A Model of Inter and Multi Disciplinary Domains, and their Mutual Interactions

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ABSTRACT

The Melvil ***Dewey Decimal Classification*** system maps the human knowledge domains into a library classification decimal system, which means that the knowledge is discretized. The domains are countable similarly to how Cantor proved the countability of the fractions' domain.

The debate about the "***inter-"*** and "***multi-"*** disciplinary domains may also be extended into "***sub-domains" or*** from another point of view – into "***super-domains***".

However, Science and Technology has rapidly developed after it was classified. If at the beginning, two decimal digits were enough to classify the world's knowledge into a knowledge domain, today we need more digits – about five. This means we are able to display about a million domains of knowledge. The decimal point indicates the sub-division in the ***zooming-in***; the number of such decimal points is unlimited. Thus, the number of hierarchical levels in the knowledge-tree is unlimited. The maximal level is unreachable since it propagates in time.

This intriguing issue raises doubts whether the tree is the most appropriate structure in the current state of the knowledge classification. However, I believe that the knowledge tree is a convenient way of expressing various connections between the knowledge domains. There are other models such as multi-level graph-networks that approximate closer to reality. These models can be further visualized by graph diagrams.

The knowledge diagram is more complicated, considering the interaction between science and industry relative to each domain.

The model of reality might be compared to the ***object-oriented*** programming languages approximating reality in order to construct more naturally computer programs that can model the world.

The mutual correspondence of the knowledge domains is dynamic. Some examples of relatively new domains are as follows: biotechnology, bioinformatics, nanotechnology, integro-differential equations, data warehouse, data mining, requirements engineering, micro biology, and bio-chemistry. There is an overlap between the various domains.

The phrase "humans know less about more and more about less" represents the trend of future science and technology. Another interesting phrase is "an image is worth a thousand words." Figures 1 and 2 show the possible relationship between the knowledge domains represented by various geometrical objects and their properties such as color, form, perimeter type, and position.

Research and design are two complementary human activities that, from the dawn of history, have improved Western civilization. New discoveries and research were made possible by former technological innovations. Many areas of research mutually upgrade and improve themselves in a positive feedback loop. However, mathematical proofs represent a different kind of a symbiotic research-design relationship.

Keywords: Inter-discipline. Multi-discipline, research, design, basic theory, symbiosis**,** government regulations.

1. INTRODUCTION

The presented models review several variations of relationships among the knowledge domains. These relationships will be represented by two mainstream domains: science and technology.

This paper analyzes various types of science-technology relationships and provides examples from different fields for both the science and technology components. These relationships constitute the test case of our goal of describing a model representing inter- and multi-disciplinary knowledge fields.

2. DEPENDENCE: SCIENCE AND TECHNOLOGY

The mutual co-dependence between science and technology is schematically represented in **Figs**. 1 and 2. Technology may contribute to science (**Fig**. 2 (a)) science can contribute to technology (**Fig**. 2 (b)), or they can mutually reinforce each other (**Fig**. 2 (c)). These relationships are analogous to the relationships among organisms, namely symbiosis**,** synergism and commensalism.

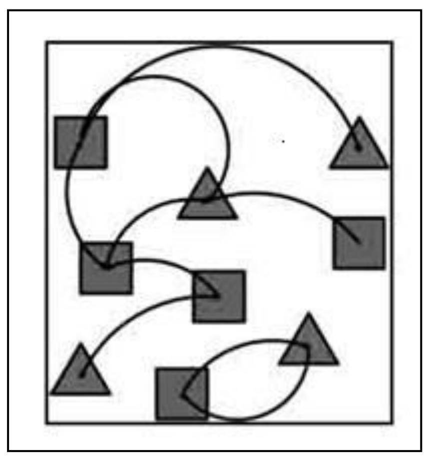
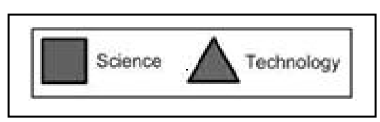


