Evolution of “good continuation” principle

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> “Wherever the understanding of humanity will take a step forward, there people will honor the name of Max Wertheimer and turn back to his thought with a sense of gratitude and affection”
>
> (Artur Asch, 1944)

Abstract : The General Systems Theory and Gestalt Psychology are very much connected by their genesis and basic notions (whole, parts and relationship). Therefore any development in Gestalt theory is interesting to the Systems science.
For five decades computer scientists try to implement some models of human intelligence based on psychological knowledge into the computer. In particular, many of the problems were pattern recognition and image understanding problems. Naturally, it assumes the use of basic principles of Gestalt psychology. It is always a challenge to represent psychological theories to the computer: the computer demands absolutely clear description of terms, notions and procedures, while psychology suffers from fussiness of many definitions. Therefore, an implementation of any psychological model in the computer takes a lot of work in clarifying psychological terms and notions. Only then a step toward creating an intelligent computer could be made. From that work not only the computer science, but - let us hope - the psychology itself can benefit.

That softness of psychological knowledge does not give any advantage to the "exact" computer science, and does not put the computer science in superior position. Still the psychology is the only basis and source of ideas for the computer Artificial Intelligence - the main road of computer development. In his book "Productive thinking" [6] M. Wertheimer in 1943 (before the computer was invented!) forecast many of the problem that computer science would meet in next 50 years [5]. He warned about wrong ways of development, and proposed a number of solutions. Unfortunately, the computer community didn't learn that lesson, until now. At the same time, there is a number of examples of successful applications of real psychological knowledge, particularly - of Gestalt Psychology.

Introduction

That paper represents an analyzis of one of the basic principles in Gestalt Psychology – “ good continuation” principle – from computer (read “mechanical”, or “phisical”) point of view with all restrictions it carries. By the way, Wertheimer didn’t oppose physical approach to the Gestalt approach. On the contrary, he thought that
“wenn wir Wissenschaft treiben wollen, wird oft hinzugefügt, dann müssen wir ja doch analysieren, auf die Elemente gehen; wer wollte denn wissenschaftlich versuchen, ein solches Fließendes, Strömendes irgend zu fassen? Und dabei tut solches die Physik dauernd! Und dabei ist es bloß ein altes erkenntnistheoretisches Vorurteil, daß die Physik rein mit Stücken arbeite, sondern gerade dies: das Fließende, das Strömende, von Ganzgesetzlichkeiten Beherrschte, ist Arbeitsgebiet der Physik seit mehreren Jahrzehnten.[4]”

Good continuation – what it means?

All basic Gestalt principles (similarity, proximity, good continuation and so on) have to help recognize the organization of the image, i.e. divide the image in the appropriate parts and find the relations between them. In case of the simple drawing in fig. 1 the image can be described as two crossing lines “ab” and “cd”, or two touching angles “ac” and “bd”, or four lines “aO”, “bO”, “cO”, “dO”. The “good continuation” principle helps describe the image (i.e. to represent our perception) as containing two parts - two crossing lines “ab” and “cd”.

Why this choice of representing (describing) the image is preferable? What is the meaning of “good continuation”? As a matter of fact, “continuation” means a process, which develops in time. But the image is final (it does not change in time), so how can we apply a time-depending process to that unchanging image? In most cases “good continuation” is applied to a line, so, it is a “good continuation of the continuation” is applied to a line, so, it is a “good continuation of the line”. The direct interpretation of the term “continuation” is prolongation of the line, say “a-b”, beyond the point “b”. That makes no sense because the drawing is complete, and there is no intention of changing the drawing by elongating this line. The only reasonable interpretation is if “continuation” is applied not to the given image, but to the imaginable process of creating the line.

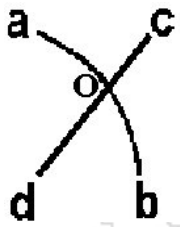

Fig.1

If the process of drawing a given line is going smoothly, i.e. the direction and/or curvature of pen’s movement are not changing much, or do not change at all (straight line), then the continuation of the drawing is easy, and this line could be called a line of “good continuation” at any point of the line (lines “ab” and “cd” at fig. 1). So, the “good continuation” principle – one of the basic principles of Gestalt psychology – assumes that perception of a drawing includes the imaginable process of recreating (or imitating) the drawing.

