

Author Contact and Affiliation Information for Papers

Paper Title: Evolutionary Algorithms in Architecture
Evolutionary Algorithms in Architecture

File Name as Submitted: Schwehr_Peter_OSB_091028e_Evolutionary_Algorithms.doc
--

Author(s) Name:	Prof. Dr. SCHWEHR, PETER
Department:	Competence Centre for Typology & Foresight Planning in Architecture
University or Organization Name:	Lucerne University (HSLU), Lucerne School of Engineering and Architecture
University or Organization Location:	Technikumstrasse 21 CH-6048 Horw / Luzern Switzerland

Author Contact Information*

E-mail:	peter.schwehr@hslu.ch
Mailing Address:	Technikumstrasse 21 CH-6048 Horw Switzerland
Telephone Number:	+41 41 349 33 48
Fax Number:	+41 41 349 39 60

* information is for the purpose of contacting authors of abstracts and papers and WILL NOT used for purposes outside of the conference or be distributed in any way.

EVOLUTIONARY ALGORITHMS IN ARCHITECTURE (VSR Algorithm) OSB_091028e

Prof. Dr. Peter Schwehr

Lucerne University (HSLU), Lucerne School of Engineering and Architecture,
Competence Centre for Typology and foresight Planning in Architecture,
Technikumstrasse 21, CH-6048 Horw, www.hslu.ch/cctp

Abstract

Change is a reliable constant. Constant change calls for strategies in managing everyday life and a high level of flexibility. Architecture must also rise to this challenge. The architect Richard Buckminster Fuller claimed that "A room should not be fixed, should not create a static mood, but should lend itself to change so that its occupants may play upon it as they would upon a piano [1]." This liberal interpretation in architecture defines the ability of a building to react to (ever-) changing requirements. The aim of the project is to investigate the flexibility of buildings using evolutionary algorithms characterized by Darwin. As a working model for development, the evolutionary algorithm consists of variation, selection and reproduction (VSR algorithm). The result of a VSR algorithm is adaptability [2]. If this working model is applied to architecture, it is possible to examine as to what extent the adaptability of buildings – as an expression of a cultural achievement – is subject to evolutionary principles, and in which area the model seems unsuitable for the 'open buildings' criteria. (N. John Habraken). It illustrates the significance of variation, selection and replication in architecture and how evolutionary principles can be transferred to the issues of flexible buildings. What are the consequences for the building if it were to be designed and built with the help of evolutionary principles? How can we react to the growing demand for flexibilization of buildings by using evolutionary principles?

Keywords: *Evolution, Typology, Adaptability, Variation, Selection, Replication, Darwin*

INTRODUCTION

Change is a reliable constant. Constant change calls for appropriate strategies and a high level of flexibility. Architecture must also rise to this challenge. The architect Richard Buckminster Fuller claimed that "a room should not be fixed, should not create a static mood, but should lend itself to change so that its occupants may play upon it, as they would upon a piano." This liberal interpretation in architecture defines the ability of a building to react to ever-changing requirements. Just as animal species have changed during the course of evolution, buildings have been adapted to meet new requirements since the beginning of civilisation. Over time, some buildings have proved to be better suited to change than others. They were better able to adapt to the new requirements of their environment, either through active intervention or because the building already met the changing requirements. It is evident that they were equipped with the more appropriate characteristics to meet the new requirements, or that characteristics which were not originally foreseen, could be activated to meet these demands. It follows that they are more successful in comparison to other buildings and possibly have characteristics which are also relevant for other buildings (designs) and are therefore widespread in the building stock. Buildings which are unable to withstand the pressure for adaption due to lack of flexibility become obsolete.

VARIATION, SELECTION AND REPRODUCTION IN THE DESIGN PROCESS

The origin of adaptability in nature was explained by Charles Darwin in the mid 19th century with his theory of natural selection. Precisely because certain traits helped organisms to survive and successfully reproduce in the past, they have remained – as opposed to those with unfavourable traits – to the present day. Only the favourable traits have a chance of survival in the long-term. Individuals with such traits outclass the competition. They are more likely to reproduce, and because of heredity, their most favourable traits are found more frequently in the next generation which in turn, give their offspring a further advantage. In this way, an advantageous variation automatically becomes more common and within time, spreads through an entire species. Single traits compete for survival [3] in which the three fundamental elements, **variation, selection und reproduction** from Darwin's evolution theory play a key role. Together they form the evolutionary algorithm (VSR-algorithm) which aims at adaption for a particular niche and reproduction success.

