Some Problems of Methodology of Scientific Research
in application to science and engineering[1]

Czesław CEMPEL

1. ***Introduction – credit work***
2. ***Research, investigation, scientific research***
3. ***Scientific method, methodology***
4. ***System approach to scientific research***
5. ***Knowledge, science, skill - abilities, engineering***
6. ***From information to wisdom***
7. ***Modeling, simulation***
8. ***Scientific and innovative problem solution –****see my book*

(Inżynieria Kreatywności w Projektowaniu Innowacji, ITE Radom 2013,p340.)

9. ***References***

You may see this text at; http://inzynieriakreatywnosci.put.poznan.pl

[1] See book in Polish; **Nowoczesne Zagadnienia Metodologii i Filozofii Badań (***Modern problems of methodology and philosophy of scientific research***)**, ITE Radom 2003,s152, see also; http://neur.am.put.poznan.pl

1. Introduction- credit work

Methodology of Science - Credit Work[2]

- editorial guidelines[3] **–**

1. Title page; with the *provisional* PhD title, personal data, affiliation, month and year of completion, name of PhD supervisor(s)**.**

2. Second page; two summaries: English and Polish.

3. Third page; contents and page numbering.

4. Concise answer to the questions given in: Qui pro Quo text material.

5. Concise description of PhD problem, with citation of papers and sources, as below**.**

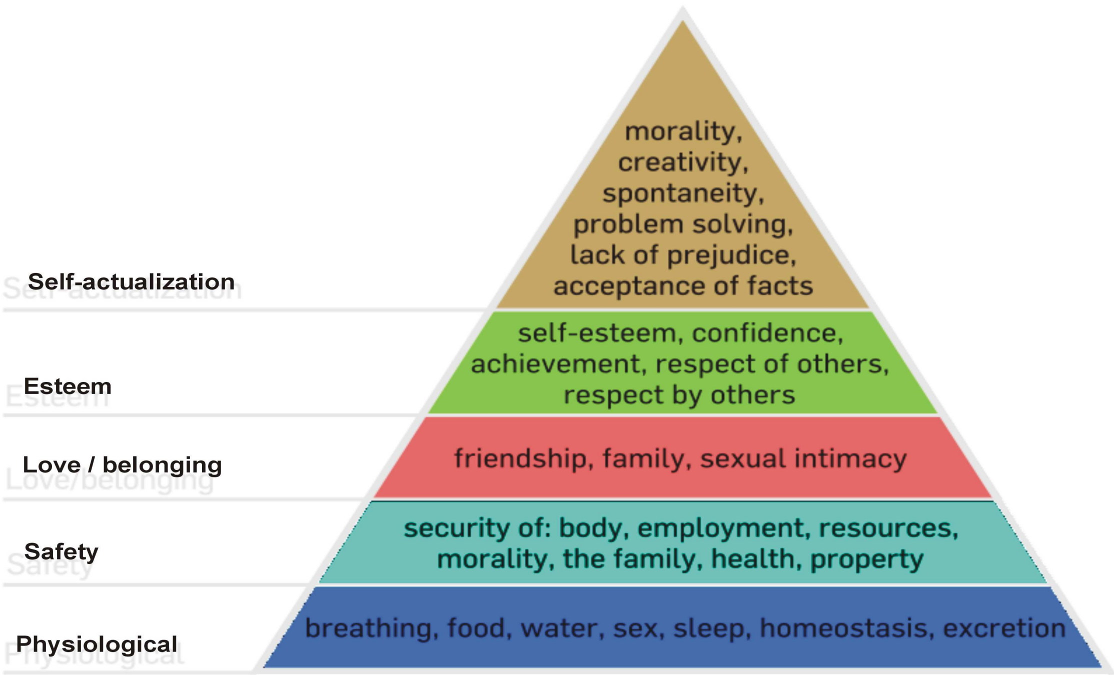
6. Utility of my research; scientific, social, economical, and other**.**

7. Summary of work.

8. References: cited in a text, for example, [Kowalski 05,ch2**]**

9. Actual mind map of PhD; as head of the tree (*branches, twigs, etc*) with different colors, shapes –as Appendix 1

10. Time schedule of PhD; number of tasks 7±2, with different colors to each item – as Appendix 2.



Maslow hierarchy of human needs

[2] Time of completion and form is the element of work assessment.
[3] Page view and numeration, as one can see here.

Motto;

This PhD course is not one more subject needed for a credit !

cc

Qui pro Quo for Methodology of Scientific Research

–first conference-

- **I would like to have PhD in engineering!**
- **Is there a realization of my cognitive needs – what does it mean?**
- **Can I find it on my personal pyramid of needs of Maslov?**
- **To whom my PhD is needed?**
  - **a) me**
  - **b) my family**
  - **c) in my workplace**
  - **d) University**
  - **e) Polish economy**
  - **f) Polish state**
  - **g) science**
  - **h) ?**
- **What I will get due to that?**
  - **a) Be a member of intellectual elite of my district, country, the world**
  - **b) ?**
- **And what is the goal or task of intellectual elite?**
  - **a) To ensure the civilization progress, or cultural one ?**
  - **b) ?**
- **So what I have to know and accomplish?**
  - **a) Real outlook of the world**
  - **b) How the others accomplished it - *methodology***
  - **c) ?**
- **What I have to learn?**
  - **a) To use creatively and effectively my mind (***but what is that?***)**
  - **b) To formulate sub problems and tasks of my PhD**
  - **c) To solve problems creatively and in an innovative way !**

d) **To implement solutions.**

e) **To publish solutions of scientific problems? (***results, method***).**

f) **?**

- **What I do really need ?**

  a) **Methodology of research.**

  b) **Research method.**

  c) **Research techniques.**

  d) **Research tools; hardware software.**

  e) **Self motivation, systematic and consequent realization of my work!**

  f) **?**

- **What I will get instead of it ?**

  a) **Progress in my work.**

  b) **Money.**

  c) **Good name.**

  d) **?**

- **What kind of problem I will try to accomplish?**

  a) **Scientific.**

  b) **Technical.**

  c) **Social.**

  d) **Economical.**

  e) **?**

- **And how I will use the result of my research ?**

  a) **Publication (***where, how?***).**

  b) **Implementation („? ? ”).**

  c) **a + b.**

  d) **Who will pay for it ?**

  e) **?**

These questions must be reliably answered, to own benefit,

and also in a credit work in a concise way.

I wish you success, and if needed can give some advice,

czeslaw.cempel@put.poznan.pl

2. Research, investigations, scientific research

To make known and usable, what was unknown,

NN

2.0 Introduction

Investigation or research is very popular notion, and as an effect of it we would like to know **what was previously unknown** to us, or to our community (*see above*). It means from one side that the local ignorance is not a real reason for making science and to begin scientific research. From the other side, there exist vast area of non scientific research and investigations having great economic utility and meaning, using very sophisticated method and techniques. It concerns for example very popular and socially important investigation of opinion pool needed in policy making, in marketing of some product and goods, and giving authorization for safe usage of some machinery.

It concerns also vast area of **testing** during the production process, validation and approval of some new product, as well as admission to use of our car needed from time to time. In all these cases of investigations we use very accurate and sophisticated measuring systems as well as advanced statistical methods and techniques to validate our decision in a presence of ever ubiquitous noise.

2.1 Scientific research

It is almost obvious that **research** may be defined and differentiated also from two sides, the problem we are investigating, and the method we apply. First about the problem, why and when, one can name the problem as scientific? Only in that case when **no one has solved it before**, and **was not published** in any scientific journal, accessible to every interested member of scientific community. And why **publication** of research results is so important, because in this way we put them under the assessment and verification of scientific community of the world. We will discuss this problem latter on, when talking about **falsification** necessity in modern science.

One can notice that the important part of scientific research, or to say much better, acquisition of scientific knowledge, is a publication of a new knowledge and its assessment by scientific community. So much about the problems we are investigating in science.

While looking at scientific methods we are using in science, let us look for the definition of science one can find published by Ackoff in his famous monographs [Ackoff 69].According to that;

Science is a process of investigations by means of procedures aiming to:

1. ***finding answers to a new questions***
2. ***solution of the problems***
3. ***seeking more effective methods of finding answers and solutions.***

While we are talking above about scientific procedures we have in mind; **tools, techniques, and methods**.

By means of **tool** we understand physical or conceptual equipment or apparatus we are using in scientific research; like thermometer, computer, or analyzer of physico-chemical components, and the like.

By means of **techniques** we understand the way or procedure of using these tools, when for example analyzing the vibration and noise at the workplace, or the way of random sampling of batch for determining the quality of products.

While by means of most effective **method** we understand, the rule for choosing the best research techniques, for the given problem and the goal of investigation. This may be the best techniques of batch sampling, the best way of measuring of some physical property like hardness, or intellectual property like intelligence quotient (***IQ***), also the best way of undertaking the conclusion or decision making.

There may be the other understanding of the method notion, specifically scientific method; we will be talking on this in the next chapter. Here, in this place more important is to say something concerning the broad meaning of the notion of science. For some purposes we differentiate the area of scientific research talking about **pure** and **applied** science. Narrowly speaking the pure science means all scientific investigations carried for the sake of science itself. This means also, that the main goal of such research do not concerns with any application. It does not exclude the fact, that sooner or latter these research results will find some important application.

As an example one can take into consideration astronomical research 200 years ago, and nowadays when we need this knowledge for the safety of cosmic travel. The similar example;

the laser effects at the beginnings after its discovery, and nowadays when we apply laser effect for different measurements, indicators, displays and even cutting of metals.

From the other side the **application** of scientific finding is a vast reservoir of research questions, not only how to make something better, but also some question are fundamental one, concerning with the discovered phenomena itself. From this perspective some researchers would like to differentiate pure and applied science as the **intention** of a researcher itself and sometimes its research organization as well.

Today, when the **costs of research** are calculated scrupulously, there is very narrow place for making pure science. In every case of contemporary research someone has ordered this, and paid for expected results. Moreover, the contractor of research has some legal rights to dispose the results and put into some application or make it secret for several reasons, market competition, national security, and the like.

From the other side, nowadays the path from research to a market is shortened much, hence there are commercial organization having money and ordering vast spectrum of research, because even today it is hard to foresee which research results has the best market potency and money refund.

2.2 Research problems in science

The first problem in scientific research is the **description** of unknown fragment of reality, which we are looking for; sometimes it is much better to say that we are doing identification problem. At first we should **distinguish our phenomena** or object from its environment, what not in every case is so obvious, like in case of UFO research, should we look for psychological hallucinations, or real physical manifestations. Our scientific description should contain also its **structural and functional properties**, and also its possible applications seen in a first approach. This first approach application may be event conceptual like for example explanation of other phenomena or it may be purely utilitarian what will be talking about latter on.

Secondly, the vast area of scientific research concerns with the **solutions** of problems. They may be the problems of assessment or evaluation, where we should **optimize** some way of doing something, where alternative techniques are known, and we should chose the best one according to some known or unknown criterion. Here, according to Ackoff belong all problems of **optimal choice**, if we are looking for the best design variant, or the best decision we should undertake, independently where the problem is deterministic in nature, or some data have a probabilistic nature, like the whether in our surrounding, or earthquake occurrence.

The other area of problems solution in scientific research is called **development**, where we are seeking solution if the way of doing this is totally unknown, but we know sometimes a collection of ineffective approaches. The best example may be here when seeking a cure for HIV, or malaria.

In a similar way as we have just shown research problems in medicine, one can think about engineering problems, of designing some piece of new equipment mechanical or electronic nature, or much modern mechatronics in nature. In this way the part of development problem is some way of innovation, making the old things in a new innovative way.

When looking for a solution of some applied problems, one can create also some criteria of quality; this may be research efficiency, in terms of functional properties, allotted time and other. These may be qualitative or even quantitative criteria, in opposition to the so called pure research, where we have usually hidden, in an implicit way, some set of assumption and conditions, and ordinary research worker is sometimes not aware of these preconditions. From this point of view one can say also that in applied research we have more clear methodological side of the problem, and due to that we can decide consciously on the best research course, their quality, dedication, costs and the like.

2.3 Promotion Research

One of the reasons for scientific research; in science and technology is acquiring the **scientific grades** and titles which are decisive in the scientific career of a researcher. This is further connected with some formal duties like being a member of scientific committee, or enables to obtain higher salary, and the like. Therefore, by means of performed scientific research and their results some authority can assess research ability of a candidate and give her/him the needed enrollment to a grade of PhD or ScD, and to be a professor latter on.

The most important question is **what and how it should be done** in order to pass promotion to desired science degree. The answer is almost like **key word**; to make countable or acknowledgeable **contribution to science or technology**. And in what way one can accomplish this is illustrated in the Fig. 2.1 and a following description.

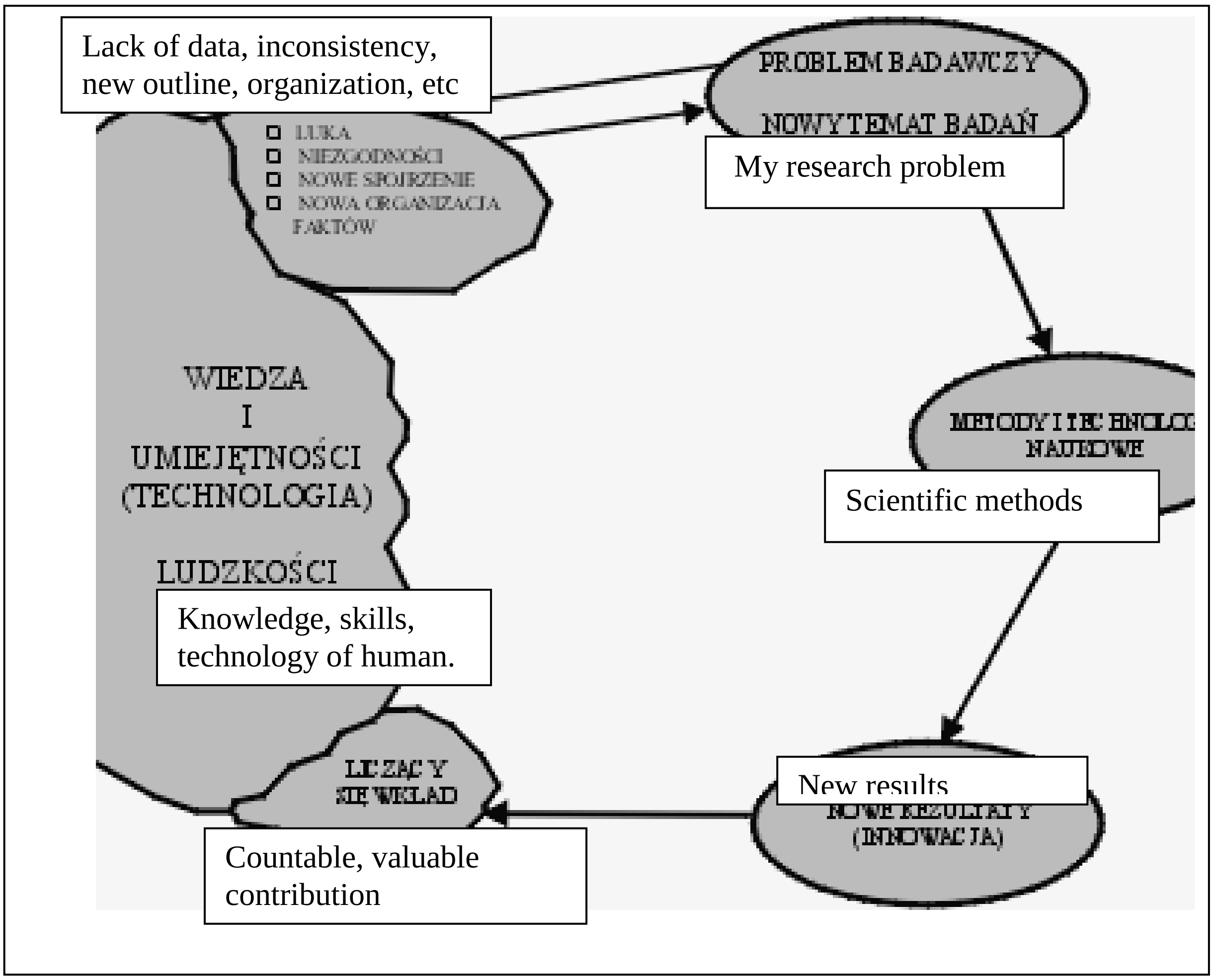


Fig.2.1.The cycle of promotional scientific and innovation research – so called ***'countable contribution'***

One can notice from the figure 2.1 that freshman in scientific research should know (*be familiar with)* at first, the area of knowledge and technology in question, and in effect to find out here its own research problem. This can be that talented PhD student will discover some **lack of data** set concerning some phenomena, or unknown methodology of research. The similar new research problem may concern **inconsistency** or disagreement of some data, which can be perceived by attentive student. From the other side basing on existing data and some **new method** of analysis one can notice new facts and/ or new connections between known facts and data. Using the same data base one can present also **new approach** what can give new insight, or new much **better organization** of already known facts and conclusions.

In this way one can formulate own research problem or even smaller research task. This is only the beginning, but experts are of the opinion that good formulation of the problem may bring us closer to its solution. From this point of view it is good to trace all association to the problem, implications and applications of the rough formulation of the problem, having in mind the best articulation and description of the research problem alone.

The next step in our scientific journey of Fig. 2.1 is an attempt to solve such formulated problem applying the best **scientific** methods and techniques being in use in a scientific community of a given area, which will bring us good results with allowable and countable errors, and without methodological bias. Doing in this way may bring us unknown results, or we may confirm already known data, but obtained by another technique and method.

One can be almost sure that reviewers of his dissertation (*PhD or ScD*) will acknowledge the research results as outstanding, giving valuable contribution to already known facts methods and technology of making products.

The same procedure of extracting scientific problem can be applied not only to the promotional research, but assessing ourselves the scientific strengths of the research problem, and find out if the solution is already ready for publication in some valuable research journal.

2.4 Summary of the chapter

In this chapter the main types of research and scientific research has been denominated, specified and described. It has been said also that the main characteristics of cognitive research is its originality and scientific publication. The main determinants of good results, beside the researcher genius, are scientific tools, techniques and methods applied by the research personnel. The social effect of a good planned and carried research is a progress in the dimension of civilization and cultural progress. The first dimension gives us new inventions, that mean better solution of our socio-technical problems, and the second dimension gives us better understanding of ourselves and surrounding reality of the world.

At the end it was shown also the cycle of scientific research used mainly for promotion of young scientists and that the condition of success is here acknowledgeable contribution to the knowledge base of science and technology.

2.5 Some problems and questions

1. *Is the local ignorance a good reason to make science?*
2. *What is net effect of scientific research division into* ***a pure and applied*** *scientific research? Advantages and disadvantages of such division, for example systemic or economical.*
3. *What are the main problems and obstacles of evolutionary progress of humanity? Can the science help here in some way?*
4. *Why the publication of scientific research is so important?*

3. Scientific method, methodology of science

The whole secret is a method.
NN

3.0 Introduction

Now we know already what scientific research is and what are their main characteristics. Hence, there is a time now to look more deeply for the scientific method, in case of theoretical and experimental research carried mainly in Technical Universities. Here our previous definition of science given in the last chapter must be specified more for the good of science itself, and its applications in particular. The **scientific method**, by a definition, **is a process of creation of clear, reliable, and consistent representation (***or meta model***) of the World**.

That is the reason why the scientific method must relay on the four important steps [Rochester 99], as below.

1. Observation and **description** of phenomena or a group pf phenomena.
2. Formulation of **hypothesis** [4] explaining observations. In physical sciences such hypothesis is some kind of cause-effect mechanism, or some mathematical formula, which can be acknowledged also as some kind of a **model**[5].
3. **The use** of the above model for the explanation of similar phenomena, another observation, or another condition.
4. Planning and making some other experiments for the verification and **validation**[6] of a hypothesis and a model.

[4] **Hypothesis** = provisional confirmation of cause-effect relation which needs experimental validation in a process of research.
[5] **Model** = simplified and problem oriented representation of some fragment of reality for the purpose of its better understanding
[6] **Validation** = testing of the homomorphism of the model and the real object.

When our testified model concerns to broader group of phenomena or objects, it may be generalized to the notion of scientific **law**[7], or even the law of nature - like the common law of gravity, and the like. Moreover, when a group of similar laws concerns with the same phenomena or objects, they may be promoted to a higher status of **scientific theory**[8], like theory of gravitation, or relativity, and others.

3.1 Sources of errors and scientific traps

What we have just said above looks objectively and reliable, but there are some immanent sources of errors and traps in science, which can be observed along the development process of some scientific disciplines, like in physics, biology, and the like.

First of all science is made by humans, they are erroneous and also have some **preferences,** likes, and dislikes. The result of these can be seen sometimes in interpretation of results of scientific investigation, sometimes even it can lead to postpone of some steps enumerated above.

The **second** source of error can occur when **ignoring** some observational results, which do not support currently tested hypothesis. The effect of such approach is, that sometimes we may validate a false hypothesis and to reject a good hypothesis. From the other side, some observations which are not supporting currently tested hypothesis **must not be** valuated against it. Sometimes, if carefully considered they are source of **better insight** and can lead to valuable conclusions, and even to scientific discoveries.

The **next** source of possible errors can be postponing the assessment of quantitative error level, especially when we have systematic errors too. This may lead sometimes to illusive scientific discoveries, which if tested in some other conditions can not pass threshold level of validation. As it is known, we have two kinds of erroneous observations in any experiment; random disturbances, which can be easely assessed with some statistical techniques, what will give us confidence interval on the given significance level[9]. Much more inflammable is a systematic error, as the result of some factors not taken into account when planning the experiment; like disturbing temperature, the wind, magnetic field, etc. This type of errors not always can be omitted, but if aware of them we can minimize their effects.

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[7] **Scientific law** = invariable relation between observations or the characteristic futures of some objects [Krajewski 98,s12].

[8] **Scientific theory** = a group of hypothesis concerning to broader area of the same discipline, having solid experimental confirmation.

[9] Experimental observations without error assessment are not valuable results of scientific work. The same concerns the economic and social data, when they have been collected observing the real systems.

At the end of enumerating the sources of possible errors in science we must be aware, that sometimes old scientific laws can be erroneous in the light of new observations carried on in some other conditions. Nobel prize winner R **Feynman** [Feynman, 99,s27] gives some good explanation of this effect, because scientific laws in physics are created as generalization of observations, moreover they are also the effect of guessing and extrapolations. They are facts which have passed by our **sieve of scientific instrumentation** on the given level of technology of measurements. If we change our instrumentation, our sieve will have smaller mesh net, and the old scientific law will not suffice to explain the result of experiment.

Feynman give us a good example of whirling gyroscope, which mass increases a little, in the same way as each mass moving with high speed close to a speed of light. But the old scientific law claims that the motion does not change the mass! Hence, much better formulation of the law can be; *"the moving mass does not change significantly its value if a speed is not too big"*. In conclusion Feynman states, that what we call today a **scientific knowledge** is set of facts and opinions with **different level of certainty**. Some of them are not certain, other almost certain, but there are no scientific statements with absolute certainty.