From all potentially possible partitions of the whole such set of parts has to be preferred, which has the **simplest description**. The simplicity of the description reflects 1) the number of parts (the less is the number the simpler is the description), 2) the relations between the parts (touching, crossing, above, to the right), and 3) the simplicity of description of each of the parts. So, the hypothesis of creating the image in fig. 1 by drawing the lines point-by-point and in random order has to be rejected as extremely complicated and practically impossible. The number of parts in cases of two crossing lines and two touching corners is the same – two, but to create the whole from the chosen parts is much more difficult in the case of corners. It is simple to draw the first corner, but drawing the second one takes a lot of concentration. First, the vertex of the corner has to coincide with the vertex of the first corner. Secondly, the direction of the first leg has to be precisely the same as the direction of the appropriate leg of the first corner. That will

give the smooth continuation in the crossing point. Same conditions have to be satisfied for the second leg. In total it is a very arduous problem. That means that the relations between the parts are very complicated. In case of crossing lines the relations are described by one condition only – crossing.
The simplest way to create fig. 1 is to draw two crossing lines. The good continuation in the crossing point for both lines is insured by the nature of the pen's movement – the inertia of the hand + pen mass.

There are good reasons why imitating the way the drawing was created is a right thing to do when looking for a short and sensible description. Before somebody begins to draw one creates a plan. The plan gives instructions on what has to be done and in which sequence. Mostly the plan is created and kept in memory, so, the plan can't be too big. It means that the number of parts in the plan has to be limited, and therefore the whole has to be divided in a reasonable number of parts. Each part has to be as meaningful as possible. That means that in our perception we try to reconstruct the plan, which was in the mind of the person that created the drawing. That also means that the organization we found in the stimuli is really the organization in drawer's mind – the organization of the plan. That is true not only when we are dealing with objects created by other human beings but also for any object in the nature that we try to understand how it was created or how it could be created. That is why the first story in the Bible is "Creation".

As a matter of fact the main notions of our approach were understood by Wertheimer as early as 1923 in his one of the most influential *Gestalt* papers [1]. Let us quote:

1. "On the whole the reader should find no difficulty in *seeing* what is meant here".

That clearly indicates that the issue discussed is perception ("seeing").

2. "In designing a pattern, for example, one has a feeling how successive parts should follow one another; one knows what a "good" continuation is, how "inner coherence" is to be achieved, etc."

Here an imaginary action – "designing a pattern" (that is the plan!) – is used for explaining the perception, and the process of redrawing the image is specified: creating genuine parts and drawing them in the right succession.

3. M. Wertheimer's point of view expressed in 1923 paper was represented 60 years later by Michael Wertheimer at al. [6]: "Assemblages of lines and dots are not perceived as unrelated, piecemeal units or as a chaotic mass, but are instead grouped into meaningful configurations based on their similarity, proximity, closure, continuity, and the like, and governed by dynamic processes such as Pragnanz, a tendency toward **simple Gestalten**". That is the last part of our interpretation of "good continuation" principle – the description has to be as simple as possible.

So, the proposed above interpretation of "good continuation" is really a detailed development of Wertheimer's point of view.

Wertheimer

Let's apply this interpretation of the "good continuation" principle – we will call it the "imitation principle" – to more complicated drawings used by Wertheimer in 1923.

In fig. 2 we see, as Wertheimer wrote, an "arc and a tangent line". How can such a description be explained by "imitation principle" based on imitation of the process of creating the drawing? Both versions (ab/c and ac/b) consist of two parts, and in each version the conditions of "good continuation" are satisfied. But to draw the version ab/c is easy: one draws the arc and then the tangent line. To draw a tangent line is easy – it is enough to draw a line, which touches the arc; that line will necessary be a tangent. It is not so easy to draw the version ac/b – first the part ac, and then an arc, which is tangent to the given line in a given point. So, the simplest representation will be "an arc and a tangent line". As a matter of fact, in the process of perception we understand not only the right partition of the object but also how successive parts should follow one another: in drawing "arc + tangent" it is much easier to draw an arc first and then the tangent than vise versa.