But can biological evolution theory be translated without restriction to architectural design? Is not architecture a cultural achievement and therefore subject to other principles? And are not cultural works, in general, a deliberate, purposeful process, which is not the case in biological evolution which depends on mutation and genetic recombination. Nevertheless, the planning process of a building is characterized by variation, selection and reproduction.

The process from design to realization of a building is an iterative process which presents and selects solutions. At the end of this sequence of creating and critique, the solution appearing most suitable is chosen, giving the codified planning result. This is a four-phase process:

Phase 1 – Defining the Program

The program for the projected building is defined in this phase. The client commissions a planning specialist to design his building. As a rule, the client already has concrete ideas about the building and its use. These ideas are culturally embedded. Guided by experience, his knowledge and his architectural preferences, the architect (ideally) takes up these ideas, evaluates, reflects and discusses his client's precise needs. He compares these with the fixed parameters such as location, orientation, building regulations, finances etc., highlights conflicting goals and sets priorities by selecting specific concepts. At the end of this phase, the requirement profile of the projected building has been determined and the target agreement (e.g. space allocation plan, use, cost ceiling, deadlines etc.) has been formulated.

Phase 2 – Planning the desired program by generating variants and selection

Variants are generated, selected and further developed in the design phase. In this internal generation of variants, ideas are generated in a creative process, reviewed and compared with the target agreement. Appropriateness and feasibility are key factors in the process. Deciding on a building component (e.g. a closed façade) allows only specific further architectural combinations which lead through internal selection to variance reduction. In addition to internal selection, there is also the external selection – in the sense of Rittel's development etc.) - which the planner can hardly influence. The concept is reworked until all influencing factors contribute to a sustainable compromise. This process can only be brought to a satisfactory conclusion, when priorities which enable different weightings to allow subsequent selection, are set between the parameters. Alberti's definition of beauty pleasing architectural expression is a high and only very difficult to achieve aim. For him, beauty is a particular harmony of all the parts, whatever the object, such that nothing can be added, taken

away or altered without making it less attractive. Referring to his definition, Alberti also emphasizes that it is necessary to exert all creative and mental powers to reach this achievement. [5]

Phase 3 – Codified Design Concept

To evaluate the design concept, discuss it with colleagues, present it to the client and involve experts, ideas needs to be communicated on a level which is objective, understandable and clear. This level is termed by Bertram as the level of planning reality [5] where design concepts are determined by mathematical spatial concepts and represented in an objective, unprejudiced manner. As a rule, plans, sketches and models serve to illustrate the outlined building concept. The ideas, that is, the codified design concept in the building plan, are documented at the end of the design process. In doing so, the planner not only considers the invariable building elements (e.g. glass facades), but also imagines the variable elements such as change of mood (light, rain, time of day etc.). His professional knowledge enables him to arrange built elements in order to visualize the intended phenomenological variances of a particular setting. This serves as a guideline for the realization of the building [6].

Phase 4 - (Re)Production

The building can now be built based on the codified planning concept. Each projected building therefore holds a magnitude of information and embodies awareness potential. Buildings at location or on paper conveyed architectural phenomenon offer potential for future solution models [6]. A building can be exemplary for planning problems of a similar kind and selected elements (e.g. building components, constructions details, design, spatial framework etc.) can be reproduced. Once the building has been realised, it is in competition with other buildings and subjected to different degrees of continual selection pressure. When a building no longer meets requirements, the selection pressure becomes too strong and the building has to be adapted. Certain elements (e.g. heating system) are completely renewed or the existing floor space allocation has to be adopted. Seen evolutionarily, the appropriate characteristics can be reproduced in the second phase of the building's use.