The above enumeration of possible errors and traps in scientific research is not comprehensive if we do not mention and describe the **scale effect** (*of a time or/and size*). This means that the same phenomena proceed differently if we change its scale, like for example when we pass from the chemical laboratory, where the main tool is the test tube, to the technology line in a factory. Also in mechanics the small and large cubes of rubber deform differently, etc.

Scale effect concerns not only these phenomena but also such fundamental physical quantities like energy and time. The problem of different scales of energy explains brilliantly another Nobel prize winner R **Penrose** [Penrose 96,p335]. "Contemporary physical theory is strange a little; it embraces two levels of natural phenomena. The first is a **quantum level**, where we have phenomena of very small scale and here the most important are small not continuous differences of energy - **quanta**. The second **classical level**, where we have large scale objects with physical laws of Newton, Maxwell and Einstein. And because quantum physics is a new development some people are thinking it should explain also the classical physics. But it is not so, there exist two scales of energy, and on the quantum level nothing can be said about classical physics level, and vice versa.

The interpretation of the **time** as fundamental physical quantity is much more strange, or better to say - complicated. On the quantum level no one is talking on time, the best example is here Bell's postulate on **quantum non locality**[10], which approves infinite speed (*non-locality*[11]) propagation of quantum phenomena, one can say we have no time as a physical variable, the quantum world is timeless. On the other hand on the level of classical physics with high speed comparable with the speed of light we have Lorentz contraction of time [Jaworski 71,p621]. Also, among the mechanical phenomena we are using two time scales; so called short time of vibration and acoustical phenomena, an a long time called lifetime of the object where we have evolution of properties of the object. The good example is here fatigue phenomena of metals due to oscillating loads, what in the long time increases damping and decreases the stiffness in the object under consideration. In the same manner we have acting corrosion in the dynamical field of working mechanical objects or the machine.

3.2 Scientific methods, methodology

Concerning a scientific method as such, we have been talking above several times, but being on some level of generality we should define at least two methods well in use in empirical science [Leszek 97]. The first of them is **induction** method which consists on the formulation of scientific assertions (*for example scientific laws*) on the basis of some individual scientific observations. This is the fundamental issue of empirical sciences, and we have mentioned already R Feynman who mentions extrapolation and guessing the laws in physics. The second method of scientific thinking is a **deduction**, which is the "*derivation of logical consequences on the basis well known assertions and laws*" [EPWN 98], and this method is not so dangerous, like induction sometimes can be.

It is worthwhile to give here another method of scientific thinking, better to say scientific decision undertaking called **statistical inference** [Hajduk 01], [Apanowicz 03], which is very important part of empirical sciences concerning the group of objects and phenomena. Here on the basis of statistical methods one can say that phenomena under consideration exist with a given probability $\mathbf{X< 1}$, and with the significance level of 98%, for example.

Finally, let us take the notion of **methodology**. In reality this notion is very frequently used in science, therefore there exists some number of its definition. One of the shortest and consisted definitions is given in Encyclopedia of System Sciences and Cybernetics [Francois 97], where one can find;

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[10] Jon **Bell** (1964) – Non locality postulate = "the world is non-local on the level of quantum individual phenomena [New Scientist 98].

[11] The phenomenon is a local one if the propagation speed is finite.

methodology is an arbitrary set of rules, procedures, practices and techniques for the needs of given discipline of science.

Hence we know already that scientific methodologies are discipline oriented, and a good methodology in mechanical engineering may be useless in psychology, and vice versa.

Very similar definition of methodology is given by Bazewicz [Bazewicz 95,p23],

"methodology is a set or consistent whole of methods, techniques (*instrumentation*) in definite discipline of knowledge and science".

In another place Bazewicz claims that the methodology is a synthesis of existing methods and from this point of view one may understand it as **meta method**.

It is worthwhile to study this monograph, because it is an interdisciplinary outline of methodology used in all systems of human activity research. In order to show that it is not empty claim we will take two figures from this book, which illustrate the research steps and cycle one can apply to humanities research or even in science and technology. The Fig.3.1 is almost self explaining and needs no special explanation. While the second picture Fig.3.2 is oriented to experimental research with the use of statistical method of data processing and inference, and as previously seems to be self explaining.

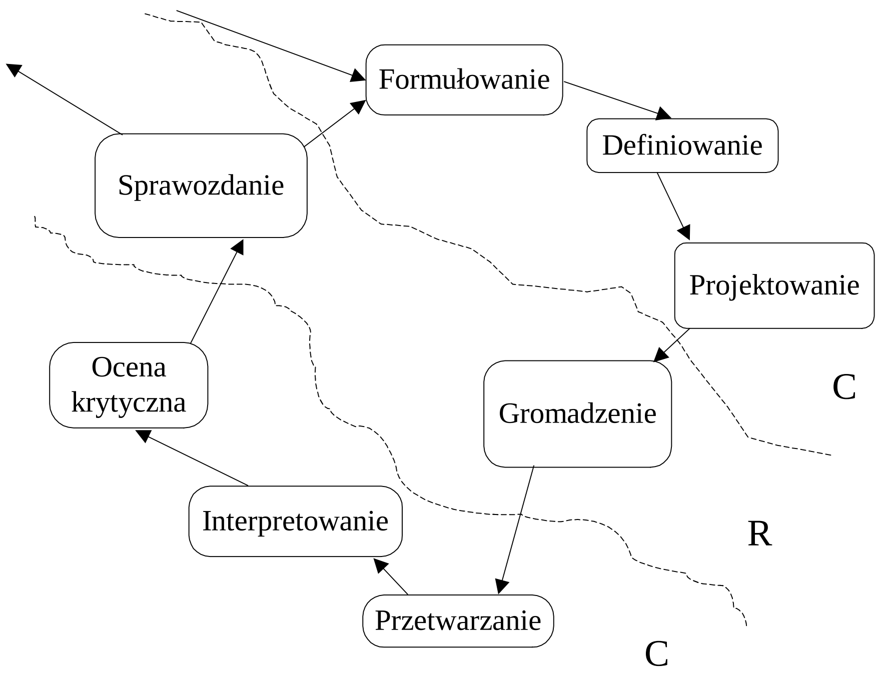

Fig.3.1.Generalized chain of activity in scientific research of real systems [Bazewicz 95,ch.2.32]

Fig.3.2. Chain of activities in a design and execution of experimental research [Bazewicz 95,ch.2.33]

From this point of view it is worthwhile to look in the internet version of the Encyclopedia of Fundamentals of Cybernetics [Krippendorf 77], where we have an attempt to determine the structure of methodology. In doing this one should consider features as below;

- The goal of a given science discipline
- The way a given science discipline erased
- Affirmation and generalization which are already included
- Philosophical foundations or assumptions
- Connection to other science disciplines and to applications.

And the goal of methodology itself is not the description or analysis of some object or phenomena, but process of scientific inquiry itself. This is in order to look trough limitations and possibilities of a given techniques, to elucidate a hidden assumptions and their **epistemological**[12] consequences, to suggest explanation of success and failure, to develop and testing generalization of scientific procedures.

[12] **Epistemology** = theory of scientific cognition, it has strict connection with methodology of sciences.

3.3 Mind and intuition in science

Our thinking instrument is a peak achievement of the evolution, or creation on Earth, and is not simple in itself, moreover the real research of a human brain and mind are still in development, that is why **21-**th century is called **century of mind** research. Talking about thinking process we should distinguish between brain and the mind. The brain is living structure of 10^9 neurons and much more neuronal connections, which pave the road to a memory and thinking process. According to some researches all activity in a brain is electro-physico- chemical in nature, and brain itself is a **biological interface** to a mind.

But what is a human mind, there is no univocal answer to this question simply because we are just differentiating between brain and mind activity. And just a while ago we come to the useful analogy, that brain may be considered as some kind of hardware, and mind is partly the software we are feeding to the brain, self creating feedback loops between different software products. We will be talking more on this problem in the chapter concerned with creative thinking. Here we have signaling the problem only with the main emphasis on **intuition** as much helpful and a 'strange' property of creative mind. According to popular textbook on psychology [Sperling 95,p396], we have;

"intuition is a direct knowledge about something, which was not anteceded by introductory analysis and reasoning",

in another way it is the knowledge about something without information concerning its source. While, already mentioned *Encyclopedia on System Theory and Cybernetics* claims, that **intuition gives idea of solving a problem without reasoning process**.

All known great minds of this World; the leaders, explorers, inventors and scientists with DaVinci and Einstein on head appreciate greatly this property of developed human mind. Leaders intuitively perceive the premise of a problem solution, and testing it next by rational thinking and acting in this way. While, innovators and scientists are using additionally calculations, trial designing and experimentation.

Albert Einstein is a father of very brave statement; **"on the way to discovery the mind has not much to do. There is a quantum leap of our consciousness, you may call it intuition, and the solution is coming to you, and you do not know from where and why it came"**.

According to some other sources, not obviously scientific but more metaphysical, the intuition is ability to reach in a higher spheres of being (*spirit*) [Pierce 01,ch 9]. This is because man can exist in a three states or conditions; the state of being which is characteristic to a spirit, the state of acting characteristic for a mind, and the state of having characteristic to our body (see Fig.3.3). Looking for the picture below (Fig. 3.3) one can imagine now that most of us are oscillating between **having** ↔ **acting**, rising very rarely on the wave of intuition to the condition of being, knowledge and spirit.

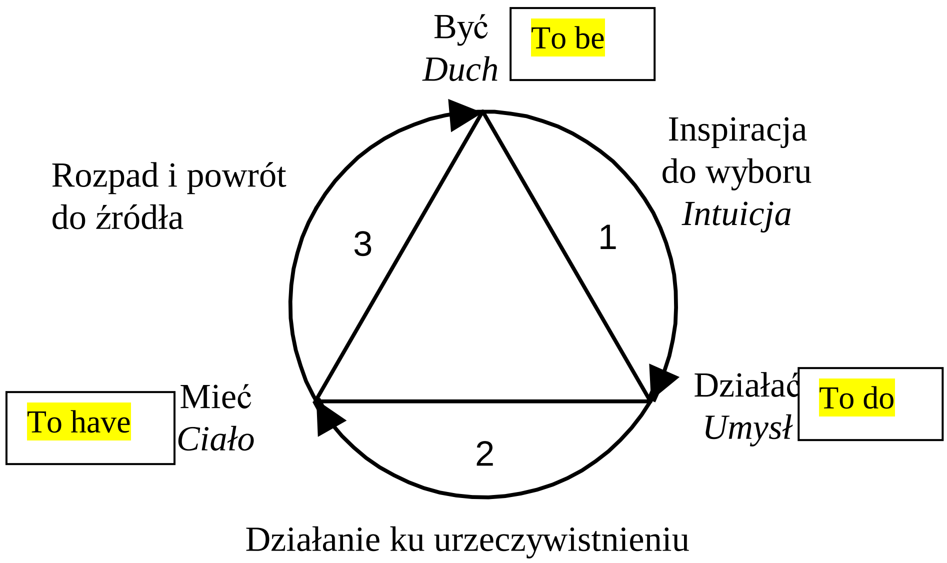

*Fig.3.3 The full cycle of creation; **being – acting – having** [Pierce 01,ch9].*

And now useful questions follow. How it is possible that some of us are following own intuition having results mostly predictable? How to use our brain, and mind in order to use fully our higher ability of thinking, whether it is conscious thinking or unconscious, our own thinking or some other people? The most important matter is that solution of the problem we are facing must be correct. Whether problem solution comes to us in the form of intuition or we are reaching to some other **reservoir of good ideas**, it is not so important. Let us review some experimental facts on our thinking which can help us when facing some new problems, which solution is not known as yet.

Our brain is some biophysical interface to our mind, which is located inside and around of our body. There are two way feedbacks between our brain and mind and each one can influence other. In a normal conscious state we are in so called **beta state** and frequency of brain waves is fluctuating between **14-30Hz**. But if we are in the condition of half a sleep, or reading something our brain activity goes down to state of **alpha** with the frequencies of **8 – 13 Hz**. Going deeper into some condition of meditation or hypnosis one can come to **theta** state with the frequencies **4 – 7 Hz**, and into the deep sleep we have **delta** state of brain with a frequency range; **0.5 – 3 Hz**.

From the practice of many creative people we know that flashes of intuition mostly come in the alpha state of a brain, and some people can consciously lower the brain activity in order to use the **higher mind** properties i.e. intuition. To obtain this routinely one can use special mind exercises described in some books [Silva 96], [Day 97], [Pierce 01], attend special courses like Silva Mind Control, or to use specially prepared classical music [Ostrander 96], [Dryden 99], or some modern version prepared specially for these purposes called **Metamusic**, **BrainSync**, and the like. Modern approach to awaken the higher brain activities is connected with the phenomenon called biofeedback in connection to encephalography (EEG). According to Dr J Hardt this is possible after few days course with the extensive using of EEG training [Hardt 2012][13].

Well, let assume that by the help of described above techniques, I have slow down my mind and concentrated on the problem, but from where the needed information will come if any? The great minds of the world have been thinking on this problem since thousands years ago. The Hindu philosophy for example postulates the existence of so called Mind of the World - **Akasha**[14], one of the fathers of modern psychology C G **Jung** postulates the existence of common unconsciousness, and every one of us can have access to this reservoir of human thoughts. In the similar way, well known system theorist E **Laszlo** [Laszlo 93] postulates the special **psi field**, what allows to explain the intuition, telepathy and other not fully recognized to that time consciousness phenomena, like clairvoyance, and the like.

So having access to the Mind of the World one can obtain innovative ideas for some problem solution, and then using rational methods and scientific instruments and techniques verify and develop our intuitive ideas. I wish much success to every one in these undertakings.

3.4 Summary of the chapter

In this chapter about methodology, the scientific method of research has been presented as having four steps; 1-observation of some object or phenomena, 2- introductory hypothesis explaining observations (*model*), 3- prognostic use of hypothesis, 4-experimental validation of the new model (*hypothesis*). As a next in clearing this 4 steps method some possible errors and traps has been explained basing on historical records of science development.

Beside of experimental errors in observation important in experimental sciences, much important is a nature of posing a hypothesis, which in many cases is some extrapolation beyond some verified area of science. Hence, as Feynman has said, the scientific knowledge has statements with different **level of certainty**. Also the important obstacle in passing

[13] J Hardt, **The Art of Smart Thinking**, Biocybernaut Press, Santa Clara CA, 2012,p326.(*see Polish translation*)
[14] **Akasha** = Hindu name for the reservoir of thoughts of the World.

knowledge from one area to another one, is the scale effect in physics and science at all, as for example the differences of energy notion in nano and macro physics, and different interpretation of time in non-local phenomena, and time scales as dynamical time and life time.

Besides instrumental possibilities of avoiding errors in experimentation, the main force driving the scientific research is a good chosen method of research and the knowledge of scientific methodology. However, this is disciplinary and problem oriented, hence there is a great role of epistemology in understanding and carrying the scientific research, similarly as the development of creative and intuitive mind of the researcher.

3.5 Problems

1. *If someone do not obey the 4 steps scientific method, is there possibility that research results will not have scientific value?*
2. *Why intuitive guessing of final result of research can not be the last step of scientific inquiry?*
3. *There are three methods of scientific thinking; induction, deduction, and statistical inference, which one is most dangerous, and why?*
4. *What is the name of World reservoir of creative thinking results, how to reach it?*

4 System approach to scientific research

The object acting in its environment is a system for our research
NN

4.0 The beginning of contemporary science

The era of contemporary sciences was preceded a long time by alchemy, astrology theology and scholasticism typically taught long ago at medieval universities of Europe.

The start of modern science was much easier due to the invention of printing in Europe[15] made by German craftsmen J **Guntenberg** (1397 – 1468). Hence in 15 century it was possible to disseminate printed information much quicker and more reliable, that it was at the time oh hand writing of books. But it seems to the author that development of modern science has to start from the dismantling of Ptolemaic geocentric thinking. This was the great contribution of astronomer *Nicolaus* **Copernicus** (*1473 – 1543*) from Frombork, a city on the border of Poland and Prussia, who has the observational data and the courage to challenge long established Ptolemaic thinking, that the Earth is a **center of the World**, what was the foundation of the Catholic Church doctrine. Copernicus knows this fact well, so his discovery was published by printing in Netherlands already after his passing.

Supporters of Copernicus ideas in Italy had great troubles; as philosopher *Giordano* **Bruno** has been executed by stack fire, and well known physicist *Galileo* **Galilei** (*1564 – 1642*) has been thrown to custody and must publicly dismiss Copernican idea in order to work safely at home. Galileo is father of contemporary physics and made a great contribution by research in gravitation. Latter comes the time of astronomer *Johanes* **Koepler** who verified and modified a little the great Copernican discovery. Following this the creation of modern science went to Northern Europe, far away from the destructive influence of the Rome.

Francis **Bacon** (*1561 -1626*) philosopher of sciences, the creator of **empirics** and **inductive** thinking presented his thinking in the book ***Novum Organum Scientiarium***. Some

[15] In China printing was invented several centuries earlier.

years ago after this publication, a French mathematician and philosopher *Rene* **Descartes** (*1596 – 1690*) presented his complimentary method of **deductive** thinking, when starting from the general axioms and irrefutable laws one can come to a good detailed solution of the problem under consideration.

The four rules of thinking invented by him (*Descartes*) are today as important as they have been, in particular for the problems of engineering without bio and human intelligence components. Hence it is worthwhile to cite them here in detail [Orloff 06,p23].

- Do not believe anything, unless you are certain it has no doubts on your side.
- Reduce every observed hardship (*trouble*) into the small components, where you have no doubts in understanding.
- Form your inference as a ladder, coming from the small facts and observations you have no doubts on him.
- Always prepare entire hypothesis, and in an outline of inference be sure you have forgotten nothing.

This type of scientific inference is called today **reductionism** and it has long history of success, and even today is used in classical physics and engineering, when system under consideration does not have bio or intelligent components.

4.1The growth of modern science

The times of *Isaac* **Newton (***1643 – 1727***)** and *Gotfried* **Leibniz** (*1646 – 1716*) was the beginning of modern science and engineering. Newton and Leibniz invented independently differential calculus, the basis for contemporary theoretical sciences, at the same time. Newton also introduced the foundation of mechanics, optics and gravitation, while Leibniz invented foundation of mechanical calculator, pumps and machinery needed in excavation of silver in the Harz Mountains in Lower Saxony-Germany.

They both created solid foundation for the development of modern science and engineering, as mathematical modeling and mechanical calculation has been possible from that time. The waiting time for development in engineering was not so long. The invention of the steam engine, electricity and electric motors has made the foundation of railroad transport and mass fabrication, while the invention of Diesel and petrol engines paves the road to a mass road transport. In science the triumph of physics as foundation of modern day technology was unquestionable, and the development of science itself at the end of 19 century was unquestionable too. Some physicist has been even thinking that some physical constants need more accuracy and the **edifice of science** will be complete.

But it was scientific illusion, as within a few years the beautiful picture of science and knowledge has been changed completely. The first destruction of science edifice has been started in 1905 when Albert **Einstein** presented his theory of relativity which exclude absolute motion, absolute time and gave a limit velocity as a speed of light. A few years latter in 1920 Max **Planck** has introduced on the level of atom radiation the quantization of energy exchange. Without this condition Planck theory of black body radiation is not correct giving infinite energy of radiation. This fact was the starting point for creation of **quantum mechanics**, which describe the behavior of matter on the fundamental micro level.

The next blow comes to mathematics in 1934y when Kurt **Goedel** Austrian mathematician, presented his **incompleteness** theorem [Krippendorf], which in short gives such explanation of incompleteness;

“**every consisted axiomatic system contains statements which are impossible to prove using knowledge of this system alone”**

In other words there is no science discipline which can be self standing and self-sufficient. This theorem has had catastrophic influence on the mathematics, but his meaning is far beyond one scientific discipline. Using analogy thinking and applying this to cosmology it is impossible to prove the existence of God, using our verified and certified knowledge. But if one assumes the existence of higher level intelligent being, who uses and operates high level of energies on the planetary or galactic level, one can find that the existence of God is fully credible and fully justified [Cempel 97].

But it is not the end of troubles coming to main stream science, we have mentioned already, as physicist from Ireland *John* **Bell** concerning the quantum physics has published his famous statement; **“*reality must be non-local*”**, that means that on the quantum level interactions are instant and the speed of light is not any obstacle here.

Summing up all these radical turnovers, there is a question now, how it is with our science? At the beginning from careful research we constitute laws, rules, theories, and latter on sudden shock is coming, which endanger consistency of our science edifice. What is wrong here, it is not only the question of denser sieve associated with the new technology of measurement and instrument making, as Feynman has said?

4.2 Revolutions and paradigms in science

Let us take a closer look on these phenomena by the notion of scientific paradigm formulated in 1962 by T S **Kuhn**. As it is seen from the above description the development of science is not a continuous process, it goes wit some jumps coming after the period of continuous growth. The mechanism of this development is as follows. After some time of knowledge accumulation, there is need to solve new problems, and its new non standard solution leads to a crisis, to unknown earlier new ways of thinking and inferring, for example relativity of motion, energy quantization, etc. One can draw from this situation two conclusions; firstly – **science is self adaptive system** it corrects it own errors, mainly by means of experimental verification as Feynman said latter on. Secondly, the exhaustion of development possibility inside the given interpretation of reality leads to a crisis, and to a need to **change the paradigm** into a new one. This situation have been analyzed by Thomas **Kuhn**, and he has published in 1962y the main book of contemporary philosophy of science; **The structure of scientific revolution** [Kuhn 01]. The main message of this book is as follows;

"The scientific discoveries lead to scientific theories, which may bring to crisis in scientific society. This crisis's in turn may lead to revolution in science, which changes outlook of scientific world, what according to Kuhn is the change of paradigm"

From this time, the notion of **paradigm** has made a great carrier, and not only in a science, having today some number of meanings; from the mental model of the problem and even a world, as for the system of notions and belief by means of these we understand and interpret our world.

The upheaval series which experience physics and mathematics we have described already, but in general one should add at least two fundamental changes of paradigms; systemic or holistic in science and new paradigm in economy and management called knowledge economy or even the **civilization of knowled**ge which has been started in an Western economy some years ago.

In contemporary science, from the times of Newton and Descartes, we are using **reductionism** or mechanical paradigm, according to this;

the whole new system can be making known if we isolate and examine its parts.

This paradigm is still valid almost in entire engineering sciences, when we do not investigate complex systems with use of bio or thinking parts.

The new **systemic paradigm** was growing slowly, firstly in biology beginning from the first half of a previous century. The reason why in biology is simple, if we isolate all parts of the frog, and investigate their property, and put them together letter on, the frog will not jump and make sound. Up to now we are not able to isolate **"life"** as a part of living systems; we do not know even what the essence of life is.

From the other side Aristotle was the opinion that "**the whole is more than the sum of parts**". But the real breakthrough in system thinking was during second world war, when system thinking was applied with a great success to the defense of the Great Britain, and latter on to the formation and lead of the Atlantic sea convoys from the USA to England and Murmansk in Soviet Union, during the rest of the II w.w, (*see for example [Cempel 2000]*). This facts and great success of systemic approach in connection with new scientific achievement like cybernetics (*Wiener, Ashby*), game theory and simulation of market behavior (*von Neuman, Morgenstern*), the information theory (*Shanon*), gave the great push to the rise of **System Theory**, as a generalization of thinking from many scientific and management disciplines. The main paradigm here is systemic and holistic approach to investigation and creation of complex system. In a short, latter on the system thinking was adopted in engineering as Systems Engineering, when considering the life cycle of products; beginning from conception, design, fabrication, the use, recycling and reuse.