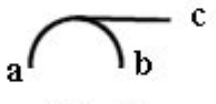

Fig. 2


Fig.3

Fig.4

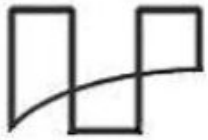
Fig.5

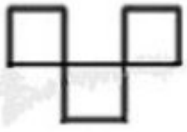
Fig.6

For explanation of some figures Wertheimer introduced and applied new principles - closure: "From an inspection of Figs. 3 and 4 we are led to the discovery of yet another principle: *The Factor of Closure*".

In some cases these two factors create a contradiction (fig. 5): according to the "good continuation" the figure has to be divided in a "rectangular chain" and "smooth line"; according the "closure" principle it has to be divided in three 4-angles. Wertheimer remarks: "In Fig. 5, for example, it is not three self-enclosed areas but rather *The Factor of the "Good Curve"* which predominates".

To clarify the problem let us analyze fig. 6. In this case both factors are applicable as well, but now *The Factor of Closure* will predominate in our perception: we perceive three self-enclosed units. Let us try to eliminate the contradiction by applying the "imitation principle". The simplest description for the partition of the second figure is "three quadrangles" and the relations of the parts are simple (they touch each other only in the corners). If we will try to represent fig. 5 as consisting of three parts the description of each part will be complicated, and the conditions of the connections between the parts will be complicated. It is almost impossible to redraw the first figure by drawing consequently the first 4-angle, then the second one, and then the third one. The fig. 5 creates a Gestalt that is common for a set of figures in fig. 7, but the fig. 6 creates a Gestalt, which covers a quite different set of figures (fig. 8).

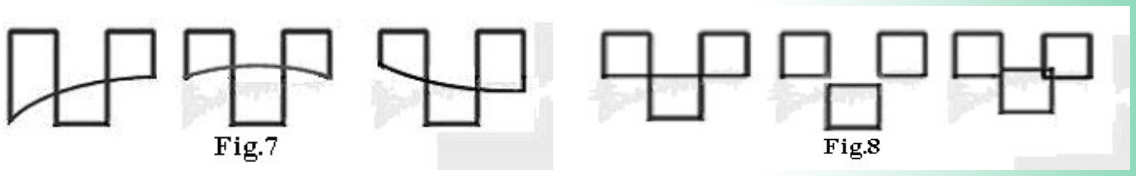

Fig.7 Fig.8

As time passes a new definition of "closure" emerged: the principle of closure applies when we tend to see complete figures even when part of the information is missing (see appropriate examples in fig 9a). How does the "imitation principle" manage this situation? The instruction for reproducing the fig. 9a will be as follows: "start to draw a circle, continue, and stop before closing the curve". The description of the closed circle (fig. 9b) will be "start to draw a circle, continue, and stop on closing the curve". Omitting small details both figures create the same description, the same pattern, the same Gestalt – the circle. The same could be said about fig. 9c: it happens when the circle was drawn by hand.

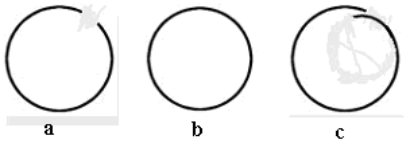

Fig.9

From mathematical point of view the circle with a gap is not a circle (because a circle consists of **all points** at a given distance from the center. It differs from an ideal circle in a number of features: one has a closed curve, and the other doesn't; one has derivatives in each point of the curve, and the other doesn't in two points (ends of the curve). In our perception we represent the figures not as geometrical abstracts but as tracks of movements in real physical world, which are never precise and exposed to disturbances. In that representation (contrary to mathematical one) all the mentioned figures are the same – "circles".

Kohler

10 years later, in 1935 W. Kohler published the book "Gestalt psychology" [2] in which he expressed two important ideas. The first one is that "particular visual shape goes with the existence of a corresponding visual unit, which, when segregated, has the shape" (p.108). It means that we percept not the abstract shapes, but real objects, which have that particular shape. The second one is that "the things around us are for the most part very stable entities" (p.110). Both ideas establish connections between our perception and the real world.