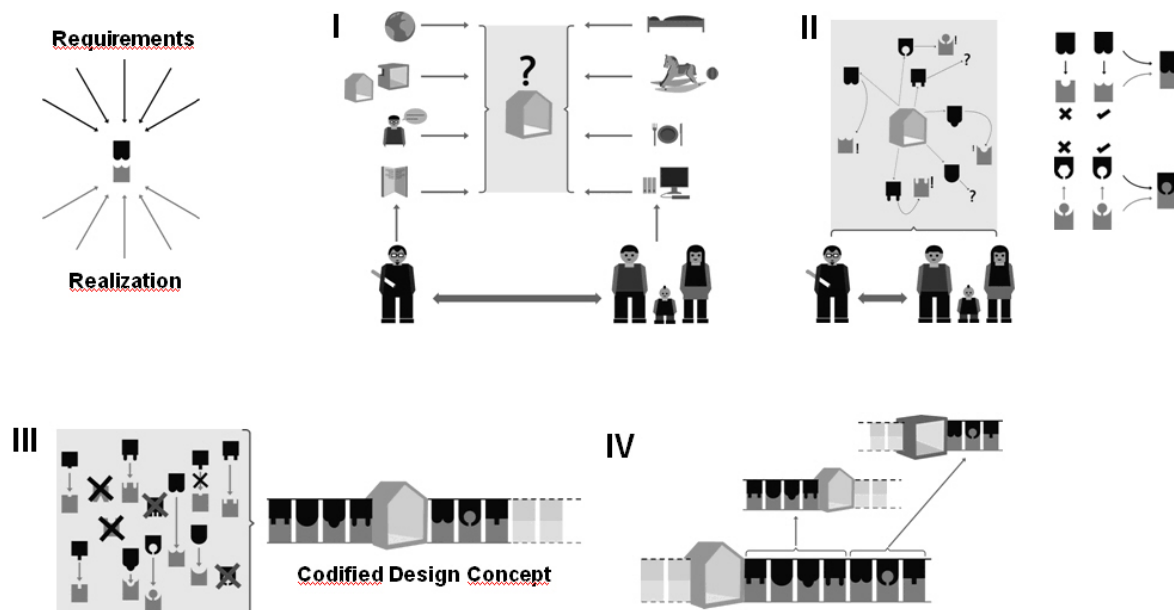


Figure 1: Variation, Selection and Reproduction in the design process ©cctp

EVOLUTION IN INFORMATION PROCESSING

In biological evolution, reproduction follows by passing on hereditary traits through genes. As part of a chromosome, they are responsible for the phenomenological characteristics (e.g. brown eye colour). All the genetic information found in an organism is collectively known as the gene pool. Different hereditary traits can emerge depending on gene constellation and dominance. This is known as phenomenological plasticity.

In architecture, there are no genes which are responsible for the features of a building. However, as mentioned earlier, each building has a set of information [6] which can be extracted by the observer's respective cognitive agent [7]. A building's appearance is the sum of all discernable features. In addition, every individual has a schema i.e. an internal representation of the outer world. This structure is also known as knowledge. Amongst others, this is where instructions (behavioural patterns) are stored. These enable us to react to situations accordingly. When a certain situation arises and no behavioural pattern is to hand, organisms find themselves in a state of uncertainty. Only by changing the structure of the internal schema, e.g. getting informed and creating new solution models, can knowledge be enriched. If the architect does not have a solution, he has to inform himself and create a new systema new variation which enables him to solve his planning problem. To develop and evaluate solution variations, the architect depends on certain information. Besides his own repertoire, he also taps into other information sources: his memory, built and documented projects. Apart from accessing information, the architect also generates information whilst working on the problem. He will document the results of his own work and compare notes with others involved in the planning process.

It is apparent that evolution, in both biological and cultural understanding, is information processing which triggers a series of actions.

- In natural science, evolution is understood "*(...) as the gradual development of a system which reacts to external influences depending on experiences made in the past.*" [3]
- For social science evolution is "*(...) a process which memorizes and multiplies information, constantly producing new structures and characteristics.*" [8]

Unlike Darwin's evolution theory, in architecture, knowledge is consciously applied, information processed and other buildings are evaluated as an information memory. This information transfer can be explained by Richard Dawkins' theory of the meme. For the evolution biologist Dawkins, the cultural analogy to a gene is a meme. Just as "genes propagate themselves in the gene pool by leaping from body to body via sperm or eggs", Dawkins theorizes "so memes propagate themselves in the meme pool by leaping from brain to brain" transferring ideas, concepts, ideologies and behavioural patterns. The external manifestation of a meme of a built structure corresponds to the characteristics of the phenotype in gene theory. A meme is a unit which can replicate itself. The reproduced information unit becomes effective in the coded planning result. The building is an external manifestation, or in Dawkins' sense, a vehicle [9]