The **Systems Engineering** at the beginning was used in military and space research and design, but with the first lectures for students in USA universities in 1965y, it passed quickly for the civilian use. It was done latter on much quicker way with the adoption of information technology, mechatronic and ecological design.

John von **Neuman** was mentioned already in this text, but his scientific contribution concerns not only with the game theory and market simulation. During the **II w.w** he has worked in a secret Manhatan project, and after the war he elaborated the first algorithms for serial calculation what is currently in use in a digital computations. Also, he is the author of first papers on cellular automata, the basis for today's parallel computation, and more importantly the inventor of the code for the first self replicating information agent, or better to say software robot.

The first digital computers, ENIAC for example, was large, heavy and very unreliable, and was not a scientific and technology breakthrough, but important is that they have change our way of thinking in computational sciences; from the continuous one to a **discrete or digital** in essence. From that time digitalization and processing numbers, words and recorded knowledge is possible and is the essence of modern information and communication technology (**ITC**). But only the invention of transistor and circuits with very large scale of integration (VLSI) has pushed application of digital computation to a science and to industry in the sixties of the last century. This was one of the reasons why US economy has changed from mass fabrication industry to a service and information economy. In today's terminology we are talking on change of the industrial paradigm; from the mass fabrication to the economy based on information and usage of knowledge. In the same way we have now the change of civilization paradigm, to a post industrial economy based on knowledge, where (*as Toffler has written*); the knowledge can be a substitute of almost all production ingredients and components.

4.3 New paradigm of science and civilization

The traditional thinking way in science is based on Cartesian paradigm, Newtonian, or Baconian, because its main ideas has been formulated by this three great minds. Today this way of thinking in science is called **reductionism** or mechanical paradigm.

The contemporary paradigm can be called holistic, systemic, or ecologic, but any of these adjectives does not give its real nature. This is because modern scientific thinking according to Frithoff **Capra** is directed by five criteria. Two first of them are concerned with our understanding of the nature, and the remaining three to the epistemology, that means to the creation of knowledge, as below.

1. **Reversal from the notion of part to the notion of the whole**

Traditional thinking according to reductionism paradigm has assumed that the dynamics of any complex system can be understood if we know the features of constitutive components.

In a contemporary systemic or holistic paradigm we have reversal of previous relation. The features of the constitutive components can be understood only when we know the dynamics of the whole system. What we name the part is functional fragment of unbreakable net of the system relations.

2. The reversal from the notion of the structure to the notion of the process

The traditional paradigm has assumed that there exist primeval structures and forces and mechanisms proactive which are giving the processes. In contemporary paradigm any structure is understood as the effect of the internal process, and the net of internal relations is dynamic in nature.

3. Turnaround from the objective science to the epistemic science

The traditional paradigm has assumed that the scientific descriptions are objective that means independent from the observer and the process of cognition is independent from the applied methodology.

Contemporary holistic paradigm assumes that the epistemology must be included into the process of creation of the new knowledge concerning natural phenomena or new technology. There is no consensus up to now, what part of epistemology must be included in a research process, but there is a growing concern that the epistemology has to be the integral part of every scientific theory.

5. Turnaround from the notion of knowledge as an edifice to the notion of a net as a metaphor of the knowledge

The metaphor[16] of the knowledge as an edifice consisting the fundamental and absolute truths, rules, and other knowledge bricks, has been dominating in a science and knowledge of the Western civilization from thousands of years. Hence, in periods of paradigm change there was conviction that foundation of our knowledge are breaking down. In an approach of contemporary systemic paradigm the metaphor of edifice is replaced by the metaphor of net or web. Our reality is perceived as a web of mutual relations, and by describing it as a new we are creating new web of relationships. What is important in such web, there are no fundamental relation or absolute relation. Whatever is going on in one knot of he web influences the other knots in the web, but of course the locality principle is holding on.

If the knowledge is understood as a web, hence the role of physics is also changing, and now physics is not a universal scale to understand the other discipline of science and knowledge.

6. Turnover from the notion of the truth to the notion of approximate description

The Cartesian paradigm has been based on the conviction that the scientific knowledge can give as an absolute certainty. In a context of contemporary paradigm we are of the opinion that al **notions, theories and discoveries are limited** and are only some kind of **approximation**. Moreover science can not give us the whole and full understanding of the reality. Because scientist are not looking for the truth (*in the sense of absolute accordance between the description and its phenomena*), but are looking for the limited and approximated description of reality, valid on the given level of he development of technology of measurements. These descriptions and understanding must be under the continuous pressure of Popperian falsification[17] theorem also.

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[16] **Metaphor** = statistic structure, the figure of speech where one of the expression obtains the other meaning
[17] **Falsification** = an attempt to show that some statement is **false**.

In order to understand better the changes of paradigms it is good to place them on the series hitherto changes of civilization paradigm of humanity in a history of his total development. In a technology and economy such changes of paradigm are passing more quickly than in a science, especially lately. According to Freeman [Freeman 95], the first paradigm of technology and economy has been based on the **forces of a nature**, in particular on muscular force of the man at first, than animal, wind and the water. The **steam power,** as the second economy paradigm steps in slowly at the end of XVIII century. The **electric po**wer step in to our economy in the middle of 19 century, at the end of century due to Tesla inventions, the generation and dispatch big electric power was already accomplished as a new technology. The **mass fabrication** as a fourth economy paradigm was at first in car and food industries, where these branches of industry have been dominated due to this. The contemporary fifth economy paradigm is **information technology**. These have been in constant development since the end of Second World War, but only now they are the pushing power of development in science, economy and technology. And as Freeman has said it is not too early to claim the future sixth economy paradigm **bio – environmental – friendly**.

4.5 Premises and implications of new paradigm in a science

The emergence of the new paradigm in science and economy has been the effect of changes in thinking of humanity elites. Concerning science only, let us remind ourselves the main turning points in the change of paradigm from reductionisms to systemic and holistic in nature. The relativity theory of Einstein, that means relativity of motion and observer has shown that also in science there is nothing solid, all is in the motion, "***panta rei***" as Heraklit has said 2.5 thousands years ago. Then it came **quantization** of energy and action introduced by Planck with the latter development of quantum mechanics, which by the analogy can be outstretch to the other science disciplines and cognition of humanity.

Not long ago after that we have **uncertainty principle** of Heisenberg [Jaworski 71,s848], where on the level of atom scale we have quantization of interaction (*product of energy and time*). That means interaction on the level of atom can not be less than one quantum, that means also we can measure and calculate with accuracy of one quant only ($h/2\pi$, *h – Planck constant*), but not less. This discovery of lack of continuity in micro physics, and minimum quantum action has it own consequences in other domain of sciences.

In theory of signals analysis and in practice as well, the product of frequency interval and time duration of analyzed signal can not be less than 2π. It means that the frequency analysis of short interval of signal by means of Fourier spectrum will be fuzzy below certain frequency interval. It seems to that this approach looking to fuzziness of a measurable quantities can be transferred to other branches of science and engineering, psychology, sociology, etc [Francois 97,p382]. We do remember that on the semantic level there is a joining growing confusion the **Goedel** incompleteness theorem of logic and mathematics, which by analogy can be extended hypothetically on other symbolic systems like languages, ideology, religion, etc. Talking figuratively we need in all these cases some help in a form of **hook from the sky** [Penrose 96,p347].

Let us go to other strange phenomena and strange behavior. The real confusion in identification of dynamical systems and processes comes from nonlinearity phenomena, which is graphically explained by figure 4.1. This is worth also a special explanation in terms of system behavior in a large interval of variables describing system behavior.

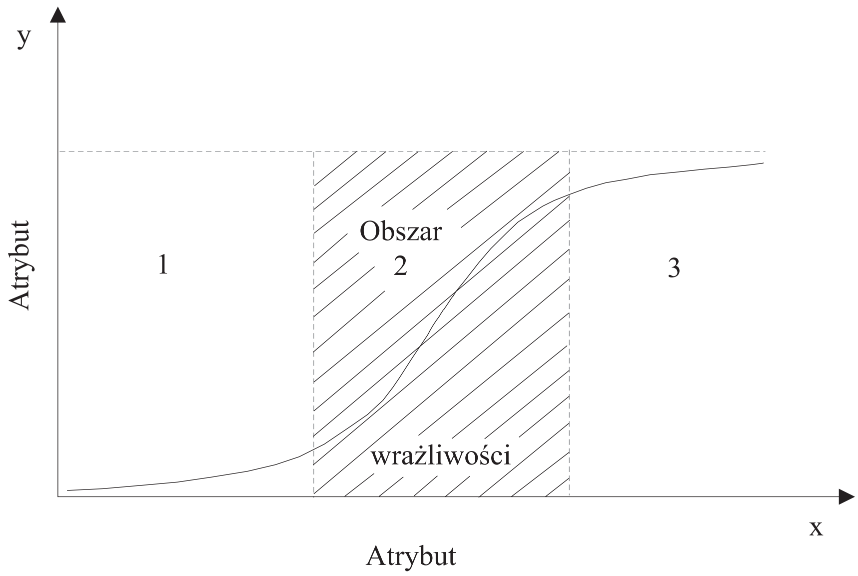


Fig. 4.1.Graphical illustration of nonlinear dependence between two system's attributes, [Cempel 00,ch.4.7].

As it is seen from the Fig.4.1 in the first area of attributes variability, their interdependence is very weak and can be easily omitted in identification research as the error of measurements (*usually* $\pm 5\%$). In the middle range of attributes their interdependence is very strong, and again very weak in the third range. If we identify system behavior in the range one or three only, the total dynamical behavior of dynamical system will be a great surprise, because we assume that there is no dependence between attributes **x** and **y**.

This is the essential error, while nonlinearity in deterministic dynamical system gives quite different unexpected **chaotic [18] behavior**. The probabilistic behavior of many phenomena like fluid turbulence in nature is quite normal, not strange. But very strange is so called **deterministic chaos** discovered not so long ago in simple deterministic models and systems if they have nonlinear dependence of variables. Such strange behavior have been observed sometimes, but no one outside of **Lorentz** from MIT (*the beginning of sixties previous century*) not investigated these phenomena basically and deeply. This may be the reason that Lorentz has had for the personal use one of the first digital computer devoted completely to his research of weather forecast [Stewart 94].

The problem of weather forecast at that time has been described by three nonlinear differential equation of the first order. And during the research it turns out that the final results of simulation depends on some intermediary approximation and from the starting point too. This influence on the weather was so strong that Lorentz has called it the **butterfly effect**. This means for example that the wing motion of butterfly in Alaska will give heavy thunderstorm in a New York. Latter on during investigation of deterministic chaos there was found out much similar behavior. There arise latter chaotic mathematics and dynamics, and even there have been introduced some parameterization of chaotic behavior in the term of Poincare measure. There was found out also that deterministic chaos is a close related to self similar structures so called fractals, and their together describe so called structure of irregularity.

There is much more irregularities, surprises and strange phenomena in science, hence many scientists is of the opinion that good theory is such which was not falsified already. It was confirmed in the thinking of Austrian philosopher of science *Karl* **Popper**, who was of the opinion that every scientific theory must be tested by falsification from many sides [Francois 95,p135]. During the later discussion of this hard condition of falsification there was opposition to that, the main opponent was Lakatos, a Hungarian philosopher, who has formulated alternative method of scientific validation, but we will not go into the detail of this problem [Chmielewski 95] . However this falsification criterion of a good science has been fully acclaimed in the world of science. And as *David* **Bohm,** English Nobel prize winner in physics, is claiming, the successive experiments confirming the given theory are **increasing our level of confidence** of this theory, but it **never makes the truth**.

[18] Chaos = disordered phenomena, total, not possible to forecast

4.5 Summary of the chapter

The development of contemporary science was outlined very briefly, together with the troubles in physics and mathematics at the beginning of the 20 century. This was leading latter on to the change of science paradigm as holistic – systemic. This change of the paradigm was shown in much brighter approach, showing premises and implications in a different branches of science, technology and economy. From this considerations one can notice the hierarchy of a tools which we need to apply in science;

Paradigm → methodology → method → methodic → research tools

The summary and complement of the above, is that one can adopt falsification rule of Popper, applied to every scientific statement.

4.6 Problems

1. *Please show the further implications of non-locality theorem of J Bell.*
2. *What do you know on zero point energy -ZPE, dark matter and dark energy.*
3. *Please describe possible effects of nonlinearity in a nature and science.*
4. *Please illustrate uncertainty principle in physics and other branches of science.*
5. *Incompletes theorem, what is about, what it gives to science?*

5. Knowledge, Science, Skill, Engineering

Scio me nihil scire!

Socrates

5.1 Knowledge, skill

5.2 Science, engineering

5.3 Methodology of acquiring scientific knowledge

5.4 Summary of the chapter

5.5 Problems

The knowledge is a notion understanding almost by everyone, and due to this reason it has many meanings. We will take this into consideration, as the main goal of scientific research is acquisition of **new knowledge** and finding some applications to this knowledge.

5.1Knowledge, skill

The Encyclopedia of Systems Engineering [Francois 97] has been cited already many times, and the key word knowledge in different meanings and associations occupies there six pages of large three column format. So, let us begin from the simple definition of knowledge given by the UNESCO vocabulary;

"the knowledge is a result of learning and cognition verified in practice"

Simple, is not it?

The result of learning can be stored in the memory of knower, but also memorized on the other data base. Hence one can say, that knowledge differs from knower in such way as data base from computer disk, which stores it. Moreover, the knowledge one can sell; it is a **good** or **wares** more and more valuable when we approach civilization of knowledge. One can trade knowledge, implement it, teach it, ascribe different representation and finally acquire new knowledge with the use of old one.

In general, the acquisition of **new knowledge** is a result of recursive interaction of observer with the reality, and the 'observer' has to have the basic properties of mind, like human, neural net, information agent, and like other artificial intelligence devices. This recursive interaction gradually changes the state of the observer up to the stable state, on the given level of error, what means that given portion of knowledge was successfully acquired. In the same way there are formed the algorithms of self learning.

As we know already, the new acquired knowledge has different level of certainty, or better to say reliability. It depends on the given fragment of reality, but mostly on certainty and reliability of learning algorithms. The way of new knowledge acquisition will be treated extensively here in a separate point.

The information is a part of knowledge (*see next chapter*), it is **descriptive** and arise as a response to several questions;

what, which, who, how much, where, when**.**

On the other side the knowledge is **instructive** and communicated mostly as the response to questions concerning some activity, **how to**, to do, to understand, etc. Sometimes, by some people, the knowledge is acquired but not verified in action; one can say it is non-operable, like in many educated people in Poland.

The knowledge itself is perceived and stored twofold, as the **explicit knowledge** in books and teaching materials, etc. The second type of knowledge is **tacit**, or implicit, which can be better named as **skill**. And this has to be acquired in the interaction wit the reality only. One can know how to use bicycle theoretically, to cook, but here the knowledge alone is not sufficient, the practice is needed, and a practice connected with the intelligence make as a true master.

5.2 Science – Engineering

The skills on the higher level with some foundation from science and aiming to change and transform the reality are usually called as **engineering**. Using the holistic paradigm one can present the connection between different branches of science and branches of engineering like on Fig.5.1. Limiting ourselves to the main disciplines of scientific cognition we have from one side physics with its elementary questions and types of energy, up to the sociology and philosophy with its subtle energies of human and social interactions. On the other side of the figure, at the skills we can start from the grossest components like civil or agricultural engineering up the social and system engineering. The whole picture and system of knowledge, skill and engineering is supplied from general system theory and philosophy, as it shown in a picture 5.1. This integration of science and engineering emanating from the picture is reflection of the statement of H **Seyle**, creator of the well known stress theory, who has said;

in science there are no narrow disciplines, there are only narrowly thinking scientists, and in a nature every branches are connected with others**.**

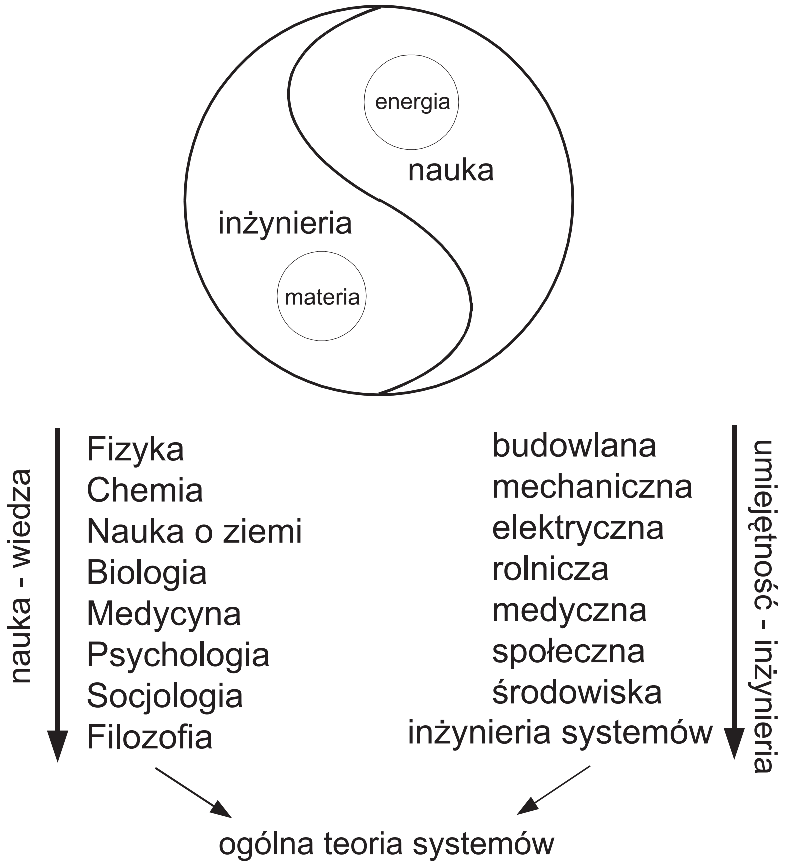


Fig. 5.1 Knowledge and engineering in the hierarchical order of aggregation matter and energo [Cempel 00.ch.3.2]

Following this statement of H **Seyle** nowadays we are witnessing the creation of the integrated engineering disciplines, like **mechatronics** = mechanical engineering + electrical + electronic + informatics; **bionics** and bioengineering = biology, biotechnology, mechanics, electronics, informatics, **nanotechnology** = physics, chemistry, biology, mechanical engineering, electronics informatics, and all that is in micro scale of nano = 10^{-9}, with a future possibility of self replication in a massive scale.

There are some other differences of science and engineering, some on socio-technical scale, what has been pointed out by Eder and Hosnedl in; **Design Engineering –** a manual for enhancement creativity;

the lack of knowledge does not hurt in science, but in engineering results in disasters of infrastructure and transportation.

The other difference between science and engineering is the goal of activity or practice and kind of questions putting up. In short, the aim of science is **cognition of reality**, while the aim of engineering is **transformation of reality**. Let us look for these more precisely looking for the question and answers or advised activity. Looking at these problems by systemic paradigm we will have.

Cognitive questions –SCIENCE

1. **What is it –** distinguishing of fragment from the universe (*ontology*)
2. **How is it –** rough (*approximate*) description of fragment (*epistemology*)
3. **What is the structure –** structural model (*axiology*)
4. **How it works –** functional model (*black box, grey box, white* box)
5. **How to apply it –** possible application (*valuation*)
6. **How to research and investigate it better –** methodology

Application questions – ENGINEERING[19]

1. **What do we really need –** articulation of need and utility
2. **How to attain the need –** a concept of fulfillment (*product, organization, etc*)
3. **How to design** - design alternatives
4. **How to pro**duce **–** technology, costs
5. **Where and how to sell** – market, advertisement
6. **How to use it** – usage (*goal, methods*), service
7. **How to reuse it** – recycling, phase out, disposal

The present author is hoping that due to materials presented in this text together with the system paradigm in the whole life of the system, the reader will better answer to the cognitive and engineering questions and also existential in nature too. Hence, it is almost sure it will be much easier to answer very important question; **how and for whom to live!**

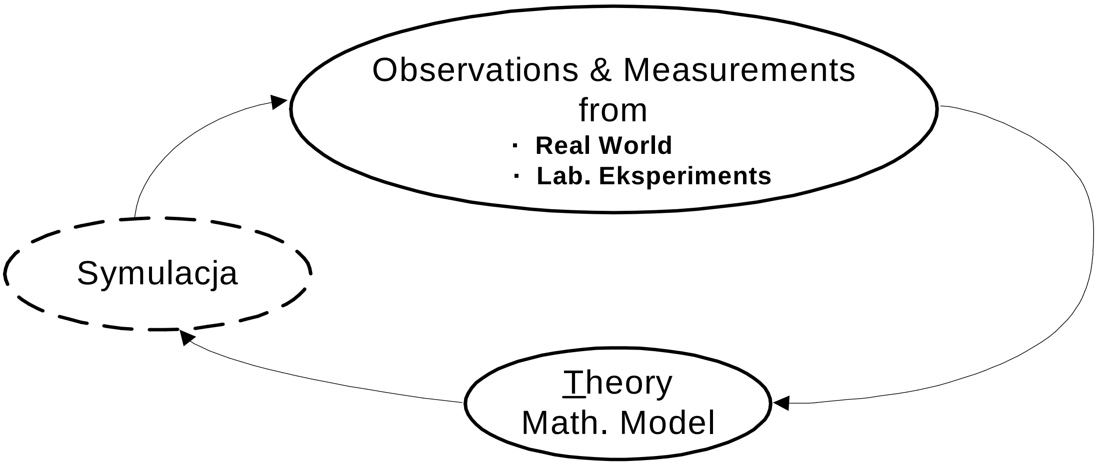
The interesting considerations in these matter are presented by **Pogorzelski** in his book on system theory [Pogorzelski 99,s33]; **live according to your mind, your courage and with your self responsibility. Because now there is a time that people of the Earth has to be sovereign, not only concerning the important issue, but in the matter of day-to-day thinking, acting and consciousness**.