Fig. 1 Science-technology general view of the space graph of human creation's elements (research, technological inventions) types using the following legend:



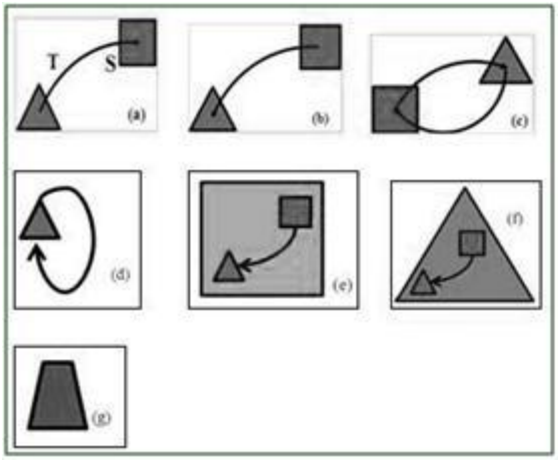


Fig. 2 Seven types of science – technology relationships:
(a) Technology supports science; (b) Science supports technology; (c) mutual reinforcement; (d) self reinforcement; (e), (f) Aggregation (Scientific, ot technological dominance, respectively) of one of the previous relationships or other relationship, containing other components; (g) Duality of techno-scientific domain – mixing shapes (square and triangle) and colors (blue and green) of the original shapes.

Symbiosis is defined as a mutually beneficial relationship between two organisms. Synergism is defined as two components having a combined effect which is greater than the cumulative effect of each component by itself. Commensalism is defined as a relationship between two organisms where one organism benefits and the other organism doesn't gain anything and doesn't lose anything.

We will discuss in the following sections milestones in science-technology developments, emphasizing the types of each of the mentioned relationships.

3. PYTHAGORAS THEOREM

An example of research that was helpful in the design of many useful objects (i.e. science supporting technology – **Fig**. 2 (a)) is the Pythagorean Theorem [1] (**Figs**. 3 and 4).

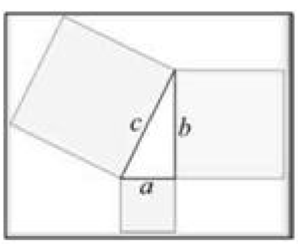


Fig. 3: Pythagorean theorem: a visual presentation: of the formula $c^2=a^2+b^2$, i.e. the sum of the areas of the two squares on the legs (*a* and *b*) equals the area of the square on the hypotenuse (*c*).

The application of that theorem has been used in measuring geodesies, navigation, prediction of celestial configurations and calendar determination.

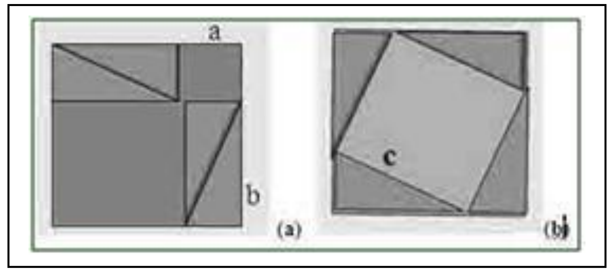


Fig. 4: Four triangles ordered in a square demonstrate the Pythagorean Theorem: The surface of the inner square (b) equals the sum of surfaces of the inner squares, where as the surface of the triangles remain the same in both sub-Figures (a) and (b), comparing the corresponding squares surfaces, the famous formula $a^2+b^2=c^2$ is derived.

4. MICROSCOPE AND MICROBIOLOGY

Discoveries and ***research*** were made possible due to former technological innovations. Robert Koch (**Fig**. 5 (a)), is one of the fathers of microbiology. He was greatly helped by a previous invention, the microscope.