In architecture, memes are both genotypic and phenotypic effective. In analogy with the evolution phenotype, the architecture phenotype carries all physical characteristics of a building. The phenotype is not restricted to morphological characteristics, but also includes physiological (heat transfer coefficient of the chosen wall structure) and functional characteristics (e.g. comfort). In contrast, the genotype of a building is to be considered as the

entirety of the existing knowledge for this particular building type, its use and problems. During the planning phase, this knowledge is contrasted with the "achievable" in the process of generating variants and selection. At this point, we are reminded of the selective effect of the constraints resulting from building regulations, location, finances and social conventions etc. The codified planning project - the construction plan - is a result of these processes. Memes are therefore active on both the genotype level in generating information on the building type, as well as on the phenotype level. By selecting relevant features and system characteristics, they influence the decision as to which function, construction and interpretation of design ideas can be realized in the building project. The information memory "building" is therefore a meme pool of architecture. Besides functioning as replicators, memes are important for mutations and variance in cultural evolution. Development in architecture is not possible without memes.

MUTATION AND VARIATION

Accidental variation is the driving force and a condition of evolution. Variation within a population is the result of mutation and genetic recombination, and genetic rearrangement through sexual reproduction [2]. No two individuals of a population are alike. Some traits give better potential of survival, others encourage biological fitness increasing chances of reproduction. Others are disadvantageous because they make survival and reproduction more difficult. Variations occurring in a population always happen by chance and not systematically. Depending on the niche (the relational position of the population in its ecosystem), variations can be an advantage or possibly wasted potential.

In architecture, innovation can be regarded as the counterpart to mutation. Although innovation is often "developed" purposefully, due to easier access to information sources and knowledge transfer outcomes are frequently characterized by powerful inherent dynamism which is controllable to a limited extent only. A "recombination" of knowledge is for example prefabricated parts. Successfully applied in the automobile industry for decades, they are now making an impact in building refurbishment with prefabricated retrofit modules i.e. for façades [10]. Another example of recombination is the current discussion on greenhouse gas emission reduction into the atmosphere, which has a significant influence on the typology of future buildings.

The result of mutation and recombination is variety and variance. These factors make it possible for the niche to be used optimally in the sense of an advantageous environment, which means, to successfully defend it against other competitors or to occupy it respectively.

In this context, *adaptive radiation* seems especially worthy of mention. It describes the process of species splitting within a relatively short period of time into several species, each of which is adapted to different ecological niches. Adaptive radiation occurs when there are a lot of unoccupied ecological niches, geographical separation and a less specialized parent species. "An evolutionary species is a line of ancestors-offspring-populations which maintain their identity against other such lineages and have their own evolutionary tendency as well as historical destiny." [2]. The architectural equivalent to the evolutionary species is the building type. Adaptive radiation is its variance, through which many modifications of a basic pattern (e.g. ground plan) are achieved by adapting to different topographical, urban, climatic and user-specific conditions.

Variance is also a key factor for success in spreading its own meme in the meme pool. Highly specified solutions are often one-way solutions. For example, *Gründerzeit* (Wilhelminian style) apartments are still today very appealing and of stable value because of their high use flexibility. On the other hand, apartments with specific solutions for a specific way of life are at an evolutionary dead end. Lack of flexibility e.g. apartment layouts of the 60s, nowadays makes them difficult to let because society values and in turn, tenant's requirements have changed fundamentally. These are solutions with an inadequate degree of flexibility which results in restriction of use and therefore not suitable for further distribution. Buildings which have memes with the necessary phenomenological plasticity in construction, design or layout are fitter than other buildings.