[19] **Engineering** = technology of transformation of the reality, based on the scientific foundations for the benefit of humanity and the environment

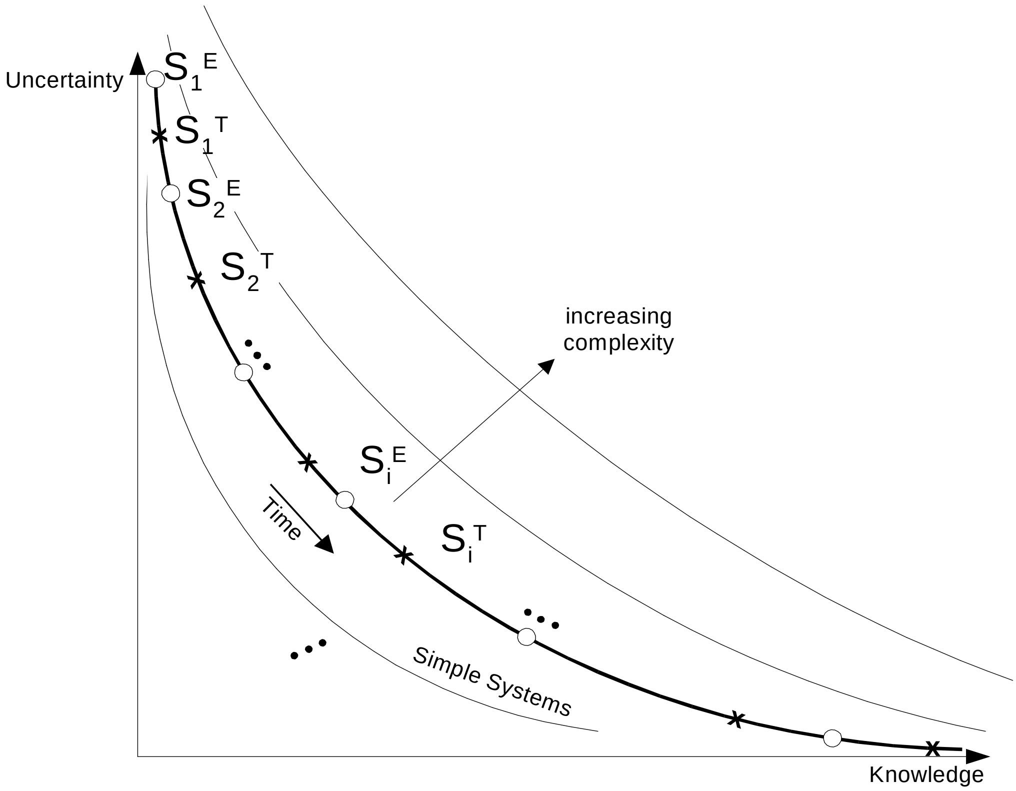
5.3 Methodology of acquiring of scientific knowledge

There is an interesting question now, how we did obtaining such level of knowledge, skill and technology? Is there a common method of acquisition or discovering this knowledge and technology? It seems to the author that this situation is better explainable graphically like on Fig.5.2 [Natke 93]. The first picture in a Fig.5.2 present the acquisition of a new knowledge by means of the cycle; experiment – theory, that means that the experiment gives the basic facts and by means of these facts one can construct some type of model of the phenomena or object. The successive refinement, extrapolation and interpolation of the validity of the model put up the new question as the basis to the new experiment and interactive cognition of the given fragment of the reality. This former dyadic approach in a research is nowadays complemented to a triad; **experiment – theory – simulation**.

The possibility to use simulation follows from two new betterments in research; firstly we have more and more better and accurate models of objects and phenomena. Secondly we have growing calculation possibilities by means of smaller and better computers and calculation software. The foundation of every **simulation** is a good model, and the simulation in action can be two fold; the contraction of the space time scale or its expansion. In any case it is very useful in a research and use of complex systems. However, every model contains some part of verified knowledge and some part of fuzziness or even probability, as it depends on the type and the dimension of the investigated problem. This may be the typical empirical model from the one side, by the different level of the analytical and mathematical dependence, deterministic, fuzzy, or even probabilistic depending on the complexity and freshness of the system and its model (*see a part **b** of the Fig. 5.2*). We will be talking more on this problem in one of the next chapters concerning models, and modelling.



(a) The Experiment / Theory Cycle



(b) Uncertainty - Knowledge Relations

Fig.5.2 The experimental - theoretical cycle of acquiring the scientific knowledge from the world, as the journey on the ignorance surface [Natke 93].

This way of acquiring the new knowledge from real world we will complement by more detailed tables entitled Knowledge Generation, and taken from Encyclopedia of System Science [Francois 97,p200]. The first the left one Table 5.1 presents the taxonomy of empirical acquiring of knowledge, while the second table presents the division of non empirical method of knowledge acquiring.

Table5.1. The detailed taxonomy of different methods of knowledge acquiring [Francois 97,p200].

Table: see entry KNOWLEDGE GENERATION (A taxonomy of)

Criteria for discrimination	Types of knowledge generation
Knowledge generation from real world	Observation
	Experimentation
	Instrumentation
Knowledge generation using a model based on:	Simulation
Type of behavior	Trajectory
	Struktural
Type of change	Continuous
	Diskrete
	Process interaction
	Discrete event
	Activity scanning
	Discrete arithmetic
	Finite state machine
	Quasi continuous
	Discontinuous
	Combined
	Catastrophic
Type of determinism	Deterministic
	Stochastic
Spatial distribution of models	Spatial
Boundary - valued model	Boundary value
	Fixed boundary
	Variable boundary
Network model	Network
	Bond graph
	Petri net
	Queuing network
	Networkflow
Organization of model	
Fixed	Allopoietic
Variable	Autopoietik
non-reproducing	Metamorphic
Self-reproducing	Object oriented
	Cellular
	Game of life
	Self - similar system
	Fractal

Table: see entry KNOWLEDGE GENERATION by non-experimental techniqes (A taxonomy of)

Criteria for discrimination	Types of knowledge generation
Using numerical methods, which can be	
Deterministic	Computation
	Optimization
	Prediction (anticipation)
Stochastic	
Model is deterministic	Monte Carlo simulation
Model is stochastic	Statistical inferense
Using nonnumerical methods	
Synthesis	Module interfacing
	Model coupling
	Fusion/composition
	Rule fusion
	Rule composition
	Compilation
Inferencing	Reasoning
	Induction
	Primary induction to formulate:
	Hypotheses
	Laws
	Secondary induction to formulate
	Theories
	Deduction
	Qualitative simulation
	Approximate (fuzzy) reasoning
Speculation	Guessing
	Hypothesis formulation
	Belief formation
	Certainty factor of belief
	Belief maintenance

These tables are worth of individual rethinking, but it is worth to remark also the meaning of the first table. Here by the experiment one understand material world investigation as well as investigation on the mathematical model, and even in the virtual reality - VR[20]. The right side of the table 5.1 is much fuzzier in methods as it allows also the speculation and guessing as the way of acquiring new knowledge.

[20] **Virtual Reality** = advanced type of sensory simulation, where the operator is working, and this is direct technical extension of his intellectual work [Kerkhove 96,p99].

From the above short overview one can see all the riche of contemporary ways of knowledge acquisition, the knowledge from the real world as well as from the dedicated processing of existing knowledge. In some cases it may look like in science fiction, the human researcher is generating the new idea, and the intelligent information agent[21] is verifying all possibilities of new idea and even proposes some similar ideas.

5.4 Summary of the chapter

In this chapter we have been learning what knowledge is, what a science, skill and the engineering. Now we know that the goal of science is acquiring new knowledge, and the goal of engineering is fulfilling the social needs and transforming or even creating new reality. We have learn also that optimal way of knowledge acquiring is a triadic way of experiment – theory – simulation, and this can also be illustrated as a journey on the ignorance surface.

5.5 Problems

1. *Please show the differences and specifics in acquiring the knowledge in science, engineering and the art.*
2. *What is in common in these three domains of human activity?*
3. *Is there some conditioning of progress in these three domains?*
4. *Please verify the hypothesis below;*

"Empirical sciences operate with observed facts and rules, while a philosophy and the art operates with some opinions". For example ***Plato*** *(or Derida) has said ….., write,……., etc.*

Ho do you se this fact?

[21] Agent = intelligent software realizing some task.

6 From data, information to a wisdom

Wisdom is the rarest commodity in the world

NN

It will be the most precious for us if we can find and learn, what relations are - if any, between the data and the wisdom, which is most wanted feature for the thinking people of the world.

6.1Creation of the wisdom

Previously we have used many times the notion of information, but in terms of its creation and transmission it is not primary ingredient. The primary component of information is **data set**, but alone they do not have any meaning. They can be stored in a written paper form, written on some type of carrier, or computer disk, etc. Only **information** as data set connected internally (*data structure*) have some meaning. Interesting is now what is the definition of the notion of information?

The simplest definition on can find [Francois 97,p178] is; ***"contents of a message which can induce action"***, but different association and description of different meaning of information occupy several pages, similarly as in the case of definition of knowledge.

Not al types of information are able to be sent to the user, some information is **inherent** or better residing in an object. Usually it is some type of **morphogenetic information**, concerning with internal connections in a given element or event the entire object. In this way we are talking about information residing in crystals, DNA ribbon and many similar stabile structures including the atom of hydrogen. In the same way information is residing in a structure of any organization, natural or human

The information, independently of data carrier, can be created, transmitted , transformed, destroyed, reclaimed, and as such do **not contain the energy**. While all operations on it demand the energy, in the same way like transmission occur possible by means of any carrier.

Going higher on the road from data to wisdom, if one can synthesize some information around the central notion then one may obtain some **knowledge**. For example a set of information concerning the properties of electric current and electric field lead us to the knowledge of electrical engineering. Going further on integrating according to some code of action many fields of knowledge one may come to wisdom. The good illustration of this way from the data to wisdom presents the table 6.1 taken from the rapport of Computer Technology Research Corp. [CTR 96] .

Type	Form
Data	• Numbers • Words
Information	• Full statements • Summary statements • Combinations of words and numbers • Aggregate numbers
Business Inteligence	• Words • Statements • Aggregate numbers • Rules
Knowledge	• Words • Statements • Aggregate numbers • Rules • Descriptions
Wisdom	• Multiple knowledge • Internalized • Integrared into all actions

Table6.1 Creation of the knowledge and wisdom from the data [CTR 96,t4.2]

As it is seen from the table, the passage from the lower level to the higher is associated with some grouping, aggregation, filtration, giving some meaning and semantic connections (*rules*). And the highest level in a table - wisdom, is internalized and integrated in all actions. And there is some condition according to this one may call that, some action has been taken as an act of wisdom. The **wise man knows how to act**; he is not looking for some external justifications; professional, ideological or even some religion one.

On the road from data to wisdom it appears also some new component not shown in a table but worth to review and to show its value, this is **understanding**. According to Bellinger [Bellinger 00], understanding is cognitive process, analytical, interpolative and even probabilistic and **can not be equated** with the knowledge. It is because; the difference between understanding and the knowledge is similar as between learning and remembrance.

In this sense artificial intelligence systems have some understanding, because they are able to synthesize new knowledge from previously stored information and knowledge. So, understanding have different dimension, similarly as the number of connections between data and information. That is why the road from the data to wisdom can be presented better on a two dimensional figure 6.1.

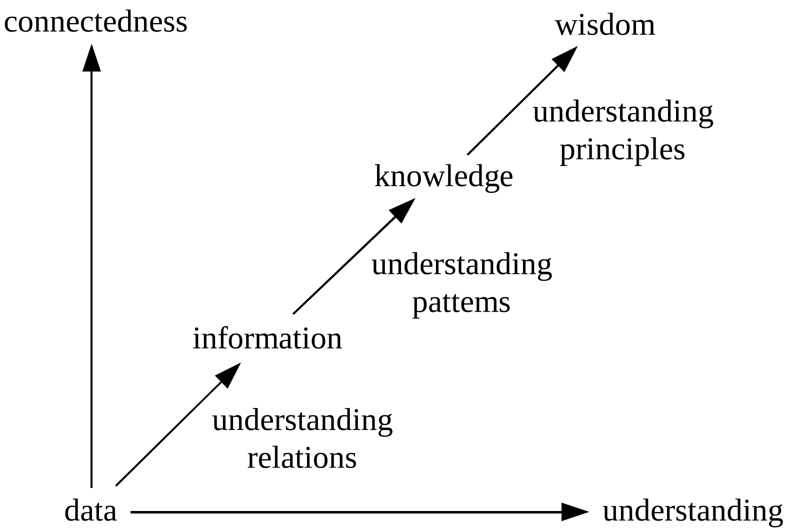


Fig.6.1 The way from data to wisdom on a plane of intensity of understanding and connectedness [Bellinger 00]

The above Fig.6.1 clearly points out also the below descriptions and statements;

- Data set is not information
- A set of information is not a knowledge
- A set of knowledge is not a wisdom
- A set wisdom is not a truth.

That is why in order to pass on the higher level of data organization we need dedicated integration carried on from the higher level.

6.2 Cycles of knowledge existence and demand for a knowledge

The creative transformation from the data to a knowledge shown in a table 6.1 and Fig.6.1 can be described in terms of a process as a cycle of knowledge creation. This important cycle can be illustrated in another way, maybe much better receptive to memorizing and understanding, such as on a Fig.6.2. Here one can see all processes of filtration, aggregation and abstraction, which are forming the pyramid of knowledge.

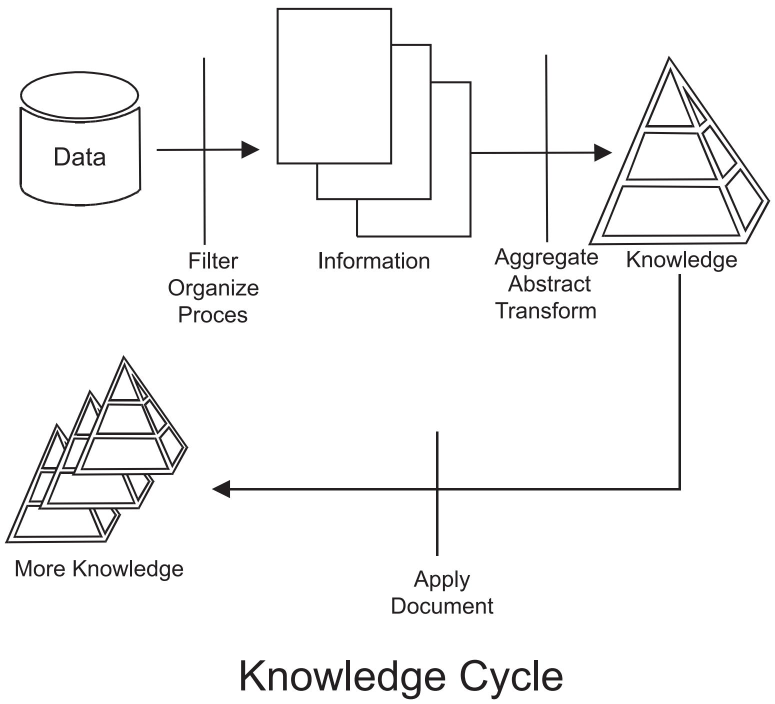


Fig.6.2. Graphic illustration of a cycle of knowledge creation [CTR 96,ch.4.6]

The creation of knowledge is connected with social side of demand for a new knowledge. Hence, there is also social cycle for a new knowledge consumption and application. This is connected with teaching and learning, as well as preparation of teaching materials and books, where the knowledge experiences the way from the explicit to a tacit and vice versa, like on Fig. 6.3.

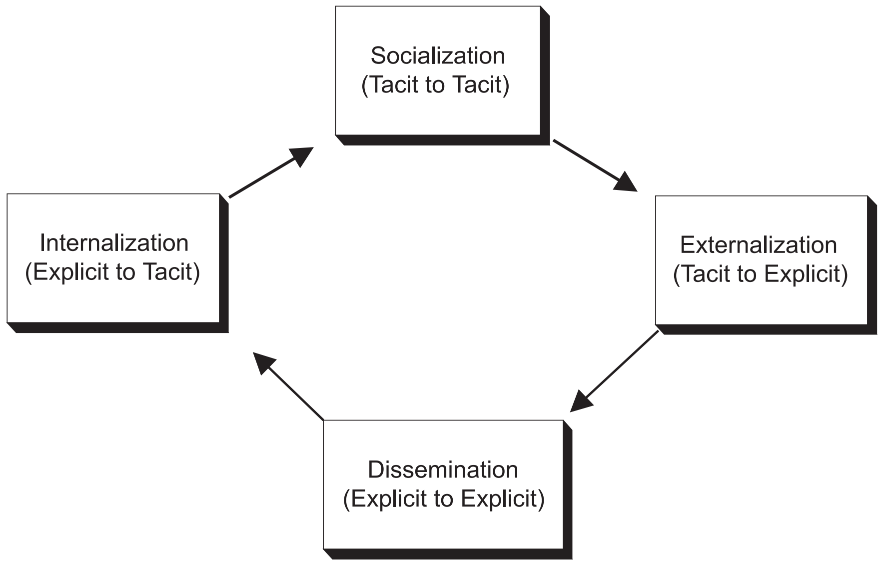


Fig.6.3 The social side of knowledge cycle [CTR 96,ch.4.6]

On the social level of knowledge interaction there is another process of creation and using (*consuming*) the knowledge from the same source but on different level of aggregation. The best explanation of this process is illustrated on Fig. 6.4, and one may call it as social pyramid of knowledge creation and consumption. It is seen from there that the scientists investigate reality, create models, and data bases. On the higher level of consumption of knowledge there is only aggregation of knowledge up to the level of **indices**, like stock exchange index or the like, for the use of ordinary citizen.

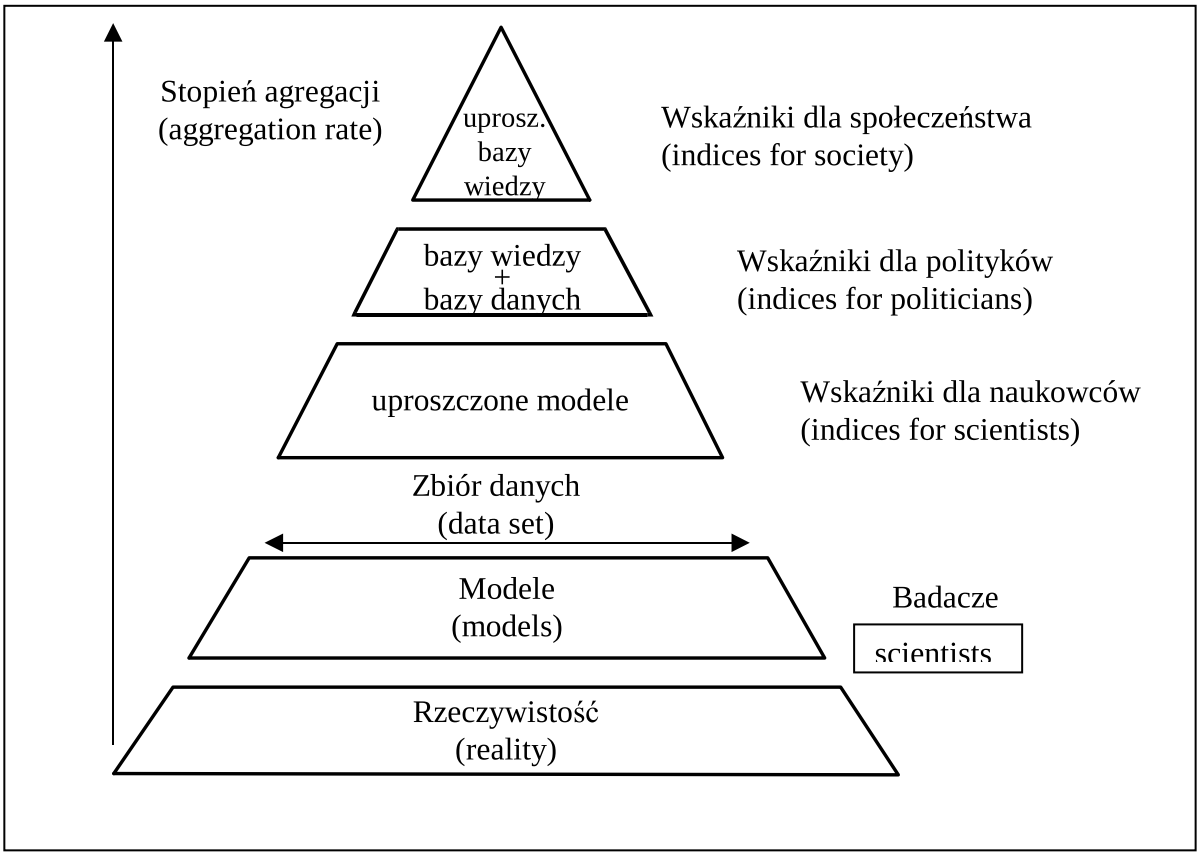


Fig.6.4 Social creation and consumption of knowledge with different level of transformation, [Natke 00,ch.13].

In dependence on evolution of social level of given population (*nation, part of it*), there is different need for knowledge consumption and use. Also, what is much important, the consumed or internalized knowledge transforms reflexively the society itself. How much it is justified and how much it interfere with the society development one take a look into the rules of knowledge ecology of Wojciechowski [Wojciechowski 86], as below.

1. Thinking process generate changes in human and the society
2. Ability to change self and the environment is proportional to the level of knowledge development.
3. Knowledge creates the need of self development that means the need for a new knowledge.
4. Thinking intellectualizes a man.
5. To be a human means to direct himself into the higher level of human hood.
6. The complexity of psychological problems is proportional to the level and complexity of life.
7. The number and complexity of problems is proportional to the level of knowledge.
8. The need for experts for solution of different problems is proportional to the level of knowledge evolution.

As some kind of summary of the above one can say;

YOU ARE, WHAT YOU KNOW,

and maybe it is good to add also;

AND WHAT YOU HAVE ACCOMPLISHED TO PUT INTO YOUR LIFE,
AND YOUR WORLD.

6.3 Summary of the chapter

We know already that organized data set creates information, while organized set of information creates knowledge, and organized knowledge disciplines creates wisdom. But set of different wisdoms does not give a truth. The created knowledge is living in a society in its cycle of knowledge consumption. Hence, quicker and broader the knowledge internalization by a society is, the quicker society changes itself. And as we know, the knowledge connected with tolerance and love creates miracles on individual scale and the social scale as well.

6.4 Some problems to think

1. *Is the knowledge a commodity or a substitute of any product or system component?*
2. *Why some people and some nation too use the knowledge differently, for the progress or for the regress and damage?*

3. *Is that possible to be comprehensive human, engineer, scientist, while putting attention only on specialization?*
4. *Why the learning of a new knowledge by humans and by its society is so slow, even nowadays? Take as an example, or starting point religions of the world.*
5. *Even there, some nations are learning very quickly (Finland[22]) and some are retarded on the way of evolution like Poland[23]. What is the reason for this difference in societal learning.*

[22] 200 years ago no one has heard on Finish nation.
[23] We are proud of thousand year history.

5A. Models of systems and their behavior

Our thinking is a processing of models - the maps of reality,
but we hardly remember that a ***map is not the reality !***
NN

5.1 Introduction

As we already know the systemic approach to the creation of new systems is characterized by an intensive use of simulation to foresee the future behavior of systems, and to predict in advance their possible scope of a lack of system control (***functional risk***), far-reaching side-effects of system use (***environmental risks***), and the gradual loss of efficiency of the system as a result of system wear (***risk of failure***). Therefore, before moving to a stage of system conceptual design, it is worthwhile to study by simulation of a system's behavior during all phases of its life, especially of its operation. Because as repeatedly stated previously, an optimal system must retain its **optimality** during the entire life cycle, from conception through physical implementation, until its final cassation and recycling at the end of life. So, the system behavior should be quantitatively and qualitatively examined throughout its life cycle as much as possible. This requires the possession of **reliable** validated models of systems evolution, and the quantitative models are best. But if it is impossible to have them, there is still always the possibility of forecasting the system behavior with the method of experts querying (*Delphi)*, or the method of *scenarios*.

Let us suppose here, however, we have the quantitative models that can predict the behavior of the system, which is possible for a relatively simple system, and this will give us some opportunities to infer by analogy. We will therefore examine the simple systems behavior by observing them through the prism of controlling values, or by observing only their **input – output** values, or other values proportional to them, the so-called **symptoms** - if our system is not directly **observable**[24]. Sometimes, however, as we may see below, the knowledge of the structure of a system allows deducing its behavior by analogy.