In his book Kohler discussed similar problems using more complicated figures (for example see fig. 10a). W. Kohler arose a reasonable question: why don't we see in fig. 10a shapes shown in fig. 10b and 10c? His answer is: "because we perceive the image as "a Maltese cross in a quadrangle", we can't see at the time other shapes". That answer can't satisfy us because it only creates the next question: "why do we percept the cross and can't percept any of shapes 10b and 10c?" Kohler did not answer the last question.

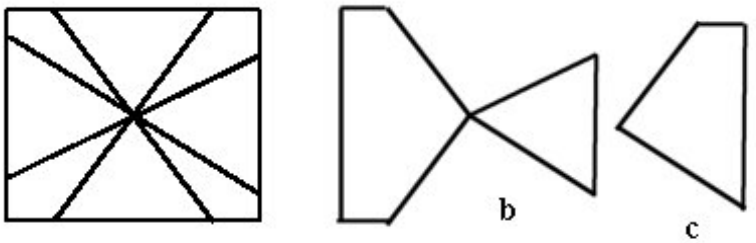

Fig.10

What will be an answer to that question according to the described above approach? “Maltese cross in a quadrangle” is the simplest description of fig. 10a and that fact determines our perception. The description, which includes fig. 10b as a part of the whole will be extremely complicated: it is not easy to describe the shape of the fig. 10b alone, it is not easy to describe rest of the whole, and it is not easy to describe the structure of the whole, the relations between its parts. That is why unconsciously we perceive “Maltese cross in a quadrangle”. We can perceive the fig. 10c as part of the whole only consciously, only logically by isolating imaginarily this part from the rest, so, suppressing the rules of Gestalt perception.

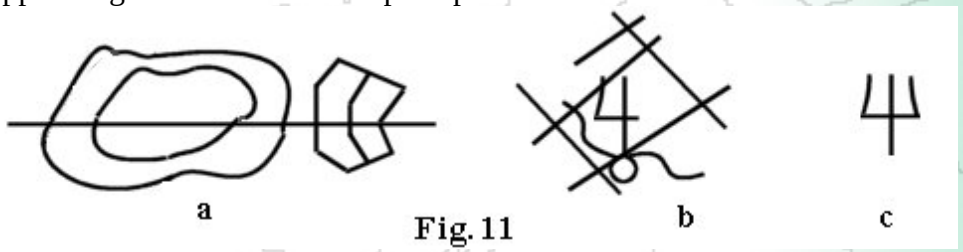

Fig. 11

Other figures analyzed by Kohler are shown in fig. 11. Koler tries to explain, why in fig. 11a nobody see the “4” and why in fig. 11b the “4” is seen at once. His first remark is “it is by no means the unusual character of the environment, which prevents seeing the “4” in fig. 11a “. But “unusual“ is not an explanation, it is an emotional response.

His second remark is: “In fig. 11a conditions of organization are such as to favor the formation of other objects. In fig. 11b an equally strange environment contains no such conditions, and therefore the number remains a segregated visual thing”(p.115). Because the meaning of “favorable conditions of organization” was not defined, there is no explanation of the phenomena.

The third Kohler’s remark is: “In fig. 11b the added lines do not tend to fuse with the various parts of the number 4 (p.114).“ It is not an explanation as well, because “fuse” is not defined. Yes, one can see that “4” does not “fuse” with surrounding lines, but why does it not? It can be shown that the problem is not in the strange or complicated environment. In fig.11c the environment for “4” is minimal (one additional short line) but the result is amazing – one can see not the “4” but the trident.

All these cases are explainable by the means of “imitation principle”. The fig. 11a has to be described as “two unknown objects through which a horizontal line is drawn”(p.108). Any other description will be extremely complicated. So, ”4” is not a part of that description of the whole and therefore could not be seen. The fig 11b can be described as “4” + 6 straight lines + two waves + two circles, and can be reproduced that way. So, the “4” is a generic part of the whole and could be seen. The fig. 11c can be described as 2-dimensional open box + central handle and is drawn that way. Therefore

"4" does not appear. As a matter of fact Kohler was close to the solution: he describes the fig. 11b as "4 and added lines" (see above the quote from page 114). That precisely describes the simplest way of creating the fig. 11b, which is the essence of our approach.