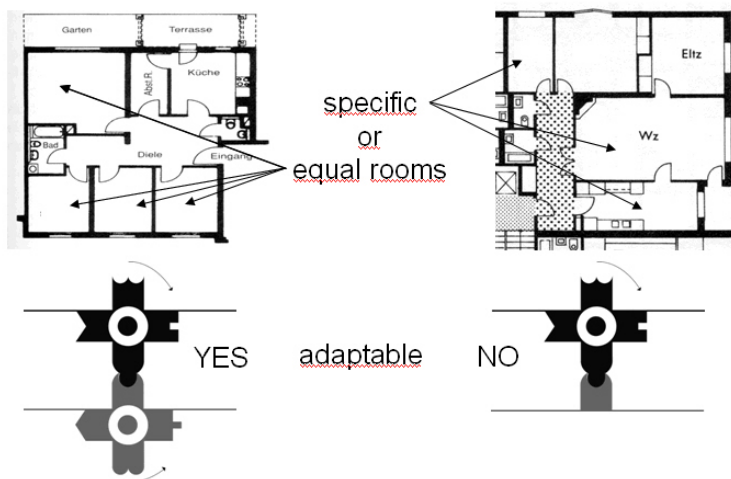


Figure 2: Specification as a key factor for Adaptability [11] ©cctp

If existing building types have an "evolutionary" past, they also have characteristics which help them to "survive". These characteristics are accurately reproduced when planning future buildings (seen from an evolutionary point of view: to propagate – to reproduce) and to find their use in existing and future building stock more easily. The result of these suitable characteristics is adaptability which shows its flexibility potential. That means buildings which can be adapted have a higher flexibility potential than other buildings. Flexibility is an indication of long-term value retention [12]. The building can react quickly to new requirements at acceptable cost, time and effort.

Based on concepts described by the Fraunhofer Institute and supported by typology-based building evaluation [13], four main building types of adaptability were identified [12].

- **Extension Flexibility (E)** refers to extension and retrofit in architecture. This involves analysing and classifying the positioning and structural properties of extensions and retrofit systems
- **Internal Flexibility (I)** defines the adaptability of a building: In which degree are modifications within an existing structure possible. What are the risks and time requirements? How does the extension influence the building?
- **Use Flexibility (N)** analyses building flexibility in relation to how it reacts to change of use. Concepts concerning the reversibility of changes and the future mono or multi-use are also considered.

- **Planning Flexibility (P)** refers to characteristics which determine whether and how a building reacts during the entire planning and construction phase. It also investigates which measures can be implemented during the planning phase in order to facilitate flexibility during a building's operation time, with the least possible cost and effort.

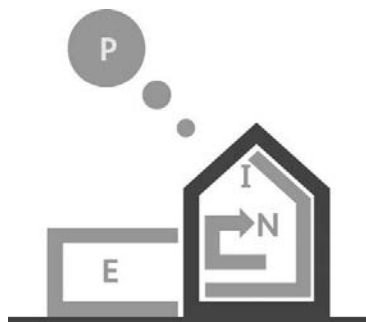


Figure 3: Typology of adaptability [12] ©cctp

Extension, internal, use, and planning flexibility are building strategies to be able to resist selection pressure as long as possible and to retain high value stability over the entire (renovation) life cycle.

SELECTION AND SELECTION PRESSURE

Selection is a key mechanism of evolution. Selection is responsible for different levels of reproduction success (= fitness) of selected individuals [3]. This means an irregular heredity of traits from different individuals in the gene pool of the next generation, leading to a deliberate change of traits in the population over time.

In analogy to the biological, the cultural evolution underlies a selection process which corresponds to natural selection. When two or more buildings become competitors, the construction which best satisfies market needs "survives" and through the meme pool, its characteristics will have a stronger influence on the future building stock.