5.2 Models, modeling, simulation

To show the essence of the problem, let us simplify the issue somewhat, you can say that we live in a world of models often not knowing about it. Whenever we think, speak, we always have in mind **our perception** of physical reality and / or symbolic one that is its **model**. It is worthwhile to stress at the beginning, that the model of a real system is like a map of the terrain and, in our mind there are only **'maps (*models*)**' of world in which we live, instead of the actual ' land '.

What, therefore, is a **model** of the system? At first, let us recall the best definition of a system,

system is the entity expressing its existence by synergistic interplay of its elements, and it exists (**acts*****) in the space-time domain***.

Therefore one can say,

model is a simplified representation of the system in time and space, designed with the intent to understand the behavior of an actual system, [Principia].

Models with which we are dealing in life and work may be; real - **physical**, such as in the scale of 1: 10, and the **abstract** models. The latter might be again divided into two classes: qualitative (*descriptive and explanatory only*) and quantitative - enabling forecasts.

In qualitative models we can only say initially **what is what** (*descriptive model*), or better **what depends on what** (*clarifying model*). Quantitative models are the dream of every system researcher and can be roughly divided into deterministic, fuzzy and probabilistic ones, depending on the certainty of knowledge we have about them. In the previous half of the century, analog models played a large role which based on similarity of mathematical description of various phenomena, such as lines of electric and magnetic field forces, and currents of liquids flow, etc. So, **analog** models of processes and phenomena were often applied and studied.

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[24] **Observability** of system means to have control over system inputs and outputs, but please consult the exact definition at Wikipedia, for example.

And what is **modeling**? It always involves a specific goal of doing it; this is because any system may be represented by many models. In a brief manner:

modeling is the search in the system for features and their connections relevant to our goal.

This is not an easy task and often it is called the **art of modeling**, like the title of the book of F Morrison, 'The Art of Dynamic Systems Modeling', [Morrison 96].

Yet one more distinction of other ways of modeling would be appropriate at this stage. This is related to the nature of the approach to the problem, from top to bottom (***top down***) or from bottom to top (***bottom up***). In the terminology of the latest American system analysis it is called accordingly: **Macro to micro** approach (*Mtm*), and **micro to macro** approach (*mtM*) as defined by Boyd [Boyd 01]. In the way from top to bottom approach (*mtM*), first we are considering the action of micro-modules by using differential or difference equation in general and integrating correspondingly when it comes to an overview of greater area, or the entire system. In the from top to bottom approach we are considering the whole system, setting the conditions for equilibrium, movement, flow, etc. And when it comes to subsystems and modules we separate them when necessary and use the same methods of calculating the equilibrium, movements, flows, control interactions.

By giving the simplest example possible, let us take the kinematics of uniform point motion. In primary school we were taught that, the displacement of a body at a constant speed is proportional to the velocity of movement multiplied by time, namely **s = v*t**, which is macro approach. By contrast, at the university we were taught to calculate the elementary increase of displacement in the elementary increase of time: **ds= v* dt**, this is a micro approach. Today we know that for the first case the initial relationship must be differentiated and we will get it on the micro level. In the second case, however, one must integrate (*taking zero initial conditions*) and we will be at the macro level. Another example of the micro approach may be the finite element method (**FEM**), of the macro approach: the Boundary Elements Method (**BEM**), or the modal analysis. In many cases, the choice of the starting level is a matter of preferences, but in some cases, there is no such choice because of the methodological shortcomings and / or deficiencies of relevant data.

Turning back to the mainstream topic of modeling and simulation, let's take a look at Figure 3.3 presenting in a simple way how to acquire knowledge about the world, one can see the interactive dyadic spiral **'experiment - theory** (*model*). This was until the 70 -ties, and since then the so called cognitive triad **'experiment - theory (model) - simulation' slowly**

has taken over the role, the simulation with the use of quantitative, predictive models, as in Figure 5.1. But again, here comes a barrier of our ignorance of what exactly simulation is, is it something anyone heard in childhood, when parents suspected we were simulating (*pretending*) the disease in order not to go to school, or church? Something in that sense too, it is pretending that when examining a model we are studying the real world. Thus:

Simulation is manipulating a model in such a way that it operates in a changed scale in time and/or space-time (*expansion/contraction****), enabling us to grasp the system behavior and interactions which would otherwise be non-observable, for example due to space-time remoteness.***

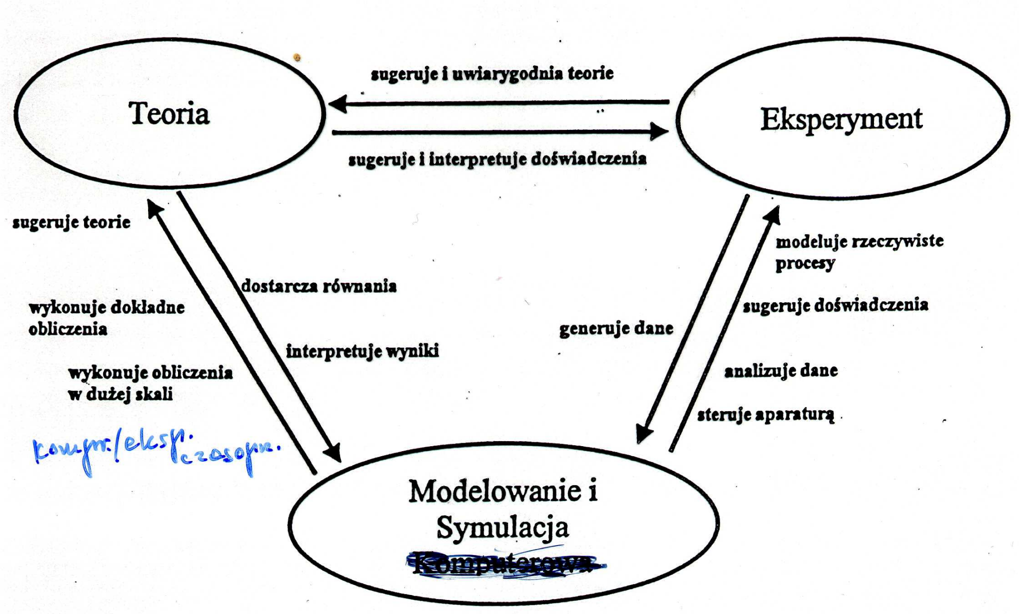

Fig. 5.1The cognitive triangle: 'experiment – theory – simulation', enabling the cognition of real world and speeding up the design of complex systems, [Kleiber 99].

This **compression** (*or expansion*) of the space-time scale gives us the appropriate perspective to grasp what happens in the system, and what due to its complexity would be impossible to observe otherwise[Bellinger 02]. This is a rather lengthy definition, but one of the best presenting the essence of simulation, similarly to the definition of a model and system. In respect with this it is worthwhile to mention that it comes from an internet source [Bellinger 02], similarly good as for finding the issues of systems theory and cybernetics at the Internet address [Principia].

We know now what a tool a good model can be, especially associated with the simulation capability. How far it is right one can get convinced by the new broader name of simulation, the **virtual engineering**, used especially in reference to the applied research and

design of everything 'what should work', in the whole cycle of life from conception to reutilization. There is already IT software optimizing the demolition and reutilization process of old cars, both in terms of time and energy needed for demolition.
Knowing enough about the simulation - a possible good tool if you have a good proven model, let's therefore take some acquaintance with some types of models, and then with cross-sections of complex systems models.

5.3 Types of models of objects, and processes

Our overall definition of system takes into account the whole spectrum of possible systems, from material through symbolic systems to conceptual systems, which consist of concepts and ideas. So how to speak and how to create models of such systems? First let's lay this fuzzy classification well in our heads with the help of the graph below as in Fig.5.2.

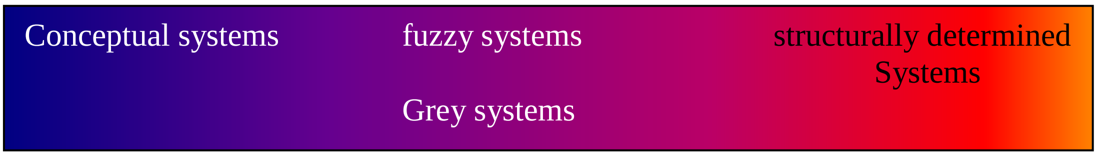

Fig.5.2. The illustration of the whole spectrum of different types of systems encountered in systems engineering, as the introduction to their modeling

On the right hand, we have fully identified systems, in terms of their structures and functions they carry. Therefore, their input/output vectors or interfaces are fully defined and measurable. Going further to the left side we are facing systems with the defined attributes (*characteristic values describing the system*), but not always measurable (*such as bioenergy*). Finally, on the left side of the spectrum, we have systems which are not fully defined objectively, their definitions of subsystems and attributes are still in the head of a designer or a leader, and they often are not even fully articulated purposely. The so called **mental models** also belong to that group; they often are the metaphors helping in individual, collective thinking, as well as they are the representation of information and knowledge.

Turning to examples it can be concluded that the majority of engineering systems, software or hardware ones, are located on the right side, in the middle we have antropotechnical systems, for example man - machine, or even socio-technical systems, companies and economy where not everything is defined and measurable. On the left hand side we will have beliefs, ideas and values of the participants of socio-technical system, for example in a company and / or in economy.

Under the concept of a model different processes and beings are understood by many authors, such as operation networks, graphs and / or activity diagrams, **PERT** (*Program Evaluation and Review Technique*), **CPM** (*Critical Path Method*) and other, aiming to improve the management of operations, projects, or production and manufacturing (*see, for example*, [Mingus 02], [Caposi 01]). We will, however, narrow the concept of a model to systems and processes in which the observable values can be distinguished, being the subject of evolution (*continuous in general*), what in a process of further analysis may be subjected to **discretization**[25].

In analytical and mathematical sense, the models in the left-hand side (Figure 5.2) have been difficult to imagine so far, although I have already seen studies modeling the system of beliefs mathematically, for example of humans, autonomous robot, android, etc. Therefore, let us look at the systems models from the middle and right side of Figure 6.2, which we will increasingly need and use in systems engineering. A pair of such models from this range is outlined in the next Figure 5.3.

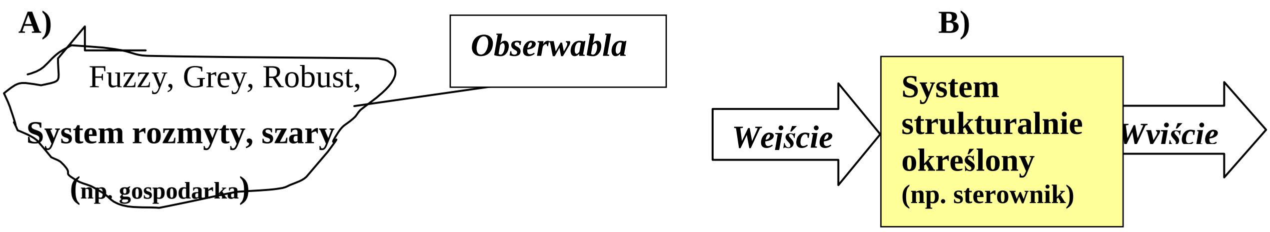

Fig.5.3. The model of a fuzzy system (left) and with fully described structure (right).

The model of system **A** at the left hand side is not fully defined; its boundaries and structure are fuzzy like in economy, where some actors declare paying taxes on "*Caiman Islands*." In such great systems, we often have the opportunity to observe some processes, such as the flow of goods, money supply, stock market indices in economics, or as indicators and indexes used in psychology and marketing. Then we are never sure whether what we're seeing is the **system variable,** whether it is the input or output value, and whether it gives the possibility to control the system. Hence, the values observed in such systems, are better called

[25]**Discretization** = transformation of continuous quantity into the series of numbers, very convenient for successive calculation.

the **observable** instead of using the concept of independent, dependent variable, or the **state variable**[26], what in mathematics and engineering sciences has a clearly defined meaning.
In contrast, the model of system **B** on the right has a fully defined function and structure, or at least a well defined **transfer function**[27] and its inputs and outputs vectors are defined and measurable. These are for example hardware parts of machinery and equipment, or their sensomotoric subsystems including software, where the condition of **reliable**[28] operation enforce the full observability and complete control of the system.

The way to obtain the system transfer function, and hence a system model, is the so-called **identification**. You can also say that for certain systems it is possible to obtain transfer function by the use of modeling procedures or better the identification experiment. The experiment itself may be **active, passive**, or **semi passive**. An active experiment is possible if we can force the system and examine its response, passive one when we can not force a response but can only watch it. In contrast, semi passive experiment will be in the case when the observation of the system starts with the known initial condition, for example, after repairs of machinery, [Cempel 89,s127].

Modeling and simulation play an important role in many fields of engineering, whether in design of entire new systems, or in improving existing ones, as shown in Figure 5.3 c, [Arczewski 08, r1.8].

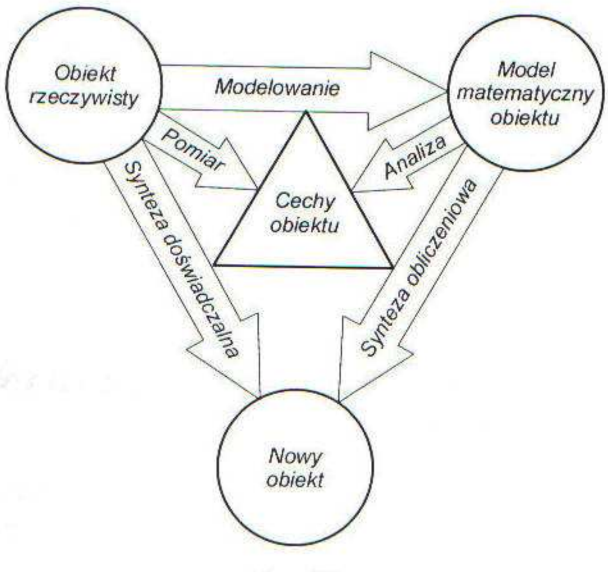

Fig. 5.3c Identification and modeling in mechanical engineering [Arczewski 08, r1.8]

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26 State variables, a set of independent quantities describing fully the state of the system..
27 Transfer function, functional or operational relation between the output and system input.
28 Reliability, a probability of assumed functioning over the prescribed time and the given conditions.

Regarding the models of structurally defined systems, it is necessary to provide a few comments about their internal structure. Firstly, if our knowledge of the interior system ends on its transfer function, we can speak of the **black-box**-type of system model, if we know certain parts of the structure and transfer function, we can talk about the **gray box** model, but if we know the whole structure of the interior, then we can find the resulting transfer functions, and the type of model is called a **white box**.

Having outlined every type of model already, let's now take an analytical look at the spectrum of possible models of systems and their behavior, from the simplest type of model like account balance, to the most complex ones like ecosystem or world civilization

5.4 The systems growth models

In many cases of system research, we have one system located in its environment, and the only observable (*the observation value*) is the state of this variable in successive moments of time. Then, on this basis, we build forecasting models of future behavior (*if it is output*) of the system for the time: $t = k + 1$ on the basis of data set of previous observations $t = 1, 2, \ldots k$. This leads to some interesting models as shown below.

5.4.1 The geometric growth of a system

Let's suppose that the value describing the output of the system **x** (*account balance, amount of the population, etc*.) is read in discrete moments of time $t = 1, 2, \ldots, k, \ldots$ for example every hour, every month, year, but $t = 1$ does not necessarily mean the beginning of system life, but just the beginning of our observation. Let the values read in order differ from the previous value of the constant 'a' so that;

$$x(t+1) = a\, x(t), \qquad a > 0. \tag{5.1}$$

It is easy to note from the above that if a = 1 then we do not observe any changes and we can say, that the observed system is static. If $a < 1$ then there is a gradual reduction of the observed value, and the most interesting case is the growth of the system output when $a > 1$. Such a model may reflect the behavior of various systems, such as the growth of a population of humans, animals, plants, and the increase in publications in some fields of knowledge, of materials consumption, an increase of debts or of funds on a bank account. In the latter case, for example, the future value of the account F compared with the present P with an annual interest rate of **100 i %** will be;

$$F = (1 + i)\, P,$$

what in terms of initial value P_o will give after n steps

$$F_n = (1 + i)^n P_o .$$

This type of growth, i.e. the increase by a constant coefficient is called the geometric growth. As one can see, this model can be very useful if the increase of an independent variable (e.g. time) is discrete, what in the age of **digitization** of calculations the case is often.

5.4.2 Herd or flock model - demography

Taking into account the number of elements in a system, for example, the number of animals or people in the area, according to model (5.1) is often too inaccurate or averaged, or in other words rough. Sometimes, therefore, it is convenient to assume that such an increase for various **age groups** of flock is different, due to their varied features such as fertility and mortality. Please note, that by using such an assumption about the structure of the model, it is becoming a grey box instead of a black box, as in (5.1). For the simplicity let's assume further that the distribution of males and females in every age group $0, 1, 2, ..., m$, (*for example, a group of up to one year, to 5 years, etc.*), is the same. This allows us to consider only females, and it will be representative for the entire herd. Let us assess the mortality of each group when transiting from i to $i+1$ group. Such a reduction of population is legitimate for every age group k, with its transition to the next group the number of individuals, reduces by the amount of the survival coefficient β_k , hence we have

$$x_{i+1}(k + 1) = \beta_i \, x_i(k), \qquad i = 0,1,2,...n-1, \tag{5.2}$$

where $\beta_i < 1$ can be estimated from surveys, or taken from the relevant demographic tables. The only age group with which the survival factor does not interfere is the youngest age group (*initial*) in each stage, i.e. $x_o\ (k +1)$. For this age group every other group adds its growth by the reproduction coefficient α_i. Thus, the state of this group can be described by the equation

$$x_o(k + 1) = \alpha_o \, x_o(k) + \alpha_1 \, x_1(k) + ... + \alpha_n \, x_n(k). \tag{5.3}$$

Having given the reproduction coefficient α_i, with the mortality coefficient β_i one can calculate the status of each age group of the herd (5.2), and then of the newly born group $x_o\ (k +1)$ and, finally, the entire herd will be represented by the multi-layered formula:

$$x = \sum_{i=0}^{n} x_i(k+1). \qquad (5.4)$$

It may be instructive if one could simulate the population of the entire herd '***x***' at different mortality β_i and reproduction α_i coefficients. This will certainly be a better assessment than the actual averaged increase by a geometric or exponential model.

5.4.3 Differential models of economy

There are many simple models of the dynamics of economic growth (*such as* [Findeisen 85], [Rappaport 86]), here we will consider a discrete model, such as quarterly or yearly model. For this purpose, we need to define four variables that describe a system of economy as shown below:

Y (k) - national or corporation income,

C (k) - consumption during the given period,

I (k) - investments in the given period,

G (k) - country (*corporations*) expenditures in the considered period.

The balance equation of such costs during time ***k*** is

$$Y(k) = C(k) + I(k) + G(k) . \qquad (5.5)$$

This means that the total revenue must be divided into consumption - ***C***, investment-***I*** and government expenditure-***G***. It is clear that the consumption must be limited and be part of the revenue

$$C(k) = m\,Y(k), \quad 1 > m > 0 \qquad (5.6)$$

Moreover, as we know we invest to increase the national income, if you mark the income growth coefficient by ***R> 0*** we can write;

$Y(k+1) - Y(k) = R\,I(k)$, ; $R > 0$ - in discrete variables
$\Delta Y(k) = R\,I(k)\,\Delta k$, - in increments
$\Delta Y(t) = R\,I(t)\,\Delta t$ - for the continuous system life time (5.7)

From the above two static balance equations we can find,

$$Y(k) = C(k) + I(k) + G(k),$$

or in another way

$$Y(k) = m\,Y(k) + I(k) + G(k). \tag{5.8}$$

Let's assume further that the state (*country*) expenditures are limited and of course proportional to the income coefficient, for example as below

$$G(k) = b\,Y(k),\ 0 \le b < 1.$$

Hence, after some transformation one can finally obtain

$$Y(k+1) = [\,1 + R(1 - m - b)]\,Y(k). \tag{5.9}$$

By comparing these with the relationship (5.1) it can be noted that the coefficient of geometric growth here is: $a = 1 + R\,(1-m-b) <> 0$. With large government expenditure, this increase may even be very small if the $G(k)$ moves closer to $Y(k)$. As a result, it would be worthwhile to simulate how the coefficients of growth 'R' and consumption 'm' change the economic situation of countries or corporations.

.

5.4.4 Exponential growth of systems

Let us manipulate a little with the growth equation (5.1) adding and subtracting the value of the observable $x(k)$ on both sides, we will have

$$x(k+1) = \quad a\,x(k) + x(k) - x(k),$$

And from this

$$\mathbf{x(k+1) - x(k) = \quad (a-1)\,x(k),}$$

in another way

$$\Delta x(k) = R\,x(k)\,, \qquad R = a-1.$$

similarly as in the model of national economy.

The time increments are unitary in our case ($\Delta t = 1$), but if they are infinitesimal $\Delta t \to 0$, we can substitute the differential equation for the difference equation as below

$$\frac{dx}{dt} = Rx(t)\,. \tag{5.10}$$

This means that changes in our dynamical system output (*product, the number of individuals, income*) occur so often that we can use the limit transfer $\Delta t \to 0$. The solution of this simple differential equation is almost immediate, since;

$$\frac{dx}{dt} = R\,dt, \quad \Rightarrow \quad x(t) = x(0)\,e^{Rt}, \tag{5.11}$$

where **x*(0)*** is the initial value of system output.

You can see from the above that the behavior of the system critically depends on the growth coefficient ***R,*** as follows:

R = 0, if we have a slump in economy (*in herd population, etc.*)

if R <0, a decrease in income *(population*)

and if R> 0, an exponential increase to infinity, as shown in Figure 5.4.

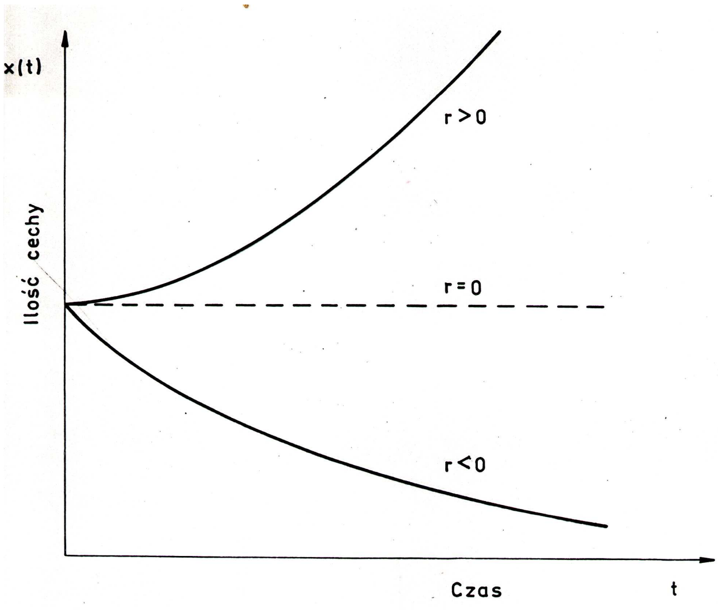


Fig. 5.4 The behavior of a dynamical system with the different exponent of growth

Analyzing the obtained result (5.11) for the discrete values of time t = 0, 1, 2, ..., k, again one can note that

$$x(k+1) = x(0)\,e^{R(k+1)} = [x(0)\,e^{Rk}]\,e^{R} = x(k)\,e^{R}\,.$$

This means that the geometric growth (5.1) is the discrete variant of the exponential growth, as we can approximately write; $a = e^{R} \cong 1 + R\,.$

If you apply the same transition philosophy with the finite difference to the limit and further to differential equations, then for a national economy model we will get

$$\frac{dY}{dt} = R\,(1 - m - b)\,Y\,, \quad b + m < 1,$$

So, this is a model of exponential growth in simple economy with balanced consumption and government expenditures, in a small time horizon.

