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Kernel Problems of the Modernization of Engineering Graphics Education[1]

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Abstract. The innovation in graphics education lying ahead of us is not only a problem of arranging the contents or selecting the focal points. The divergent opinions are actually controversies about didactic problems with philosophical profundity. At the moment, the main direction of the world education reform is to reinforce the foundation and to develop the ability – despite the bright coloring of its outer appearance due to modern graphics technique. And the kernel of foundation and ability is intelligence. So, one should take care of the right balance between theory and practice, between the basic concepts of Descriptive Geometry in updated form and the design work with all the powerful tools available on the market. One of the basic problems is still the transformation between 2D and 3D and vice versa.

1 Introduction

Different to the situation ten years ago, the problem of modernization of graphics education in China has already moved from the discussion of its developing trend towards something much more essential: How to carry it out and what are the kernels?

The rapid development has already given great influence to the contents and methods of graphics teaching. However, the explosive increase of information, the more and more shortened aging period of knowledge, so many new things to be learned by students, – all these set still higher demand on the theory and viewpoints of didactics. For instance, the total planned teaching hours of Descriptive Geometry and Engineering Drawing for mechanical engineering students at BUAA dropped from 306 (4 semesters) in the fifties to 110 today. Yet being pressed for time is still a superficial account, the far more important reason is that we must develop the students' ability of analyzing engineering problems and the ability of

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grasping key points of things. This means that we have to consider how to teach the students to keep abreast with the fast changing world. Perhaps this might be more difficult. In China, at some universities the CG course has been offered for more than ten years, but others do not have such courses at all. A few offered the course 3–4 hrs./w., others 2.5 hrs/w. There is a long way to go to make up the disparity. Recently about 20 hours, i.e. 1/6 – 1/7 of the whole course, will be designated for CG. This suggestion was made by "The Guiding Committee for Engineering Graphics Courses", a semi-official subordinate organization of the State Education Commission. This committee suggested also a 32 - 36 hr./sem. course of CG, including

1) introduction
2) transformation
3) programming for mechanical/civil drawing
4) generation of curves and surfaces for engineering
5) clipping technique
6) introduction to typical interactive software
7) common data structure
8) hidden line/surface removal
9) 3D modelling
10) interactive technique.

This year[1] the State Council of China has made public an important document "Decision for accelerating the development of science and technology". And in May 1995 the "National Conference of Science and Technology" was held. State leaders made a long and important report at the conference. We believe that the innovations in education will also be accelerated.

Hence it follows that many universities are mobilized to consider the further development of their course construction. And it is quite natural that differences in their views should arise. The essence of these dissensions lies in the valuation of *practice and theory.* In fact, this controversy appears not only in China, it seems to be something international. Hence it is necessary to analyze it.

2 Practice

When the modern techniques of graphics were confronting our original curriculum, it was natural for people to focus the attention on the equipment, on principles of the mechanisms, and the gist of operations and so on. Later, when CG and CAD parted from their first generation of fused development and each went its own way, the graphics teachers met a new problem which they never met before. Formerly, the fundamental courses were so stable that the graphics courses had no basic change for almost hundred years. And this stability has had some side-effect in the mind of the graphics teachers. But now the most rapid developing phase of CG and CAD becomes apparent, and the universal graphics software vendors improve their versions in an astonishing speed. For example, a new edition of AutoCAD came on the market within an interval of less than 6 months. Graphics technique incessantly puts forward new demands for concepts, knowledge and operational method and simultaneously, it offers incessantly new effective and high-efficiency approaches. This presses people to study how

[1] Editor's note: 1995.

to draw near to the automation of design, how to serve the design work best. Among them, some experts announced that *design is now developing form 2D to 3D* and we have to mould the new system of our curriculum in a similar way. Therewith, many colleagues have done a great deal of research work around this, and they have achieved good progress in the practice of teaching. So EG as a fundamental course has been strongly propelled forward, closing up to design, closing up with the progress of technology. I do think that this is very good. The modern graphics technique has already offered a powerful 'weapon' for the design work, particularly its three-dimensional function. It goes without saying that we should teach the students' capability to use this tool.

But when we go deep into careful consideration, perhaps there might be such a problem of how to estimate the role of directly utilizing 3D figures for designing. There is a statistic result concerning machine design: When the machine parts are comparatively simple and the assembly relation is complex, then the 2D mode of thinking and design is quicker, clearer and more definite. However, when the assembly relation is simple and the machine parts are complex, then the 3D mode of thinking and design gains the upper hand. Their shares in the actual design work are 8 : 2. This means that in practice the 2D mode still possesses absolute predominance, about 80%. Thus it is clear that the focus of the problem lies in the transformation from 2D to 3D and vice versa.