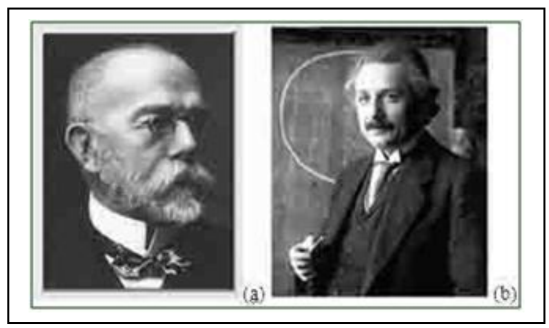


Fig. 5: Scientists: (a) Robert Koch; (b) Albert Einstein

1. The microorganism must be found in abundance in all organisms suffering from the disease, but should not be found in healthy organisms.
2. The microorganism must be isolated from a diseased organism and grown in pure culture.
3. The cultured microorganism should cause disease when introduced into a healthy organism.
4. The microorganism must be reisolated from the inoculated, diseased experimental host and identified as being identical to the original specific causative agent.

Fig. 6 Koch's postulates which define a disease causing microorganism i.e. a bacterium.

The corresponding relationship (Science and technology) is of the type shown in Fig. 2 (a), where the microscope, the technological invention, helped Koch in his research thus enabling him to arrive at his postulates (**Fig**. 6).

5. EINSTEIN'S THEORY of GENERAL RELATIVITY

Not all discoveries were made solely on previous research. Some came from insights that came from minds of geniuses. Einstein (**Fig**. 5(b)) and his theory of relativity was one such discovery [2]. Later, his discovery was validated using telescopes looking at solar eclipses.

The Eddington experiment was an observational test of general relativity, organized by the British astronomers Frank Watson Dyson and Arthur Stanley Eddington in 1919 (**Fig**. 6). The observations were of the total solar eclipse of May 29th 1919, and were carried out by two expeditions, one to the West African island of Príncipe, and the other to the Brazilian town of Sobral. The aim of the expeditions was to measure the gravitational deflection of starlight passing near the Sun. The value of this deflection had been predicted by Albert Einstein in a 1911 paper, and was one of the tests proposed for his 1915 theory of general relativity. Following the return of the expeditions, the results were presented by Eddington to the Royal Society of London, and, after some deliberation, were accepted. Widespread newspaper coverage of the results led to worldwide fame for Einstein and his theories. Another successful experiment was performed in 1919 (**Fig**. 7).

Fig. 7: The May 29th 1919 solar eclipse, showing the bending light.

Space telescopes were proposed as early as 1923. Hubble was funded in the 1970s (**Fig**. 8), with a proposed launch in 1983, but the project was postponed by technical delays, budget problems, and the *Challenger* disaster. When finally launched in 1990, scientists found that the main mirror had been ground incorrectly, as part of a sphere instead of as part of a parabola. This severely compromised the telescope's capabilities. However, after a servicing mission in 1993, the telescope was restored to its intended quality by adding a corrective lens. Hubble's orbit outside the distortion of Earth's atmosphere allows it to take extremely sharp images with almost no background light.

The advanced telescopes are founded on parabolic mirrors, which are more difficult to produce (due to lack of spherical symmetry enabling a relatively easy method of polishing), but have the property that parallel rays break to a single focus point, based on a mathematical principle (**Fig**. 9), and are more precise than the classical, spherical ones. The space telescope differs of course from the classical telescopes (**Fig**. 10) by lack of an eyepiece, which was once a great improvement enabling higher quality images.

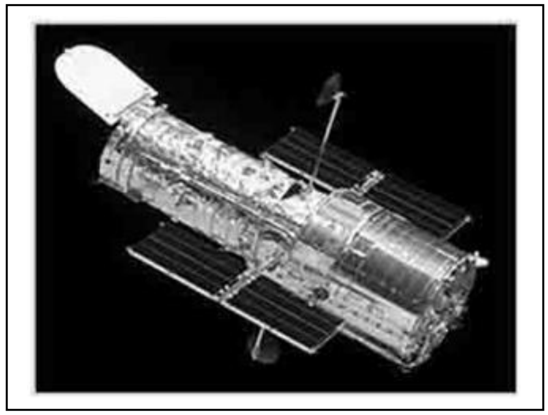


Fig. 8: Hubble telescope**.**

The modern Hubble Space Telescope has the research potential of helping mankind make many dramatic discoveries. This shows that the interplay between research and design can flow both ways.