5.5 Models of system behavior with some structural determinism

The models of systems working as lone in its environment considered so far did not follow from the explicitly presented model structure, and were merely the result of an assumed mathematical relationship of values observed in the system output. In general, the role of the input was not clearly articulated in the cause-effect sense. But there are systems, in which such an ordering is known, and system input/output clearly defined. The beginnings of system structure are therefore defined, i.e. some of its internal relationships and the relationship with the environment. Let us take into consideration the behavior of such simple systems.

5.5.1 Energy processors

The systems considered up to now did not have defined structural restrictions governing the dynamics of output change. Such restrictions are often conceived from deeper principles and physical, psychophysical, economic, sociological reasons, etc. We will now, therefore, take into account a system transforming any type of input **energy**[29] (*literally its flow in time, namely the power*) N_i into the energy of higher order N_u- which may be the product of the system operation [Winiwarter92], [Cempel93], or into another transformed form of energy, as in mechanical transmission, electric transformer, or thermo power plant. In such transformation there is always a dissipation (*loss*) of energy (N_d) and part of it is exported outside of the system in the form of power loss ***V*,** and the other smaller part is dissipated and accumulated internally damaging (*poisoning*) the system itself, as in Figure 5.5.

[29]This generalized **energy** may be of any type, physical, bioenergy, mental, emotional etc

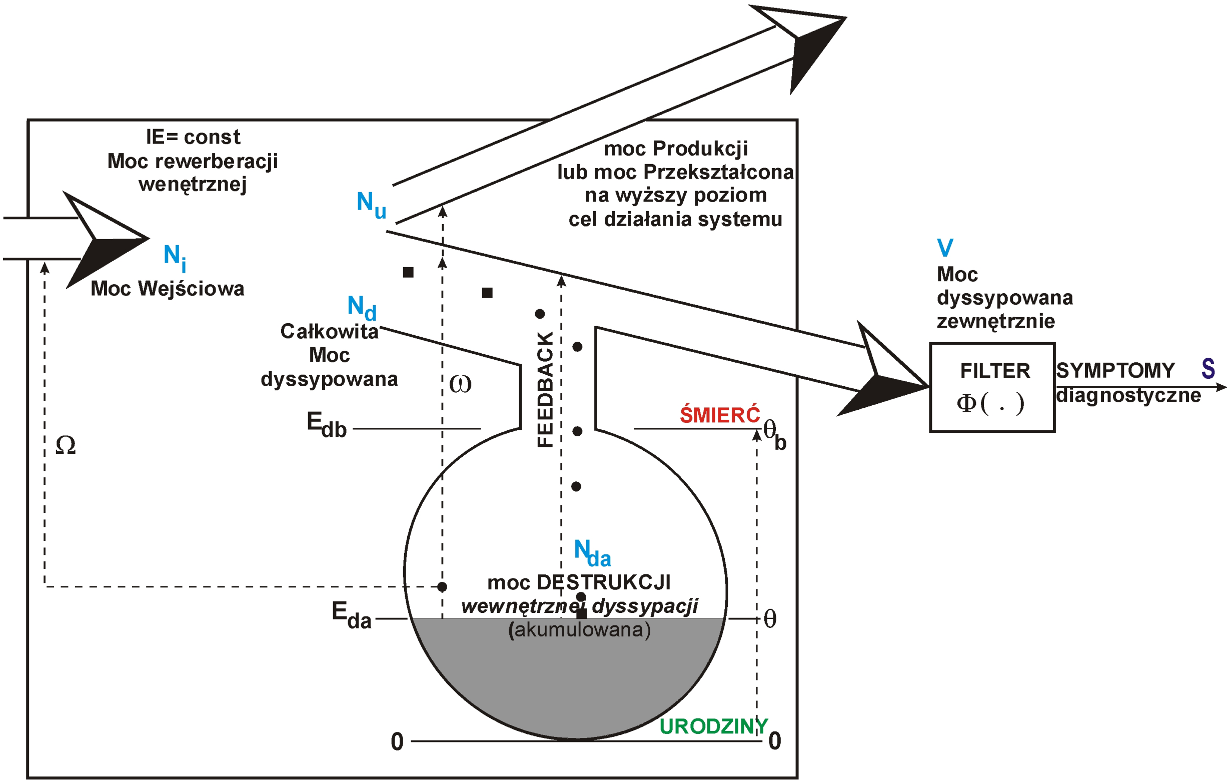


Fig. 5.5: The simplest model of energy transforming system with limited internal dissipation and some other destructive feedback shown, [Cempel 93].

Looking at the flow of power in the figure 5.3 we can write the power balance equation:

$$N_i = N_u + N_d\,, \qquad N_d = N_{da} + V\,. \tag{5.12}$$

The possibilities of internal accumulation of dissipated energy are always finite, hence it can not overpass the system dissipation capacity E_{db} (*the volume of the container in fig 5.3*), so one can write,

$$E_{da}(\Theta) = \int_0^{\Theta} N_{da}(\theta)\, d\theta = \int_0^{\Theta} [N_d(\theta) - V(\theta)]\, d\theta \le E_{db}\,. \tag{5.13}$$

here and further on the internal system life time is denoted as Θ.

In a system there is a built-in additional dissipative positive feedback, it means that the more dissipated energy is left in the system (*in container*) the greater the momentary dissipation of the system (see Figure 5.3). This can be presented as a differential relationship

$$dV(\Theta) = \beta\, dE_{da}(\Theta, V), \qquad \beta = const > 0. \tag{5.14}$$

This is a second structural relation in our system model, and the third relation will concern the relation between the total dissipated power N_d and the exported outside the system V, as below:

$$\frac{dN_d}{dV} = \alpha = const, \quad \Rightarrow \quad V = \alpha^{-1} N_d + const1, \qquad \alpha \geq 1. \qquad (5.15)$$

Calculating the increment of internally accumulated dissipated energy we will find

$$dE_{da} = \frac{\partial E_{da}}{\partial V} dV + \frac{\partial E_{da}}{d\theta} d\Theta. \qquad (5.15a)$$

and its second term can be taken from (5.13) obtaining

$$\frac{\partial E_{da}}{\partial \Theta} = N_d(\Theta) - V(\Theta),$$

and the first term will be

$$\frac{\partial E_{da}}{\partial V} = \int_0^{\Theta} \left[\frac{\partial N_d}{\partial V} - 1 \right] dV.$$

Please note that the structural relation (5.15) and (5.17) allow as to simplify the above to the form as below

$$\frac{\partial E_{da}}{\partial V} = (\alpha - 1)\, \Theta,$$

where during the integration it has been assumed; ***const1 = 0*** .

Hence, the total increment of dissipated energy (5.15a) may be written as below

$$dE_{da} = (\alpha - 1)\ \Theta\, dV + (N_d - V)\, d\Theta.$$

If we put this into the feedback relation $dV = \beta\, dE_{da}$ and using (5.17) we will finally obtain the differential equation governing the behavior of system transforming energy with internally **limited dissipation capacity**

$$\frac{dV}{V} = \frac{\beta(\alpha - 1)\, d\Theta}{1-\beta(\alpha-1)\Theta} = \frac{d\,\Theta}{1 - \Theta/\Theta_b}$$

If the denominator of the above equation tends to zero near $\theta = \Theta^d_b$ then the dissipated power V will grow to infinity. Hence, the total power delivered to system input will go to the destruction, and in effect the system will break down. Please note that we have defined a new value above, system **survival time** Θ^d_b

$$\Theta^d_b = [\beta(\alpha - 1)]^{-1}, \qquad 5.16c$$

The solution of this differential equation of energy processor life exhibits asymptotic behavior in $\theta = \Theta^d_b$

$$V(\Theta) = V_o \left(1 - \frac{\Theta}{\Theta^d_b}\right)^{-1}, \qquad (5.16)$$

and its solution, called system **life curve** is show in fig. 5.6

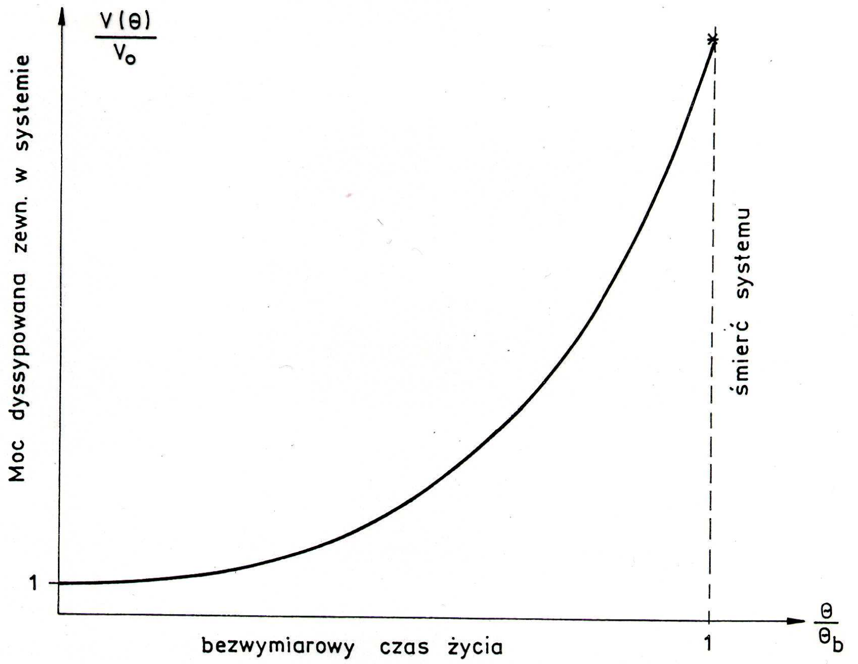


*Fig. 5.6: The life curve of energy processor with limited dissipation capacity and the system break down taking place near the asymptote $[(\Theta)/(\Theta_b)] \Rightarrow 1$.*J

As you can see from the solution (5.16) and Figure 5.6, for the system breakdown time $\boldsymbol{\theta} = \boldsymbol{\Theta^d_b}$, all its supplied power is dissipated internally (*destruction*) and externally, , because if $\boldsymbol{V \rightarrow \infty}$ then according to (5.12) the power streams Nd and $\boldsymbol{N_{da}}$ behave similarly. It is a frequently observed phenomenon in the natural and artificial (*man made*) world, and it was first time introduced for the case of wear of rotating machines (*such as turbines*) monitored diagnostically since long ago [Cempel89], [Cempel93].

This line of reasoning here, namely the introduction of structural limitations of dissipation to the model is so fruitful; that we may introduce similar restrictions (*container for example*) to the stream of energy processed $\boldsymbol{N_u}$, and others. Thanks to this, we will get not only an additional effect of system natural death as previously, but also the additional gradual reduction of the efficiency of system operation. The mechanism of this effectiveness reduction depends on the amount of dissipated energy, and the amount of energy processed, as it happens in the energy recycling systems.

Positive feedback can be also introduced into the transformed energy of higher order $\boldsymbol{N_u}$. This way one can model the mechanism of overproduction in the machinery industry, the work of a **IT** network with finite system memory, etc., obtaining a further **equivalent models** of energy processing systems. Similarly, by introducing positive feedback to the input stream of energy, systems with limited economic growth can be modeled, such as the model of economy with **VAT**. More on this topic can be found at the International Symposium Systems on Engineering materials [Natke,Cempel 95], and the author's latest work on application of **energy processor** models.

As an extension of considerations of different energy processors, let's assume that our definition of energy goes far beyond physics and is valid in all areas of existence and activity in the universe. Suppose, therefore, that energy is an potency to make the ordered activity [Winiwarter92], [Cempel98], and thus for a moving stone its mass and velocity are equivalent to energy, just like the work of man, his thoughts, the work of group of people, money, etc., all these are **equivalent forms of energy**. With such a broad definition of energy the previously considered economy is also an energy processor (**EP**), but our model was inadequate to reality because in our previous model we got an unlimited exponential growth. If we re-consider the dynamics and evolution of small production unit, for example such as farm, a workshop, where the input energy stream Y will be divided as follows (*see Figure 5*.5)).

G(Θ) - the needs of an energy processor of higher order , money / energy ΘG spent on, for example, cultural, educational, recreational, needs etc.

C(Θ) - the energy processor consumption, food, clothing, machinery maintenance, etc.

I(Θ)- - Investment in the productive capacity of energy processor *(processing*), such as additional machinery, etc.

Let us now introduce an additional tax to the consumption ***C(Θ)*** (*for example VAT*), this we will get the opportunity to accelerate the economic growth, unfortunately with the simultaneous transition of model to the finished survival systems; $\Theta < \infty$**.** As we remember from the former model, without the VAT the increase (*exponential growth)* of market economy system lasted indefinitely. So, beware of **VAT**, it accelerates the development of the system, but improperly selected it leads to the accelerated death of the system.

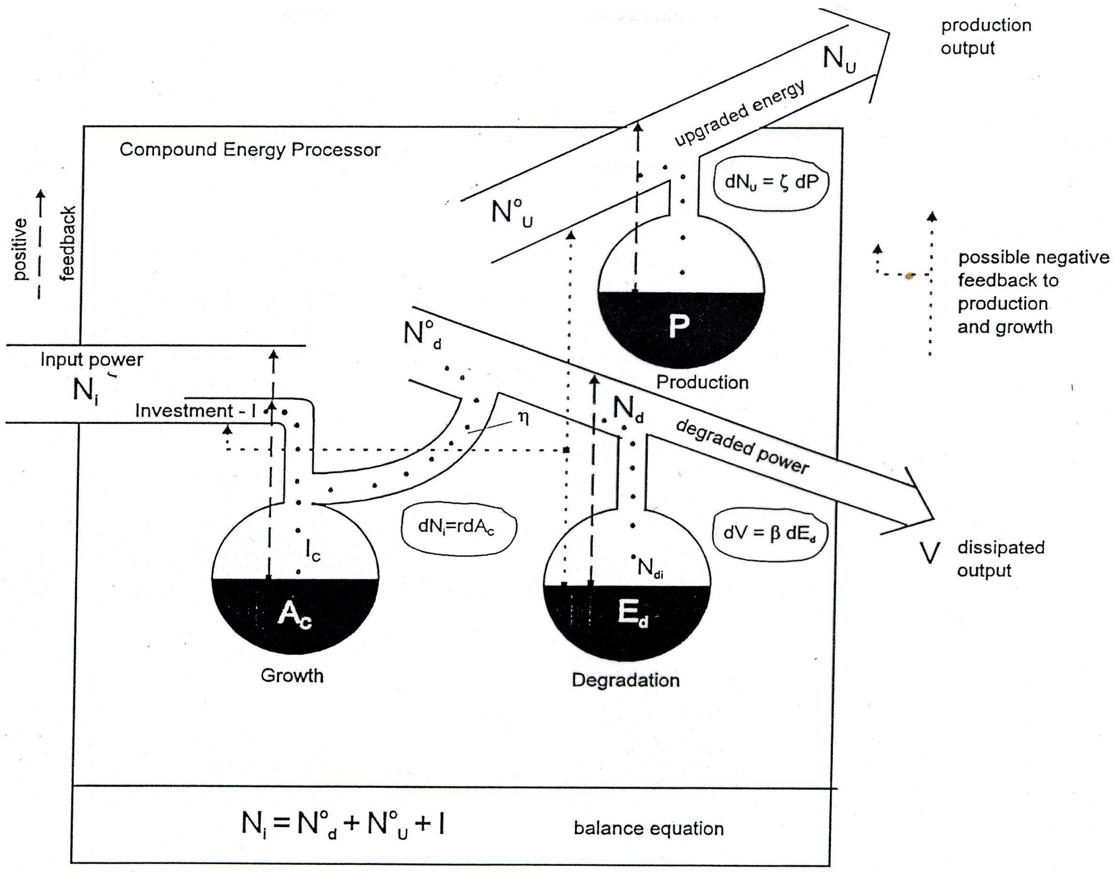


Fig. 5.7. The model of equivalent energy processor with the breakdown, and investment capability.

As stated in the introduction, around us you can find living (*working*) natural and artificial systems, that is, in the new terminology, the energy processors - the **EP**. Therefore observing some symptoms of their lives in the population of the same systems, for example, the amplitude of vibration, and / or temperature of machinery bearings, we can create different types of statistics, such as histograms of such symptoms and estimations of the probability parameters which they are subjected to. You can also theoretically show that the observed symptoms of energy processors with limited potential of dissipation, limited potential of production and growth, are characterized by the **Weibull and Pareto – Frechet** distributions [Cempel 97]. Thus, the reverse inference is also possible. If in a population we find these type of distributions of symptoms, according to Weibull or Pareto it can be concluded that in these observed systems some type of energy processor is implemented; either with limited potential of dissipation, production, or growth), or all together. If we look in this way at the statistical description of life symptoms in the surrounding reality, the artificial and natural one, we will find much in common and in most cases we can say that their life is based on the processing of certain equivalent energy. This type of conclusion is behind the table exposed below, in accordance with [Winiwarter 92]. And for the, created on this basis, model of life an evolution, many cosmological, psycho and sociotechnical interpretations can be found , as is clear from Figure 5.8. Energy processors belong to a wide class of evolutionary systems, you can find more on this subject looking to Winiwarter and his home page, [Bordalier 08].

4. Generalized Life Symptoms of energy processing systems

crossref. to levels of tab 7.	operating System	Birth&Death Processors	observed symptoms of energy transformation
14	computer system	micro-processors	produced files
14	technical production system	machines of the same type	produced dissipation energy
13	economic system / country	business firms	produced output/profit
13	socio-economic system	human individuals	produced income
12	socio-economic system	cities	produced populations
12	cultural system / language	human brains	produced words
11	bio-social system / colony	animals of same species	produced populations
10	ecosystem	biological species	produced populations
9	biotope	biological genera	produced species
8	biosphere	biological families	produced genera
7	ocean	micro-particles	produced particles
6	earth	tectonic plates	produced earthquakes
5	solar system, planets	chemical compounds	produced compounds
4	galaxy / universe	stars	produced nuclei / chem. elements

Fig. 5.8 Cosmo and sociotechnical systems with similar input/output behavior, like energy processor with limited dissipation capacity,[Winiwarter 92].

For the one type machines in different stages of *energy processor* life, we can provide additional consideration transforming distributions of observed symptom, such as vibration, into the symptom reliability ***R (S),*** and the resulting residual lifetime $\Delta\theta_r$ of a single object, on which some values of symptom ***S*** were observed. These are, however, specific diagnostic issues into which we will not move deeper (*see, for example, [Natke 97,r2.3], [Cempel 85]*).

5.4.2 Systems with saturation of characteristics

The evolution of systems happens sometimes in such way that after the initial period of growth of observables (*symptoms*), many systems features fall in a period of gradual saturation, having an asymptote on the axis parallel to the axis of time, contrary to the energy-processing systems. This happens for example, with the **demand** for most goods and services, as well as with the number of population of the given species in the face of **finite resources** (like *on the island*). It is therefore appropriate to examine the issue a little deeper and draw forecasting conclusions from it . The differential equation that can describe this self inhibited demand q, in terms of time and speed of its growth is in the form of

$$\frac{dq}{d\Theta} = g \frac{q}{L} \left(1 - \frac{q}{L}\right), \quad q > 0. \tag{5.17}$$

You can see here that the demand is proportional to the initial one 'q / L' but at the same time to the other (*residual*) demand '$(1-q) / L$'. Its solution possible to obtain by the separation of variables, is in the form of a **logistic curve**

$$q(\Theta) = L \left[1 + \left(\frac{L}{q_o} - 1\right) \exp(-g\Theta) \right]^{-1}, \tag{5.18}$$

where; $q_o = q(0)$, a $L = q_{max}$.

The logistic curve can be transformed into a straight line by the appropriate logarithmic operation, as below

$$\ln \frac{q(\Theta)}{L - q(\Theta)} = \ln \frac{q_o}{L - q_o} + g\,\Theta, \quad \text{or in general:} \quad X = A + g\,\Theta,$$

or into linear regression, what may be convenient in the system life forecast.

Graphic illustration of the logistical curve is presented in Figure 5.9, where its characteristic values are also noted; the amplitude saturation and the temporary slowdown of demand t_{kr}. As you can see from the drawing the maximal level of product (*service*) saturation is L, and the time of demand growth breakthrough is as below

$$t_{kr} = \frac{1}{g} \ln\left(\frac{L}{q_o} - 1\right).$$

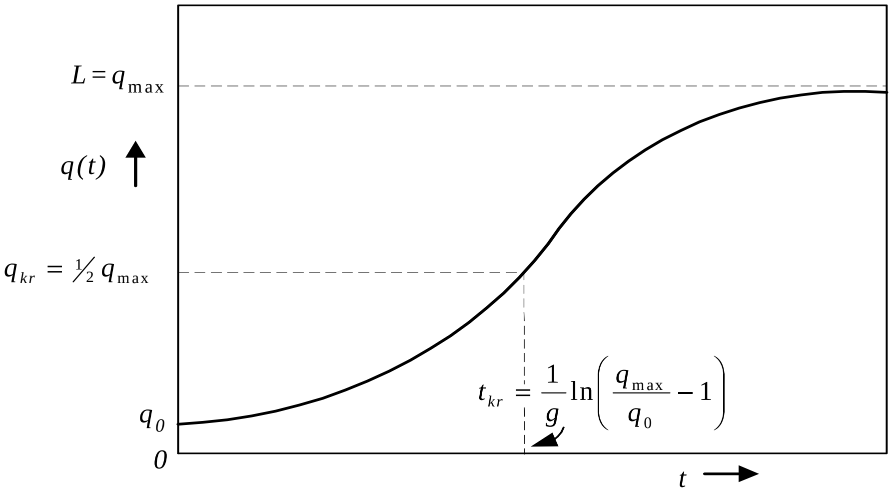


Fig. 5.9: Logistic demand curve as the solution of system model with self inhibited demand, [Hall 68].

Therefore, knowing the initial demand q_o and estimating the maximum L and the speed of growth in demand 'g', you can determine the necessary parameters to optimize the strategy of production, sales, services, as well as to maintain the viability of the species of animals or humans, where resources are limited.

5.6 Interaction models – systems in conflict

Many systems interact with the environment (*or the individuals, organizations*) being the similar or slightly larger system. Hence the two systems may be combined in a larger metasystem, in which two conflicting or cooperative systems operate in the interaction. We will investigate several such cases here.

