Vita, Università di Trieste - Progetto Dryades - Picture by Andrea Moro; http://luirig.altervista.org/flora/taxa/index1.php?scientific-name=eritrichium+nanum
- Tungura frog: Ryan Taylor/Salisbury University; http://www.sciencedaily.com/releases/2014/01/140123141957.htm
- Tree of life: Leonard Eisenberg; http://www.evogeneao.com/tree-of-life/tree-of-life.htm
- Gardiner's Seychelles frog: R. Boistel / CNRS; http://newswatch.nationalgeographic.com/2013/09/02/frog-hears-with-its-mouth-surprises-scientists/
- Draco lizard: http://www.greenretreat.org/tiny-dragons-in-asia-the-draco-lizard/
- Flying phalanger: http://versesofuniverse.blogspot.be/2011/08/hewan-hewan-terbang-aneh.html
- Wallace's flying frog: http://www.factzoo.com/amphibians/flying-frogs-gliding-through-dark-asian-rainforests.html
- Paradise tree snake: http://bioweb.uwlax.edu/bio203/s2009/houk_step/Aerial%20Adaptations.htm & http://article.wn.com/view/2014/01/30/Flying_snakes_arent_only_real_theyre_incredibly_agile/
- Social spiders: http://bosque-santa.blogspot.be/2011/02/social-spiders.html
- Camouflage of tiger, owl and butterfly: http://www.noupe.com/photography/can-you-see-me-unbelievable-animal-camouflage-photography.html
- Coconut: http://inhabitat.com/the-biomimicry-manual-how-does-mother-nature-clean-house/coconut-floating/
- Alomitra vine seed: http://news.bbc.co.uk/earth/hi/earth_news/newsid_8391000/8391345.stm
- Common burdock: http://www.natronacountyweeds.com/common-burdock/
- Quetzal: http://www.morphocostarica.com/pages/quetzal-costa-rica.html
- Avocado tree: http://www.colorsofwildlife.net/forum/index.php?topic=18037.60