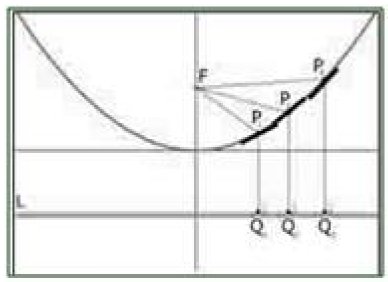


Fig. 9: Parabola demostrating the breaking parallel rays in one pont called Focus, satisfying the following equalities: $FP_i=P_iQ_i$.

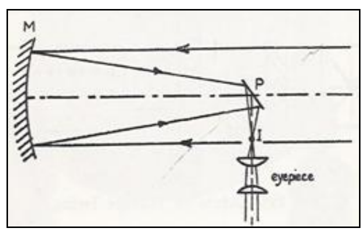


Fig. 10: Reflecting telescope.

6. BIOINFORMATICS

Bioinformatics represents collaboration between biology and computer sciences thus creating a new scientific field. This is an aggregation type (Fig. 2 (e)) of the technology-science relationship example. The common research tools are sequence matching [6]: looking for a track (sub-sequence) in a DNA or RNA strand (**Fig**. 11) and three dimension optimizations using conformational matching.

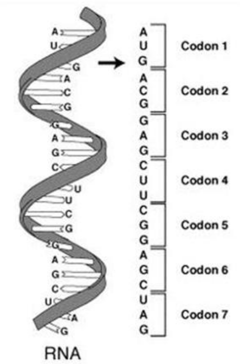


Fig. 11: Ribonucleic Acid strand and its schematic description

7. COMPUTERS AND ROBOTS

Many areas of research mutually upgrade and improve themselves in a positive feedback loop (**Fig**. 2 (d)). Computers fit into this type of category. Computer systems and their applications upgrade the next generation of chip designs using different simulation /optimization/layout programs. These improved chips are then used in programming faster and more complicated applications for designing next generation chips and so on.

The production cycle includes the following components (**Fig**. 12): the CAD (Computer Aided Design) and CIM (Computer Integrated Manufacturing) programs, the production of an upgraded wafer (later integrated in the next generation computers), an online production quality inspection and a computer analysis.

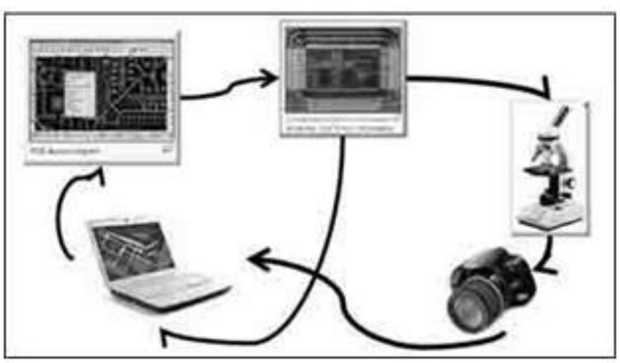


Fig. 12: The chip's production cycle including: CAD, CIM, wafer, measurements and inspection's tools.

Robotics, in a similar fashion to computers has also benefited from this positive feedback loop (**Fig**. 13).

Fig. 13: Robot's production's elements: the design and the product.

8. THEOREM'S PROOF- AN HYBRID OBJECT

Another kind of ***symbiotic*** research-design relationship lies in mathematical proofs. This relationship's type, so called aggregation**,** integrates a group of sub-relationships into a new component (**Fig**. 2 (e)).

In the past few years, computer programs were harnessed to prove mathematical theorems. An example of this is the use of a computer program to solve the long standing four-color problem [3] (**Fig**. 14). Controversy does exist as to the reliability of such computer aided mathematical proofs [4].