5.5.1 Arms race

Consider two systems (*states or organizations*), ***X*** and ***Y***, whose **destructive potential** is equivalent to the armament budget and amounts ***x*** and ***y respectively***. Suppose that the speed of change in spending on armaments is adjusted as a difference between own efforts and the efforts of the opponent perceived by the intelligence, so you can write [Rappaport 86]

$$\frac{dx}{dt} = -mx + ay, \quad \frac{dy}{dt} = -ny + bx, \quad a,b,m,n > 0 \quad . \tag{5.19}$$

The basic problem here is the stability of armaments and of economic development, which means maintaining them on a stable level tolerated in the overall development of both systems. From studies of this issue [Rappaport 86], it appears that the levels of spending on armaments can be stable if

$$m\,n - a\,b > 0 \quad \Rightarrow \quad \frac{m}{a}\ \frac{n}{b} > 1\,,$$

and hence, the degree of own efforts to the other's (*n / a; n / b*) must be slightly larger than unity. This ensures that, after the bilateral reduction of the level of investment the arms race will not start a new.

The attentive reader is left to find out the other analogy to arms race problem, for example in the field of spending on research, advertising, promotion, etc.

5.6.2 The prey predator model

It is easy to imagine that in the absence of predator ***x*** (*for example, a wolf*) the population of goats on the island is expected to grow to infinity, or with finite resources (*island*) in accordance with the logistical curve (*see previous section*). Modeling this conflict issue (*also two competing companies*) let us note that any meeting of the predator and the victim (*goat*) increases the biomass of predators and reduces the **biomass** of herd of goats. The frequency of these meetings also affects the biomass of predators positively and the biomass of victims negatively. So the issue can be modeled as follows [Rappaport 86].

$$\frac{dx}{dt} = -\,c\,x + a\,x\,y, \qquad (5.20)$$

- biomass of predator decreases without a prey

$$\frac{dy}{dt} = +\,r\,y - p\,x\,y\,,$$

- biomass of a prey increases without predator .

Please note that the second equation easily changes into the logistic equation if $x \to y$, it means if we substitute the prey (*as a consumer of limited resources*) for the predator

By dividing both sides of the equation, we have

$$\frac{dy}{dx} = \frac{y\,(r - p\,x)}{x\,(a\,y - c)},$$

what leads us to the needed separation of variables,

$$(a - c / y)\, dy = (r / x - p)\, dx ,$$

and to the solution, but unfortunately not a simple one;

$$y^{c}\; x^{r}\; e^{-a y}\; e^{-p x} = const. \qquad (5.21)$$

This solution provides closed curves (*trajectory*) on the **x - y** plane (*see Figure 5.8)* around the point of equilibrium**:**

$$x_o = r/p\,,\; y_o = c/a\,,$$

if only the stability condition is fulfilled: $ap - rc > 0$.

In this case the solutions of our model oscillate (*at x y plane*) on stable trajectories around a stable point of equilibrium. For this type of t oscillatory solutions (*vibration*) in biology, you can find many analogies, also in oscillation problems in mechanics, electronics, etc.

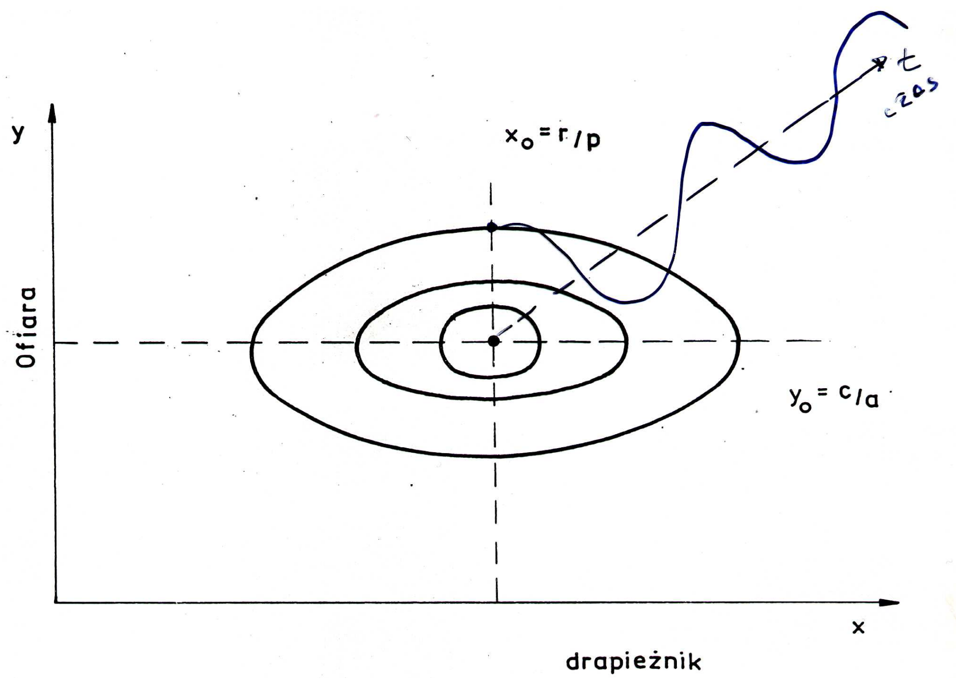


*Fig. 5.10: Stable solution of prey predator model around the equilibrium point, please note the oscillations on **t** axis.*

The question of coexistence of two **conflicting** populations can be further enriched by inhibiting the development of predator by introducing negative square component like in the logistic curve. There are also known some generalizations with ***N*** conflicting populations [Findeisen 85]. A model of symbiosis of an organism with a parasite is a little more complicated, but we will leave it here, referring to more relevant literature of mathematical biology [Lotka], [Rappaport 86].

5.6.3 Urbanization model

As the last model we will consider the model of urbanization in the country. That means two systems in an environment. Let P_r represent the population of people in rural areas, while P_u the population of people in the city. Next, let the '**r** and ***u***' mean the rate of population growth (*per capita and per unit of time, e.g. one year)* and ***'m***' the migration of people into the city. With these assumptions the following model of evolution of both populations [Rappaport 86] can be written:

$$\frac{dP_r}{dt} = (r - m)\ P_r(t)\,, \qquad \frac{dP_u}{dt} = m\ P_r(t) + u\ P_u(t)\,. \tag{5.22}$$

In general we are not interested in the detailed number of people but in their proportion, so let us introduce a new variable

$$S(t) = \frac{P_u(t)}{P_r(t)},$$

Using it in our differential equation we will get

$$\frac{dS}{dt} = (u + m - r)\ S(t) + m\,,$$

and the solution:

$$S(t) = \frac{m}{u+m-r} * \exp[(u+m-r)\,t - 1] \;. \qquad (5.23)$$

As one can see the ratio of population of both groups does not have to grow to infinity, and it can reach the stable limit as below

$$S_{lim} = \frac{M}{R - (u + m)} = const \,,$$

if only $u + m < r$, it means the rural population growth rate is greater than of the city's.

The model of urbanization could be further enriched by introducing to the second equation currently frequent returning migration from the city to the village: $- m\, P_u$, which leads to the logistic curve type population ratio [Rappaport 86], so again to the stable situation. The reader will certainly find other, better analogies to the model of urbanization, such as input output analysis in economics, etc.

This is enough of examples of typical systems in interaction, whether it is in literal biological consumption, or mutual economic competition, and other similar problems of life and coexistence. In the following we will move to more complex and non-linear systems, to great complex systems closer to life.

5.7 Models of complex systems

As already mentioned in the 70 ties - a real possibility of using computers to study the behavior of complex systems appeared. First it was possible in large research centers like at MIT in the U.S., and then also in industry. The first models of problems of the **world** appeared, as they were perceived at that time, the so-called **three bombs**; 1- demographics, 2- the supply (*consumption*) of humanity, 3-the pollution of the environment. A pioneer in these studies was Jay FORRESTER from Massachusetts Institute of Technology (MIT), the author of the famous book World Dynamics [Forrester 72], also a member of the **Club of Rome.**

Currently, these models are considerably more developed and more multilevel, what comes in a moment. But now let's take a look at the outset, however, at the model containing the main variables; the population of the world - ***x***, consumption –***z***, and pollution - ***y***.

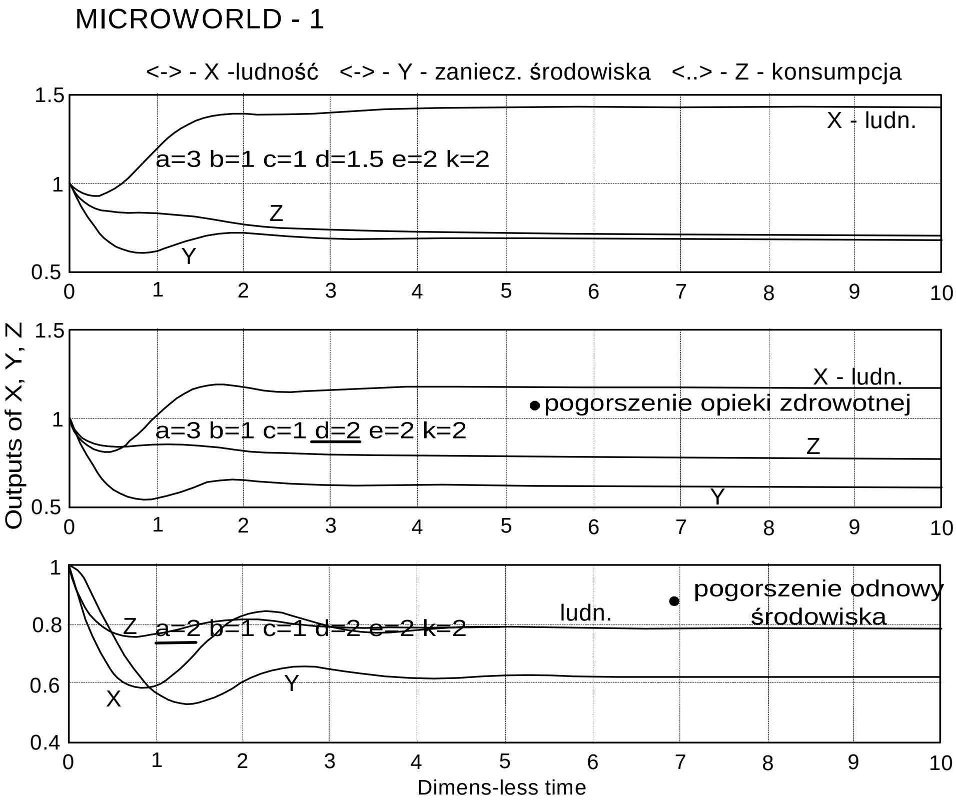
The three simple differential equations incorporating this model, on the base of the textbook [Jischa 77] are shown below:

$$\dot{x} = b\frac{xz}{y} - dxy,\quad \dot{z} = cyz(1-kyz),\quad \dot{y} = exz - a \quad , \text{ if } ; y > 1, \text{ and}$$

$$\dot{y} = exz - ay \quad ; \quad \textit{outside the specified range,} \qquad (5.24)$$

with the coefficients: ***a*** – environment renewal, ***b***- birthrate, ***c*** – consumption, ***d*** – mortality, ***e*** – environmental pollution, ***k*** – consumption limitation.

The following Figure 5.11 shows the effects of such simulations carried out by MATLAB ®, with ratios shown in the diagram. As you can see, the deterioration of health care - ***d***, gives immediately the fall in population-***x***, similarly to the deterioration of the environment - ***a.***



Współczynniki: a - odnowa środ., b - urodzenia, c - konsumpcja, d - śmiertelność, e - zaniecz. środ., k - ogranicz. konsump.

$$\dot{X} = b\frac{X \cdot Z}{Y} - dX \cdot Y \qquad \dot{Y} = e \cdot X \cdot Z - a \quad , \quad \text{jeśli } y \geq 1$$

$$\dot{Z} = c \cdot Y \cdot Z(1 - k \cdot Y \cdot Z) \qquad \dot{Y} = e \cdot X \cdot Z - a \cdot Y \quad , \quad \text{poza tym}$$

Fig. 5.11 Population, environmental pollution, consumption of the world's the effect of simulation[30] with the program **miniwelt.m.**

The popularity of personal computers and the use of them in the simulations of scientific and economic problems led to the fact, that a number of companies are offering ready-made simulation software of many complex problems of system design, operation, and finally and educational ones appeared. Just to mention some like here**: Stella, Ithink, Vensim, Microworlds** [CSM], **LogicEcoModeler, Swarm**. Mostly, it is possible to get them from Internet free of charge, at least their demo versions, which are able to teach how to solve basic problems, with the famous **'beer game'** heading. The mentioned beer game [Senge 98], is a problem of logistics in the **seller - wholesaler - a brewery system**, where it is clear that delays in the supply and the lack of information inevitably leads to significant disruptions throughout the system, regardless of the good will of the participants, the only solution is the system approach; **think globally - act locally**.

To illustrate the idea how much the modern simulation models are complicated, please examine the cross-sectional demographic model of the world, as in Figure 5.12, while bearing in mind that some branches of the model such as food, pollution, are similarly complex models themselves. I encourage you to play with these models, even for entertainment[31], and then you will see how great our personal and group (*social*) ignorance is.

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[30] Simulation effects by **miniwelt.m** program, available at the author's.

[31] Demo version of this program is in the author's possession.

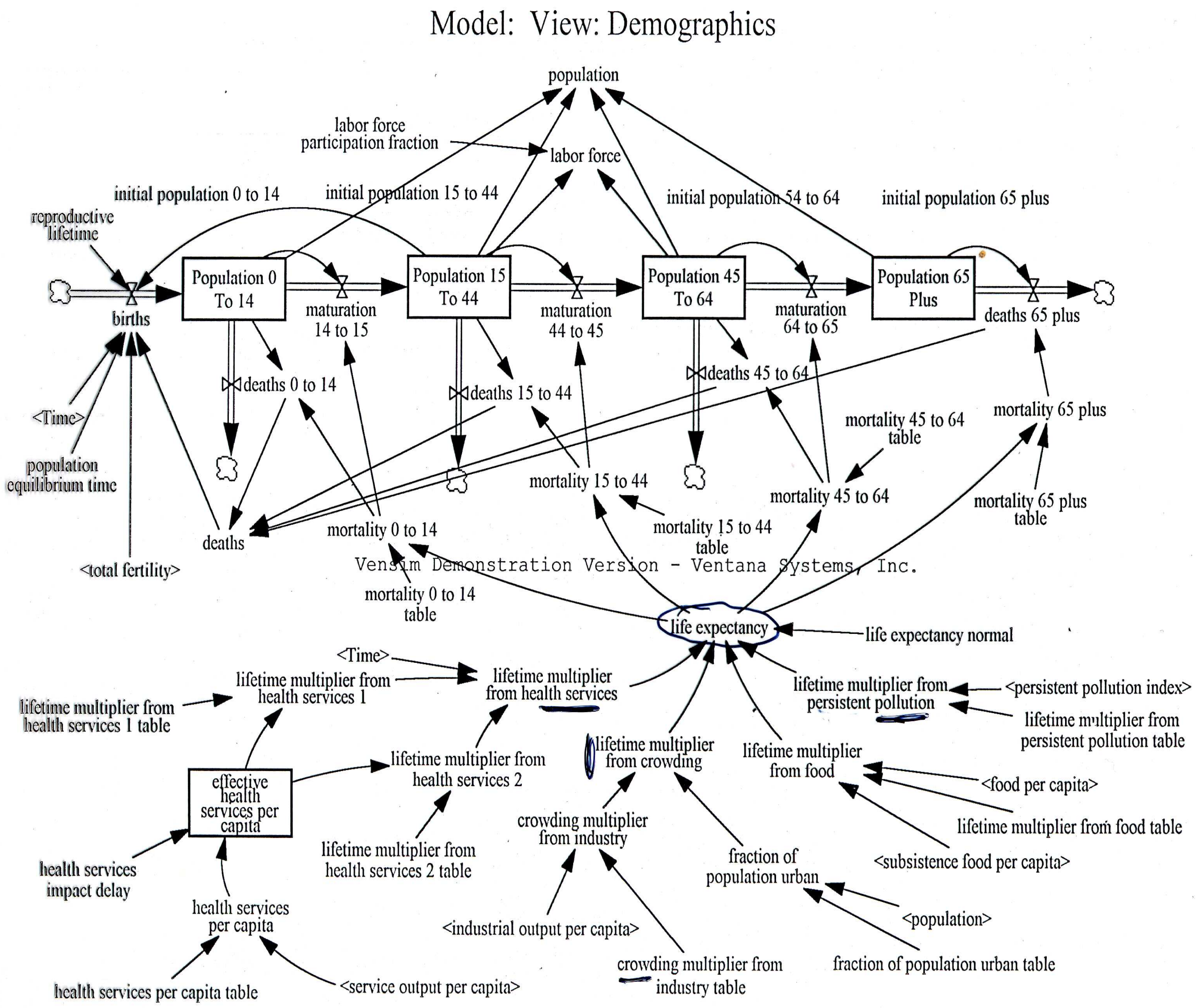


*Fig. 5.12 One of the cross sectional demographic model of the world, according to **Ventana Systems Inc**. [HPS].*

Speaking about system models we mentioned two types of qualitative models , descriptive and relational, which in the latter case show **'what depends on what'**, which is neither so simple, nor obvious in complex systems. As an example, please examine the view of the education system at the Polytechnic' Faculty (Fig. 5.13) in which we are immersed, and please say whether it is simple and complete. This figure is just one of cross sections of the education system, and the system itself and its operation will be more understandable if we

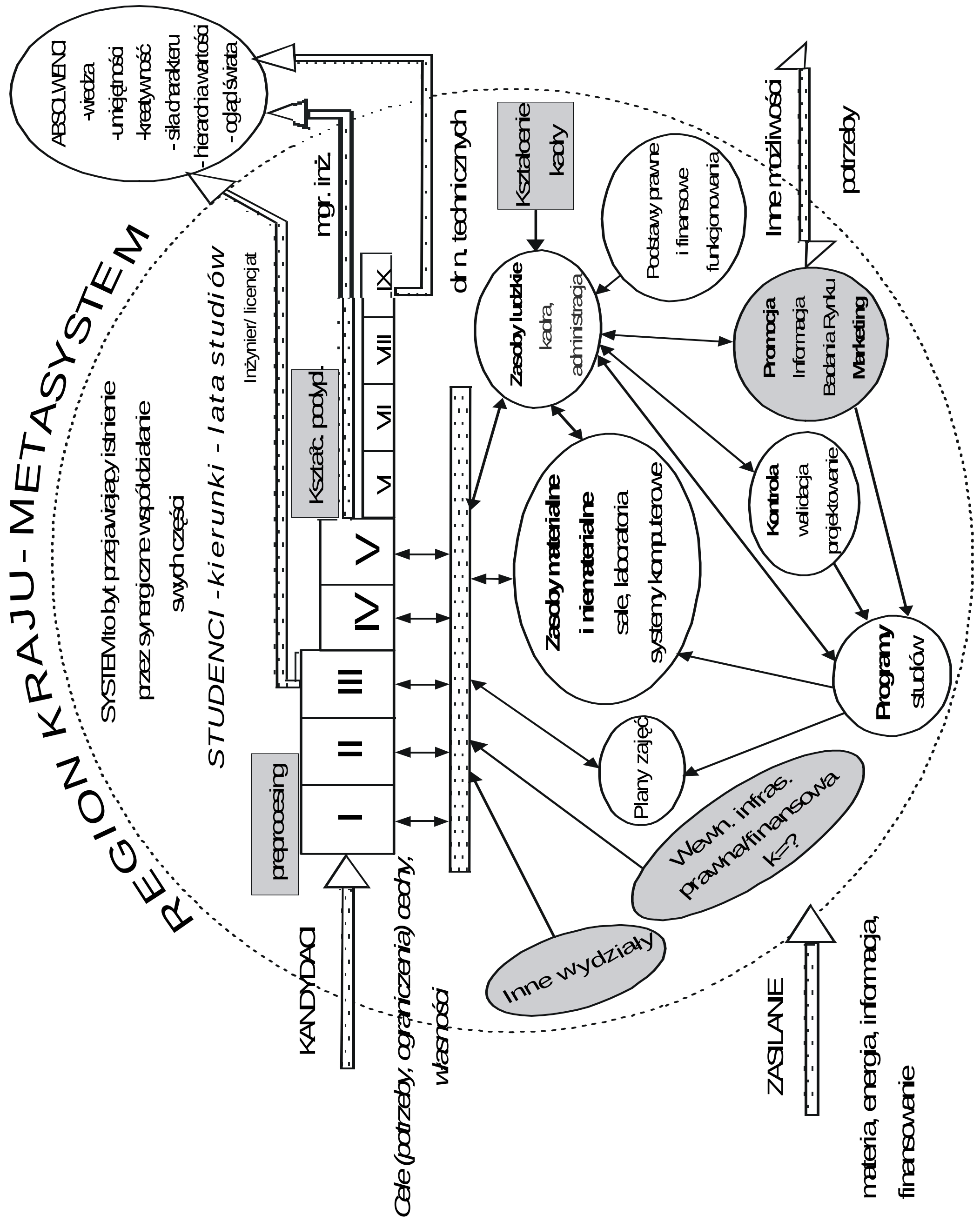


Fig. 5.13 The simplified functional model of the Faculty as a part of the University.

analyze the following (*Fig. 5.14*) representing cause and effect reasons and effects of the faculty's staff activity. From these figures we can only see the scale of problems that arise in the management of modern organizations where there are different attitudes and motivations of employees of many levels, competences located in various indirect power hierarchies.

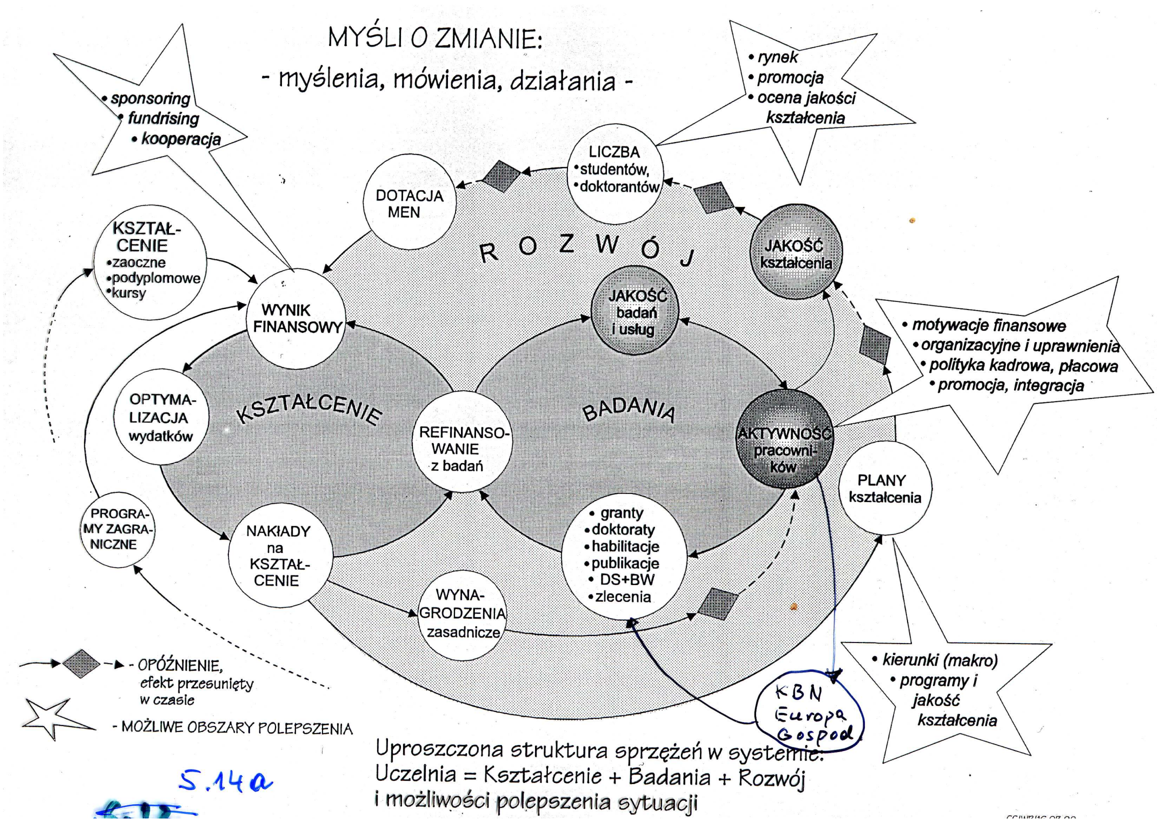


Fig. 5.14 The structure of financial and motivational interrelations feedbacks at the University Faculty model.