Recently the German corporation Siemens-Nixdorf put out a software which seems to give also an explanation for this problem. The software "Sigraph Design" displays no pictorial drawings, hence it may be regarded as two-dimensional. But it was developed on the basis of relative parameters, and it has a considerable portion for conceptual design in order to make the software closer to the designer's creative thought. Furthermore, through the function of the relative parameters, a partial and local change in a single view can obtain corresponding response in other views automatically. This is very convenient and effective.

The above mentioned introduction shows us the two phases of spatial analysis: *Form and relative position.* We ourselves had such a kind of experience in teaching. A few years ago, at BUAA some students of the aero-engine department gave us a hint of how to strengthen the development of the ability of spatial analysis: When these students completed their design of an engine, we found from the front sectional view that they arranged the parts with reasonable compactness. But the space in front of and at the rear of the parts shown in that view was not used economically. Of course, the insufficiently utilized space can be easily ascertained by a sectioned side view, but the students did not call that to mind.

When we say a machine part is complex, we generally mean that its geometric form is complex. In fact, the complexity is referred to the mutual relations between the components of its structure, and finally a problem of "form" in most cases would turn into that of "geometric intersections and tangency".

Under certain conditions the direct use of the 3D model is convenient for design work. But in more cases it will be much better to use the 3D model as an auxiliary mean to activate the designer's creative thought. Unitary pictorial representation has some limitation in the definiteness of dimensioning and in the visual sense of true shapes. When the use of 3D forms is overemphasized, then thinking must be crippled.

3 Theoretical basis of graphics

From what was described above, there is a consensus that the advanced techniques should be introduced into graphics courses as soon as possible and the drawing should be as close as possible to the progress of technology. The application of CAD at enterprises and design institutes becomes more and more wide-spread, the cost of hardware becomes lower and lower. All this is a great help for the modernization of our course.

But there is still one aspect not enjoying enough general support. That is the theoretical basis of modern graphics.

Surely, some scholars have done an excellent work on the theoretical side: Professor NAGAJIMA (Japan) and Professor D. RYNE (USA), both have contributed research results to the computerized Descriptive Geometry. They and many other scholars have made great effort for the development of graphics. But we hope that far more researchers will devote themselves to the theoretical field, and tremendous achievements will come out in the near future.

In view of the significance of the theoretical basis of modern graphics, we might as well have an investigation about the contribution of Gaspard MONGE. He published his "Géométrie descriptive" in 1795, but early in 1523 Albrecht DÜRER put forward orthographic multiviews of a human head and feet. Furthermore, the disposition of the multiviews coincide entirely with that of the first angle projection being used today. Of course, separate orthogonal views have already been used earlier: In China, in Tang Dynasty, the great philosopher and writer LIU Zongyuan (A.D. 773–819) described in his "Biographical Story of an Architect" the drawing of a palace – more than 1000 years earlier than MONGE. Then, what was really MONGE's contribution? His contribution was the basic theory of projection, the kernel of which is the multi-projections of a point. The relation between the multiprojections of a point is a high-degree abstraction of wide scope generality. It makes the projection method become a branch of science possessing solutional function and capable for finding the unknown from the given, regardless the object is simple or complicated, planar or curved. Hence, from its very beginning the essence of Descriptive Geometry is not *representation* but *solution* or *determination*. It might be better to name it "Konstruktive Geometrie", as the German scholars did. Of course "representation" is also very important, therefore MONGE himself named it "descriptive" in view of the fact that the method of an accurate representation was not yet advanced. But at any rate "determination" is a prerequisite. Thenceforth 200 years have passed, the representation method has made great progress, like a colorful dress, but the 'figure' being dressed up is still the projection of a point. This proves the power and significance of the theory. Now the computer technique opened up the way of a new development of graphics, and there are already so many interesting results in different branches. Of course, a branch of science is different from a course of teaching, but the restricting relation is obvious.

Let us try to consider the three main parts of Descriptive Geometry:

- Point, line and plane;
- curves and surfaces (in MONGE's Descriptive Geometry a solid is only the combination of these two);
- axonometric and perspective projection.