The following lemma was proved by computerized checking of all possible cases:

Lemma: Every triangulated planar graph, which has less than 40 vertices, is ***4_colorable.***

The classical proof characteristics are based on the following properties:

1. ***Convincing-*** the computer program is based on hardware and software reliability and therefore it cannot be assured that it is 100% correct.
2. ***Surveyable-*** computer programs may be traced in the so called debugging mode, statement after statement. But if the program performs millions of operations and maybe even more, it's humanly impossible to follow those statements.
3. ***Formalizable –*** Formalization means to put the ideas into forms (proof). It's difficult to relate to programming language and to the programs as to formal language. The programming resembles in some aspect, art since it is programmer depending.

The mathematical proofs based on computer's assistance do not conform to the classical property proofs. Computerized proofs are not surveyable and not formalizable. Universal programming verification and validation are not yet assured.

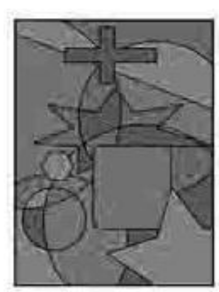


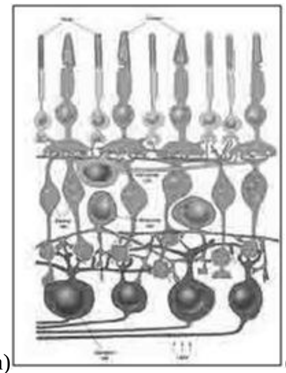
Fig. 14: An example of a four-colored map illustrating - the ***four color map theorem*** that states: given any separation of a plane into contiguous regions, producing a figure called a *map*, no more than four colors are required to color the regions of the map so that no two adjacent regions have the same color.

9. ARTIFICIAL TRANSPLANTATION

The following relationship belongs to the aggregation class (Figs. 2 (e) and (f)). This is a system composed mainly of domains from physics, electronics, biology and neurosergery. An example of an ultimate symbiotic relationship for research and design would be the futuristic possibility of melding the human brain and its technological counterpart, the computer chip. This would be due to advancements made in computer technology and transplantation techniques, such as transplantations performed on the human retina [5]. The main components of such transplantations are displayed in **Fig**. 15.

Fig. 15: Retina in various aspects: (a) frontal view; (b) retina's layers; (c) artificiel retina-chip [5].


(a)


(b)


(c)

This type of novel techno-scientific research came to existence in the last two decades spurred on by advances in nano-technology enabling discoveries in physics (new particles) and biology (bio-cellular research).

10. DUALITY

In general the roles are allocated as follows: Science investigates nature leading to discovery**.** The technology creates an imitation i.e. invention (aviation, genetic algorithms, artificial intelligence). In this context, the classification of the mathematical theorems is still philosophically problematic: are mathematical theorems human discoveries or human inventions?

This type of a techno-scientific problematic definition might be classified as a dual type (Fig. 2 (g)). This duality resembles the duality of light which behaves also as a wave and also as a particle i.e. a hybrid definition.

11. CONCLUSIONS

To summarize, research and design are both derived from the same source, namely, human intelligence, and their relationship is symbiotic in the majority of cases.

The technology of another domain enables humans to improve and to extend their senses and capabilities. This allows us to see both smaller and farther objects, to think faster, more precisely, and more effectively and to remember more for a longer time.

In our modern times, characterized by competition between research and design, it is the more practical design that wins against the more theoretical research because there is more money available for practical applications than for the more esoteric basic research. Governments can encourage more basic research by increasing funding. In this way, the best and the brightest will be found in both of these important human endeavors.

Nowadays, special academic–educational inter-multi-disciplinary courses are offered. Some new examples of such hybridized domains are bioinformatics, biotechnology, biochemistry, e-learning, neurosurgery, orthodontia, electro-optics, mechatronics, psycholinguistics, and legilinguistics.

The Management Industrial Engineering and Computer Science have a special role in the mutual interactions between the disciplines. These domains are like glue that controls and connects various domains.

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