There is one strange thing in his book: discussing these problems Kohler didn't mention the "good" continuation" principle (which leads our perception to seeing the horizontal line as part of the whole in fig. 11a) and the "closure" principle (which determines our perception of two separated objects in fig. 11a).

Imitation principle and the spirit of Gestalt psychology

Let us show that such approach is completely in agreement with the spirit of Gestalt psychology.

1. Partition of the whole is the central theme in Gestalt psychology. Wertheimer emphasized the role of parts in representing the whole. He distinguishes the parts of whole from pieces:"…the parts are not mere pieces in additional relation together, but parts of the whole" [1]. It states that only the real parts (together with their relations) represent the whole adequately. K.Kofka wrote: "To apply the Gestalt category means to find out which parts of nature belong as parts to functional wholes, to discover their position in these wholes" (Kurt Kofka, 1935). This was echoed later by L. Bertalanphy:" If, however, if we know the total of parts contained in a system and the relations between them, the behavior of the system may be derived from the behavior of the parts."

2. Involvement of the reality in the perception is the way Wertheimer follows in his book "Productive thinking". For example, the "Area of the parallelogram" problem was resolved by a purely mental process that includes imaginable cutting with the scissors and moving parts in 3D space. The concept of "continuation" is based on modeling the process of creating an image taking in consideration the features of the real physical world (time, velocity, masses etc) as well. It also uses the implicit and very reasonable assumption that parts are created in sequence, one after another. In fig. 1 it means that the hypothesis that first couple of points of the line "ab" were drawn, then some points of the line "cd", then back to the first line - is completely not acceptable.

One more example of that our perception takes in consideration not only the percept alone, but the reality of the physical world, is represented in fig. 4. The simplest way of how the drawing can be created is as follows: 1) draw a set of parallel lines, 2) cut the drawing with scissors along the line ab, 3) shift the right part down. As a matter of fact, on geological cross-sections this pattern identify a fault and a shift.

Let us remind that the very early W's experiments with turning lines demonstrate the effect of movement. From our point of view the perception of the alternating lines has to be interpreted in terms of how this situation can be produced. The only way in the real world to generate this situation is to move the line from one position to another.

3. The perception of fig. 1 as "two crossing lines", as a matter of fact, represents not only the given image, but also a set of images (like in fig. 12, first row) which our perception will refer to one class, which carry the same pattern, the same Gestalt. One of the important features of that pattern is stability: one can change some parameters of an object (curvature of the lines, intersection point, or length of lines) but the resulting

image will still carry the same Gestalt. To the contrary, if one will choose to describe fig. 1 as consistent of two angles some changes in the parameters will create a set of images (fig. 12, second row), which will not be accepted by our perception as belonging to same class, to same pattern, to same Gestalt, as the initial image does. The characteristics of the Gestalt "are applicable not only to the individual case at hand but to an infinite number of other cases as well" (ibid, p.133).

Рис. 12

This generalization function of Gestalt is remarkable. Last 50 years in Artificial Intelligence was developed - a fruitful method of generalizing experimental data (particularly in geology and medicine) by teaching a computer on a set of examples – pattern recognition. But the Gestalt demonstrates the ability of our mind to generalize on the basis of a single example (we will dedicate our next paper to that issue).

4. As a matter of fact, most drawings we see in books, posters, screens etc are created not by hand and a pen, but by lithography (complete drawing at once) or screening line-after-line. But as soon as the process is finished and we see the final image we percept it as it was really drawn by hand and a pen. That is the right thing to do, because the publisher intentionally creates an image we will interpret as a drawing. These examples emphasize ones more that the parts, the smooth movements, the right sequence of drawing parts are products of our perception and are not elements of the reality. Also the visible movement of the bar in classical Wertheimer's experiments doesn't correspond to any real movement – it is only our interpretation of the visual stimuli.

Application to art analysis

I. Let us analize what was done by Arnheim on Michelangelo's *Creation of man* [3]. His purpose was to explain the perception of the painting from Gestalt psychology's point of view.