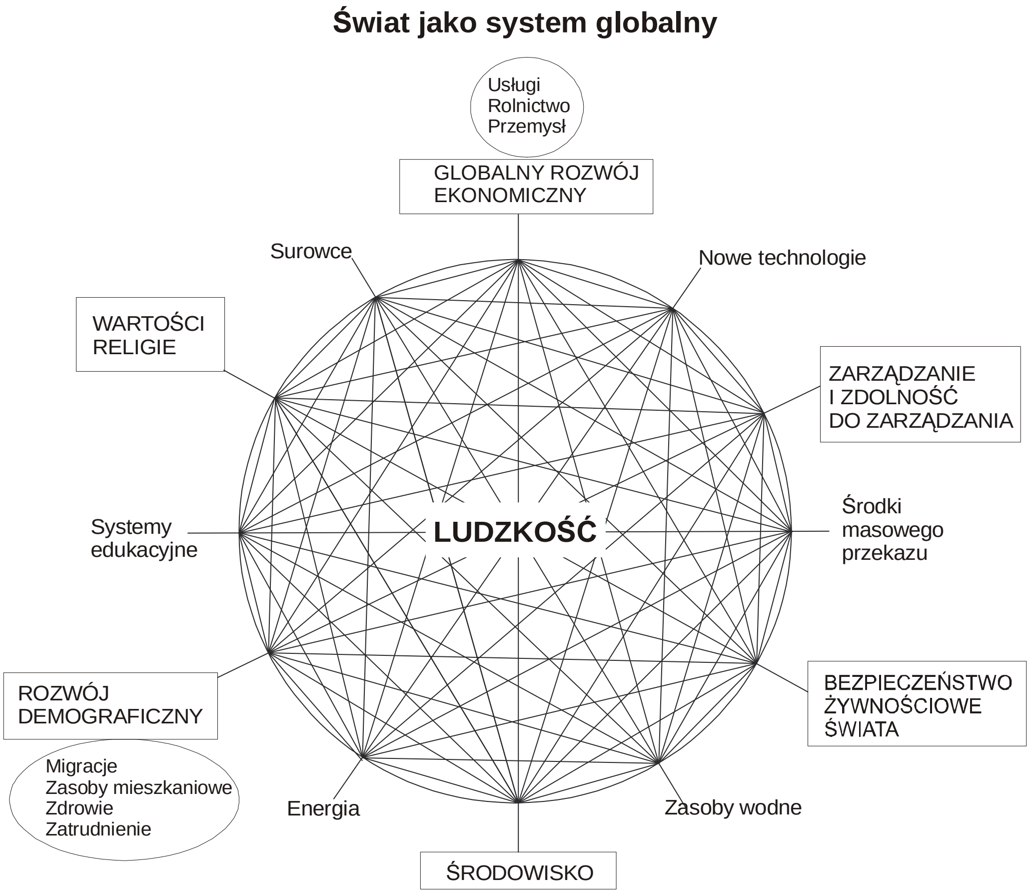


Fig.5.15 Humanity as the heterarchical system, and main determinants of its progress as possible subsystems, [Sienkiewicz 02],

The heterarchical model of humanity (*civilization*) belongs to the same group of models of complex systems, without a clearly defined structure and energy flows, as in Figure 5.15, [Sienkiewicz02]. It clarifies only **what can affect what**, even without specifying the direction and intensity of the dominant influence. Therefore, one can only call it as the conceptual model according to the left hand side of Figure 5.2.

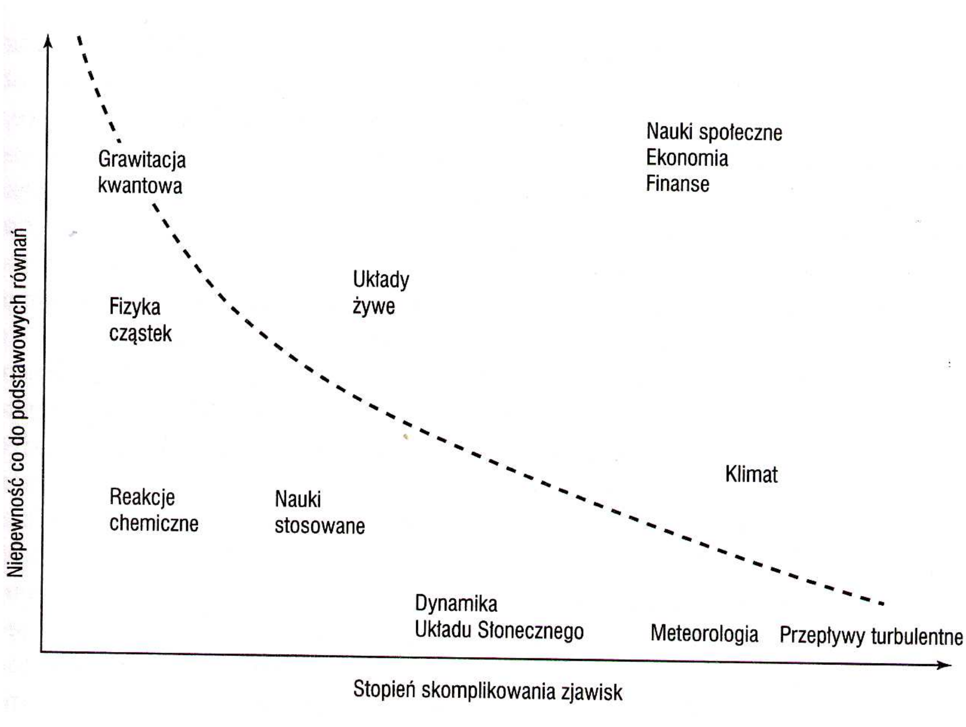
5.8 The limits of mathematical simulation

The last figure 5.15 does not give optimism, if we would like to make an analytical and/or prognostic model on this basis. But if you take into account the success of a very simplified model of environment (5.24) illustrated in the figure 5.11, we can conclude on the basis on the experience of fig 5.15, that we can create and use partial models, which will tell us something. But is that true in every case?

This is not simple and this is why it is useful to take a look at this issue. The aim of modeling is a closer insight into the behavior of an object (system), if possible by calculation. The calculations it is mathematics, equations, at least algebraic ones, and as one knows science and technology are based on mathematics. Is therefore **mathematics always worthy of trust**? Until the thirties of the last century, it seemed that it is, but in 1934r came Austrian logician and mathematician **K. Gödel,**, who proved that:

'every system sufficiently rich to contain arithmetic's must be incomplete or contradictory'.

If this theorem would concern only mathematics, then you could say: let them worry, but unfortunately it is not so. There are a number of consequences of this statement in many fields of knowledge, and above all it concerns the countability[32] and non countability of simulation problems. Further, the same concerns informatics and computer science, for example, if Gödel is right, then we can not prove that the program performing the task is the shortest possible [Barrow 05, s251]. And some even show that due to the Gödel's message is that a mathematical machine can never equate to human brain, because they will not pass the countability problem [Barrows 05,s262]. Calculations are part of natural sciences and technology, and in complex systems there are also people, sometimes also uncountable, but in a slightly different way, better to say uncertain. Please recall here only the two infallibility rules of Soros, *(chapter 3*), and we will know what we talk about. We have, therefore, three factors which can determine the boundaries of our simulation capabilities: countability, uncertainty and complexity, that is the degree of complexity of phenomena (*such as Figure in 5.15*). I think that another drawing of 5.16 taken from the already cited book of Barrows will be a good illustration of the problem of simulation boundaries.



[32]**Countability** means that something is possible to calculate in a finite number of steps, but less that immeasurable number ***N=10^110^***.

Fig.5.16 Uncertainty and complexity as boundaries of our insight by computation into the real world, [Barrows05,s87].

As a conclusion from the above figure one can say, for example, that living systems and economy will long be enigmatic and will be the field of statements and non provable experiments, without the possibility of falsification in a sense of Popper. And only the painful experiment carried out on the living body of economy will prove again, that our Guru is wrong again.

5.9 Systems evolution forecast - strategic planning

Forecasting the behavior of systems, or finding the future Input / Output values is easy if you know the model of the system, that is to say, if we have a fully identified equation governing the system and its coefficients, what is not so simple. For example, you may have the knowledge of the model type without the knowledge of its coefficients, which require an experimental identification, or statistical surveys based on reliable population of objects, or on social population.

5.9.1 Forecasting with the known model type

Hence we have a situation now where we know the type of relation describing the behavior of our system, for example it can be the exponential or logarithmic growth , as below:

$$y(\theta) = f(\theta, e); \text{ np.}; \qquad y(\theta) = A \ln \alpha\theta \, , \qquad (5.25)$$

and we neither know the scale of ***A*** nor the exponent α**.**

For the discrete time steps: ***s = 1, 2 3,*** .. with the time increment $\Delta\theta$**,** one can write the output forecast for the time $n\Delta\theta$ as below

$$y(n\Delta\theta) = f(n\Delta\theta, e) \, ,$$

if we know ***f(*)*** and ***e,*** what in general is not the case.

If in addition we monitor the system output, then our observations will always slightly differ by the value associated with the accuracy of our model, measurement interferences etc. So instead of y(nΔΘ) we will get the true value of symptom, which can be written as below

$$S(n\Delta\theta) = y(n\Delta\theta) + N_n \, .$$

Here N_n is the disturbance of measurement at ***n readings*** or the difference between the model forecast and observation:

$$N_n = S(n\Delta\theta) - y(n\Delta\theta).$$

Minimizing out the sum of these differences from the beginning of observation, by, for example, the least-squares method, we can estimate our remaining parameters of the structure of the system, based on the actual observation of the system, see, for example, special programs like **Statistica ®, Statgraf ®**, etc. This way, even without knowing the model, we can postulate the types of behavior of observables, such as a linear, square, logarithmic, function etc., and by calculating the structural coefficients of the model and we can select the model type giving the smallest error, (*more on this see, for example*, [Morrison 96]).

Going back to the estimation of the quantitative behavior of the system, let us take complex systems into account, for which the models examined in this chapter may be correct only partially - in a small fragment of their life time. This situation is illustrated in the 5.16 figure, [Schroeder81], showing the different possible fragments of the system life curve and their possible synthesis as in figure ***e***. It is easy to notice that almost each of the excerpts shown in the figure was considered as a quantitative model in this chapter, and their combination may be difficult to identify at a first glance.

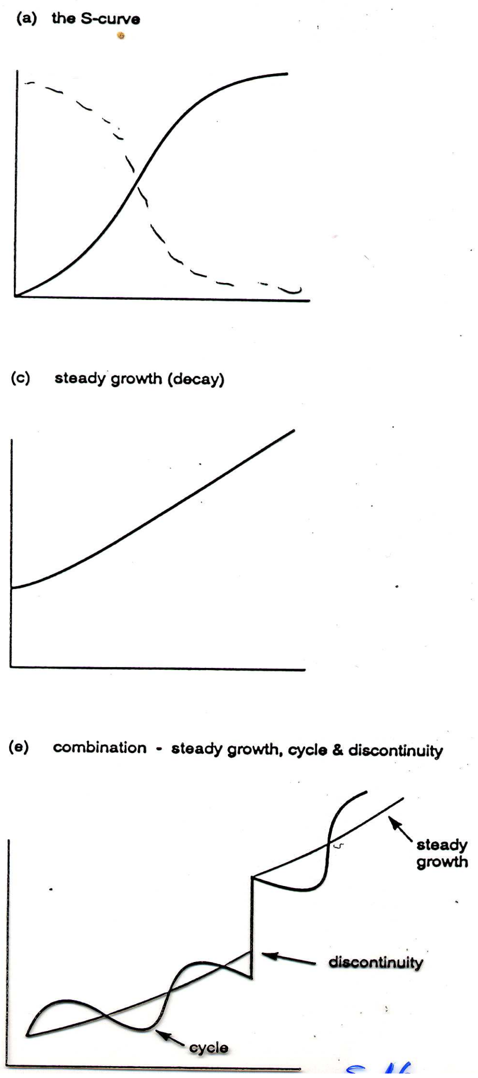


Fig. 5.17 Partial elements of possible behavior of complex system, as the element to synthesize the global life curve of symptom under consideration, [Schroeder 81].

For these reasons, and also due to the small amount of data for the curves involved, there has been a huge development of methods of quantitative forecasting of systems behavior with the assumption that their model is not known. Such methods are based on the observed past behavior of the system only, namely the time series of system attributes observed at regular intervals (*annually, quarterly, etc*). Not having a place to consider all the relevant methods of time series forecasting, let us take into account the linear regression only, which the linear, logistic, exponential growth can be brought to, if we make the logarithm of both sides of the curve (*see another form of logistic curve (5.17)*). The expected linear increase in system attribute can therefore be presented in many cases as a simple linear equation

$$\boldsymbol{y = A + B\,x}, \qquad (5.26)$$

where '***y***' is the estimated curve of a system life, ***A*** – initial value, ***B*** – inclination of the straight line.

If we have ***n*** readings or observations: $\boldsymbol{y_i = y(x = x_i)}$, then the estimators of coefficients ***a*** and ***b*** may be found in the formulae; [Greń 78], [Morrison 96].

$$A=\frac{\sum y_i}{n}-b\frac{\sum x_i}{n}, \quad B=\frac{n\sum x_i y-[(\sum x_i)(\sum y_i)]}{n\sum x_i^2-(\sum x_i)^2} \quad . \qquad (5.27)$$

As mentioned previously, this way we can look for the life curve (*function*) for time series with linear or exponential trends. More on this interesting topic can be found in specialized books on econometrics, and time series analysis, as well as specialized computing programs for example, STATGRAPHICS ®, etc. Here, at the end of our consideration, please have a look at some characteristics of different forecasting methods taken from the monograph of Schroeder [Schroeder 81] as in the following table.

At the end of the summary of quantitative forecasting methods it is worthwhile to mention the very comprehensive method of **grey systems** developed by Chinese scientists. It can be applied in all areas of economy and engineering, when we do not have too much data, and some we do have are uncertain and inaccurate. The grey system theory can be applied for modeling, forecasting, decision making and looking for relations inside the observation It is the broad area for researchers and practitioners which comes from the Far East, and the details can be found on the Internet or in introductory level in [CempelTabaszewski 07].

TIME-SERIES-FORECASTING METHODS

Time-series methods	Description of method	Uses	Accuracy: Short-term	Accuracy: Medium-term	Accuracy: Long-term	Identification of turning point	Relative cost	References
1. Moving averages	Forecast is based on arithmetic average or weighted average of a given number of past data points.	Short- to medium-range planning for inventories, production levels, and scheduling. Good for many products.	Poor to good	Poor	Very poor	Poor	Low	Neter and Wasserman
2. Exponential smoothing	Similar to moving average, with exponentially more weight placed on recent data. Well adapted to computer use and large number of items to be forecast.	Same as moving average.	Fair to very good	Poor to good	Very poor	Poor	Low	Brown, Adams, Wheelwright, and Makridakis
3. Mathematical models	A linear or nonlinear model fitted to time-series data, usually by regression methods. Includes trend lines, polynomials, log-linear, Fourier series, etc.	Same as moving average but limited, due to expense, to a few products.	Very good	Fair to good	Very poor	Poor	Low to medium	
4. Box-Jenkins	Autocorrelation methods are used to identify underlying time series and to fit the "best" model. Requires about 60 past data points.	Limited, due to expense, to products requiring very accurate short-range forecasts.	Very good to excellent	Fair to good	Very poor	Poor	Medium to high	Box-Jenkins and Nelson

Source: Reprinted by permission of the *Harvard Business Review.* Exhibit adapted from John C. Chambers, Satinder K. Mullick, and Donald D. Smith, "How to Choose the Right Forecasting Technique," July–August 1971, pp. 55–56.

Table.5.1. Comparison of the efficiency of forecasting by different time series methods, [Schroeder81].

5.9.2 Forecasting when the model is not known

Not in all cases of system design the system model is obvious as above, that is it is possible to be forecasted. And even if it is so, it may be legitimate only in a small fragment of the interesting time of system evolution. Hence, it is worthwhile to look at how the operating systems, particularly of a higher hierarchical order may change over time. But before we get to that let's first think over what objectives, types and ranges of forecasting may generally be and what **thinking about the future may** (*must*) generally be. This is well explained by figure 5.18 starting from the long-term strategic forecasting, usually at the qualitative level necessary for decisions in corporations, and ending with the quantitative operational forecasting of specific contracts, in a particular branch of production. As you can see from the drawing **thinking about the future** starts from the first extraction of important economic, social and political factors, which, will shape the future and moves further into details of the forecast area and problems.

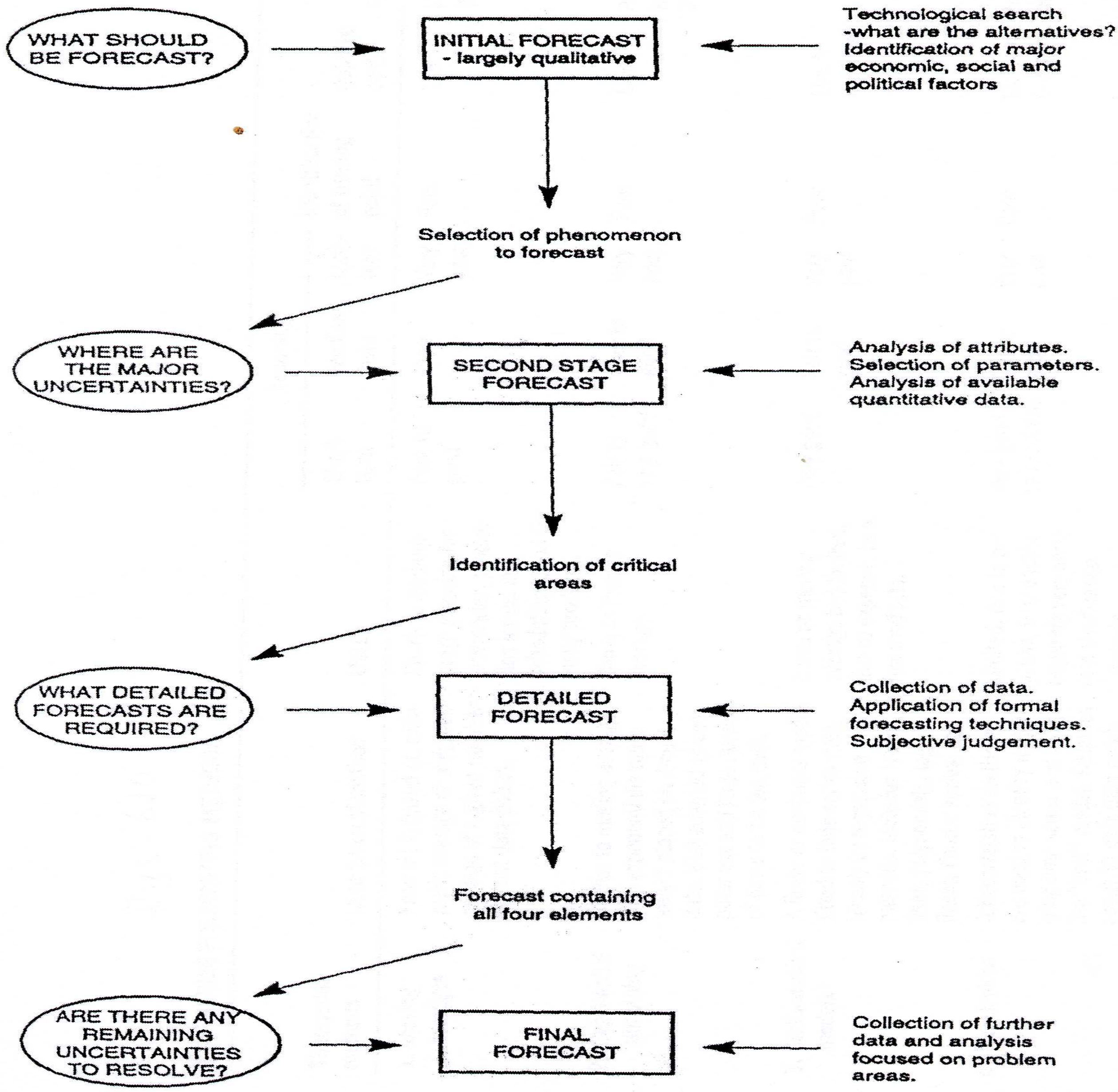


Fig. 5.18 Thinking about the future, as the beginning of a forecast at different stages [Sage 92].

In the above we have given some illustration of the development of systems during their life cycle and their interaction with the environment or metasystem. This will allow us to properly choose a model of subsystem evolution according to the analyzed design, in search of the evolution of the new system throughout its whole life cycle.

5.10 Summary

Models are our way of thinking about reality, but if we want to improve or change this reality, then our models must properly reflect the appropriate parts of reality, and in addition they must be analytical and prognostic. Let us repeat, therefore, the most important concepts related to modeling the reality surrounding us, from conceptual models, to quantitative and predictive, from simple observables to complex systems, such as the model of evolution of the human world. We have got the conviction that each model is useful, because the conceptual model organizes our thinking; the analytical model of the system helps us to study its evolution and its future states. We have also made the conclusion that not everything is measurable and computable directly, or at all, and not everything is countable, but despite this, no one will put off the **responsibility** from a system designer for its incorrect action, and especially for a disaster.

5.11 Problems

1. Recall the definition of the system and its model.

2. What is a simulation and what is the virtual engineering?

3. What types of systems are you able to distinguish, and what their models are you able to describe?

4. What are mental models and models of attitudes, and where do they play an important role?

5. What is the essence of systems interactions modeling?

6. What are the advantages of prognostic models of systems?

7. Think about your future in accordance with the scenario of Fig. 5.19.

8. What sets out the boundaries of our possibility of simulation?

9. What does the statement of K. Gödel constitute and what are its broader implications in science and technology?

9. References

Każda myśl, jeśli nie opublikowana,
nie liczy się w dorobku naukowym i społecznym.
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