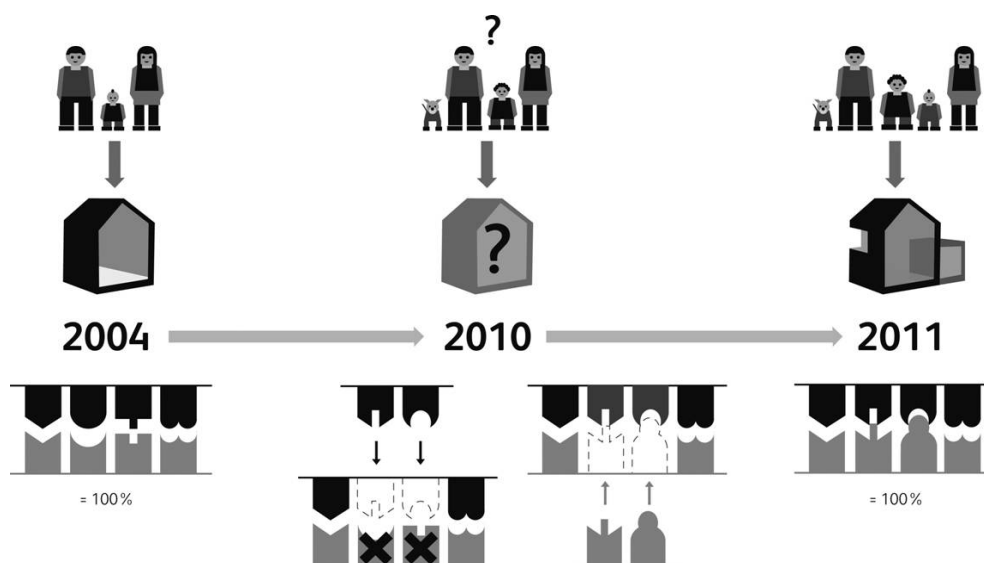


Figure 4: Refurbishment as a Selection process ©cctp

Selection can be differentiated by the type of selection strength, level, direction and intensity (Zrzavý et al, 2009). These principles have been assigned to architectural themes in the following table.

Types of selection

Special field	Type I Type of selection force	Type II Level of selection effect	Type III Direction of selection	Type IV Intensity of selection effect
Biology	Environmental selection (e.g. a climate which is too cold causes the coat to grow thicker)	Gene selection Genes compete for maximal frequency in the population	Stabilising selection Selection of individuals with extreme character values	Soft selection Selection of individuals who do not achieve specific relative values in the given characteristics
<i>Analogy to Architecture</i>	<i>Climate change promotes CO² – neutral buildings</i>	<i>Meme (tech-nology, design etc.) competing for maximum frequency in the building stock</i> <i>Building part level</i>	<i>Design plan:</i> <i>- Utilization factor</i> <i>- Height restriction</i> <i>- Type of roof</i>	<i>Modernization</i> <i>- All buildings with single glazing independent of building type</i>
Biology	Sexual selection e.g. Competing for females leads to a size difference in some animal species	Individual selection Selection of characteristics (phenotype) which are advantageous for the individual	Disruptive selection Selection of individuals with average values of a characteristic	Hard selection Selection of all individuals who do not fulfil a specific criteria or quality
<i>Analogy to Architecture</i>	<i>Architectural fashion trends</i> <i>Corporate Design in the typology of office buildings (e.g. open space)</i>	<i>Meme (Technology, Design) competing for maximum frequency in the building stock</i> <i>> Building level</i>	<i>Functionalism in architecture</i> <i>Highly specified buildings</i>	<i>Extension through addition of storeys</i> <i>- legal requirements</i> <i>- load-bearing capacity of existing supporting structure</i>
Biology	Parental selection e.g. Parents of some bird species prefer to feed chick with yellow mouths	Relative selection Selection of characteristics which are advantageous for groups of relatives	Directional selection Selection of individuals with characteristic values at one end of the distribution curve	
<i>Analogy to Architecture</i>	<i>Intersubjective and cultural preferences e.g. for building types and usage</i>	<i>Meme (technology, design) competing for maximum frequency in the building stock</i> <i>> Typology level</i>	<i>Energy efficiency:</i> <i>- optimal A/V - rating</i> <i>- Heat transfer coefficient</i> <i>> Tendency:</i> <i>Swissbox</i>	

CONCLUSION

In summary, it can be said that it is possible to explain and illustrate adaption processes in architecture on the basis of Darwin's principle of natural selection. It is essential to always exploit the niche, to occupy an advantageous environment by being more successful than the competition. Transferring this principle to flexible buildings ie. buildings which successfully resist selection pressure as long as possible, the following requirements for sound, future-oriented concepts can be deduced:

Transferring this principle to flexible buildings ie. buildings which successfully resist selection pressure as long as possible, the following requirements for sound, future-oriented concepts can be deduced:

- **Variance:** Flexible buildings have a number of concepts which can react individually to their context. Variance makes it possible to successfully occupy the niche and in Darwin’s sense, to be “fitter” than the other buildings. This variance concerns the genotype as well as phenomenological variance.
- **Fault tolerant:** Flexible buildings are planned and built knowing that their value can only be maintained over a longer time period if they can adapt to meet future demands. With this in mind, buildings are fault tolerant and not highly specified.
- **Deconcentration:** Flexible buildings have predetermined breaking points to allow building parts and systems (e.g. telecommunication) to be exchanged with little effort. Separation into primary, secondary and tertiary systems is an essential requirement..
- **Open mind:** Flexible buildings have innovative building concepts which are sustainable. Innovations thrive on an open mind and foresight. These can be achieved by exchanging information and transferring knowledge in the interests of improving the current and future environment. Interdisciplinarity and an open mind can prevent the evolutionary dead end.