The latter two parts developed earlier. In the matrix method of transformation not only perspective affine but general affine transformations are involved. The representation of a perspective projection by a 4×4 matrix penetrates into the concept of a homology.

The part of curves and surfaces is more obvious. 30 years ago, the part of curves and surfaces introduced in most Descriptive Geometry textbooks lagged already quite a lot behind the technology. The reason was the tenacious use of the synthetic method which in this case is far less convenient, accurate and common than the analytic method. Now, following the rise of CAGD in the field of aeronautic, automobile and shipbuilding industries, in civil engineering or light industry, modern surface-design methods have already been widely used. So, in our fundamental course its basic concepts or ideas should be introduced. It is not only a problem concerning the substantial knowledge of surface design, it actually touches the problem of how a university student will understand the objective world and its method of thinking. For instance, the basic idea of how a surface is given, surface patches, etc. This is not too difficult to be included in our textbooks.

Fortunately, some of our colleagues have done excellent and inspirational work. Prof. Daniela VELICHOVÁ of the Slovak Technical University presented her Descriptive Geometry course in the following way. In the second semester, the course includes many interpolation curves and surfaces (COONS, BÉZIER, B-spline and β-spline, NURBS etc.) and related basic concepts of differential geometry. All this is well blended with some selected traditional contents.

As for the most basic part – point, line and plane –, besides the work contributed by Prof. NAGAJIMA and by Prof. RYNE, there appeared a work with still more basic considerations. This was done by Prof. Franco P. PREPARATA and Prof. Michael Ian SHAMOS. The two professors epitomized the various results of computational geometry from the depth of algorithm and construction of computer science, which even covered the work of the famous scholars P. BÉZIER, A.R. FORREST and R. RIESENFELD, and they put forward a more fundamental system based upon the discussion of geometric searching and point location. They announced that the philosophical outlook is inherited from the discipline known as design and analysis of algorithms (or algorithmics). And they stated also that one fundamental feature of their work is the realization that classical characterizations of geometric objects are frequently not amenable to the design of effective algorithms. Could we get any hint from their proposition? If yes, may I ask: Is it true that modern graphics has still to lay its foundation upon synthetic geometry or simply upon ruler and compass?

4 Similarity in history

Since the fifties, there were too many repetitions in the reform of graphics teaching in China. The rise and fall of the contents and quality of teaching were violent. The reason was that undue stress was put on one side of theory and practice which originally were two opposites in a unity. In China, in many courses the teaching and learning of the theoretical parts were seriously weakened in 1958–60: and they were recovered to some extend in 1961–65. But since 1966, practice was extremely emphasized to a kind of absolute predominance, manipulative training was devoted, pragmatic immediate effect was given prominence. The recovery only began in 1976. Several times of repetition wasted enormous time and efforts. Now we are facing the challenge of new techniques, and the new high tide of the reform of graphics education is coming. *There have been astonishing similarities in history.* We ought to learn something from the past.

But from the world history of the theory of education, we see that not only in China, but also in many other countries repetitions occurred. The panel discussion at the Tokyo Conference '94 proved this also. Some scholars even called it "endless discussion". As another example we can study the experience in US. From the core of the argument about the reform based on the Structural Theory of Curriculum in the sixties to the strong movement of "Back to Basis" in the seventies all was carried on around theory and practice, college and society.

At the moment, the main direction of the world education reform is to reinforce the foundation and to develop the ability – despite the bright coloring of its outer appearance due to modern technique. The kernel of foundation and ability is intelligence. Our long-term practice has proved this also: All the students, who are good and quick in drawing and reading, are clearly and orderly minded in basic geometric concepts. There are now rich results of research both in didactics and in psychology of learning. But these results are too much highly generalized for us. So it is natural to ask, what concrete intelligence and ability should be developed in our course? If we can make some further explanation and analysis, that would give a great impetus to the reform of our course.

We do think that it is absolutely correct that the fundamental graphics course draws near to and assimilates nutriment from the design work. But the drawing near to should be in a much broader sense, not so concrete. Because in the overall teaching plan, the graphics course is the only one which bears mainly the responsibility for developing the ability of spatial analysis. And it is also definite that not only the design course needs the contents of graphics. A series of courses needs graphics as important basis.

Summarizing and drawing inferences from the technical achievements of a historical period needs considerable time and selfless work of many people. Fortunately, history has given this rare chance to colleagues of us of present age. The scattered results, both practical and theoretical, are developing to such a gratifying extent that they seem to be waiting for systematization and generalization. Look, they are beckoning to us.

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