"The structural skeleton (heavy lines on fig. 13) reveals the dynamic theme of the story". When one looks at skeleton only, which idea could be extracted? What story it represents? No idea and no story. But the trick is that Arnheim represents not the "structural skeleton" of the painting – he represents the "structural skeleton" **on** the painting (fig. 13).

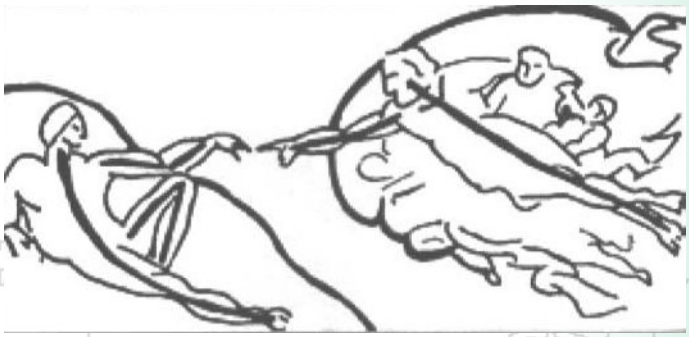

Fig. 13

Here everybody can recognize sketches of two bodies. Two of skeleton lines belong to the right figure (the God). One represents the corpus + legs, another – the right arm, but why is left arm missing? Three skeleton lines represent the left figure (the Man): one line represents the left arm, second – the left leg, third – the body + right leg, but why is right arm missing, and why the corpus is joint with the right leg? All these questions have no answer if we got the skeleton from that sketch only.

Then it turns out that the painting alone is not enough to get the right perception of the painting: "The story of Michelangelo's *Creation of man* is understood by every reader of the book of Genesis" wrote Arnheim (p.458). Now the viewer knows 1) from the caption: the two bodies are the Creator and the man and the moment of creation is represented, 2) from the Bible: the magic transformation was done by breathing a living soul in the body of clay, but that is not what one can see: there is no contact between Creator's mouth and the body of the man. But there is a touching contact with the tip of Creator's finger. Then come to mind the idea that according to the Bible there was another act of magic transformation – touching with the hand (or with a wand). So, the viewer has to make the sophisticated substitution in the attempt to understand the meaning of the painting. Only after all this mental work it can be written: "The creator *reaches out* toward *the arm of Adam* as though an animating spark, leaping from fingertip, were transmitted from the maker to the creature. The bridge of the arm visually connect two separate worlds: the self-contained compactness of the *mantle* that encloses God and is given forward motion by the *diagonal of his body*; and the incomplete, flat slice of *the earth*, whose passivity is expressed in the backward slant of its *contour*. There is passivity also in the *concave curve over which the body of Adam is molded*. The desire to get up is indicated as a subordinate theme in the *left leg*." (p.460). To create that essay one has to know the Bible, be a very articulate person, and live, at least, in XVIII century (understanding the metaphor "animating spark" demands some knowledge of electricity). That text defines the main objects of that scene (marked in the quote in cursive): Creator's arm, Adam's arm, mantle, Creator's body, contour of the earth, Adam's body, left leg. Only after that these bodies can be chosen for representation with lines, which could be called "skeletons", and the sketch in fig. 19 can be created. But there is no way to create that set of "skeletons" from the visual stimulus by applying rules of Gestalt psychology.

Conclusion

The problem of how our perception represents the real word, in which language it is expressed, is a crucial problem of thinking. The fruitlessness of 40 years long research in Artificial Intelligence (AI) was predetermined by the set of problems chosen. Vast majority of these problems were games, in which the environment, the rules and the acting objects were completely determined. So, no problems of describing the environment, of discovering the objects, of creating the adequate language appear - all of them were solved before the computer started to perform the task. As a result the fundamental problems of intelligence, of productive thinking were not even touched. It is no wonder that some local achievements in AI (including the victory of the chess program) teaches us nothing about any principles of brain functioning.

Wertheimer was damn right having in mind the problem of thinking and working so much on perception, i.e. on understanding the way our mind describes the world. It could be that the Kohler's evidence that Wertheimer was disappointed with too much attention of his fellow psychologists to his work on perception and their negligence of his results concerning thinking, have to be interpreted another way: Wertheimer was disappointed that the psychological community did not recognize that the perception problem is a crucial part of productive thinking.

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