Figure 5: Evolutionary strategies for adaptability ©cctp

OUTLOOK

This paper is the start of a research cycle on VSR- Algorithms in architecture. More extensive research on selection and variation is already being done. Further publications on this theme are in progress.

LITERATURE

- [1] Krausse, Joachim: *Your Private Sky. R. Buckminster Fuller.* – Verlag Lars Müller; Baden, 2001
- [2] Buskes, Chris: *Evolutionär denken. Darwins Einfluss auf unser Weltbild.* – Primus Verlag; Darmstadt, 2008
- [3] Zrzavý, J.; Dorch, D.; Mihulka, S.: *Evolution: Ein Lese-Lehrbuch.* – Spektrum Akademischer Verlag Heidelberg, 2009
- [4] Rittel, Horst W. J.: *Planen, Entwerfen, Design: Ausgewählte Schriften zur Theorie und Methodik* – W. Kohlhammer; Stuttgart, Berlin, Köln, 1992
- [5] Bertram, Ekkehart: *Raum in Vorstellung und Wirklichkeit: Reader zum Seminar Tragwerk und Architektur WS 2000/2001* – Universität Stuttgart, Fakultät Architektur; Institut für Innenraumgestaltung und Architektur, 2000
- [6] Schwehr, Peter: *Ein entwurfsbezogenes Orientierungssystem.* Universität Stuttgart, Fakultät für Architektur und Stadtplanung; Dissertation, 2002.
- [7] Favre-Bulle, Bernard: *Information und Zusammenhang. Informationsfluss in Prozessen der Wahrnehmung, des Denkens und der Kommunikation.* – Springer; Wien, 2001
- [8] Reichholf in Köhler, B.: *Kurzbericht Vortrag Prof. Reichholf am 30.05.2008 "Evolution der Evolution"* // <http://www.zukunfts-werkstatt.org/Rahmen/Evolutio.htm>
- [9] Dawkins, Richard: *Das egoistische Gen.* – Rowohlt; Hamburg, 2002
- [10] Schwehr, Peter; Fischer Robert: *Building Typology. IEA ECBCS annex 50, Prefabricated Systems for low Energy Renovation of Residential Buildings.* – Luzern; Hochschule Luzern - Technik & Architektur, Kompetenzzentrum Typology & Planung in Architektur (CCTP), 2009
- [11] Plans: Neufert: *Bauentwurfslehre* – Ullstein: Berlin, 1959 (20. Auflage) und Vieweg; Braunschweig, 2002 (37. Auflage)
- [12] Plagaro Cowee, N; Schwehr, P.: *Die Typologie der Flexibilität im Hochbau.* – Interact: Hochschule Luzern, 2008
- [13] Fischer, Robert; Schwehr, Peter: *Typenbasierte Evaluation. Chancen für die ganzheitliche Wohnbauerneuerung.* – Schweizerisches Status-Seminar „Energie- und Umweltforschung im Bauwesen“, 2008.
- [14] Campell citing Scott

Continuing relevant (internet)-literature:

- [15] Salingaros, Nikos et.al: *Darwin Processes and Memes in Architecture: A Memetic Theory of Modernism.* - http://cfpm.org/jom-emit/2002/vol6/salingaros_na&mikiten_tm.html
- [16] Handout: Gabora, Liane: *The Origin and Evolution of Culture and Creativity.* – <http://www.vub.ac.be/CLEA/liane>
- [17] Martucci, Angela: *Skript "Theorien soziokultureller Evolution"* im Rahmen des Seminars: Theorien gesellschaftlicher Evolution bei Prof. Hans Geser. – Universität Zürich, 2006
- [18] Dennett, Daniel C.: *Darwins gefährliches Erbe: Die Evolution des Lebens.* – Hoffmann und Campe; Hamburg, 2001
- [19] Gould, Stephen Jay: *Illusion Fortschritt. Die vielfältigen Wege der Evolution.* – S.Fischer; Frankfurt/M., 2005