

DESCRIPTIVE GEOMETRY: AN INFORMATION TECHNOLOGY PERSPECTIVE

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ABSTRACT

The author claims that descriptive geometry is an early example of information technology (IT) and that it is aimed at the same goals as today's process and product modeling and several other "computer aided" approaches. He supports this thesis (1) by proposing an abstract engineering process model, which is technology independent and (2) by looking at the transition from computer graphics towards product modeling and beyond. He proposes to augment classical descriptive geometry research and teaching with topics covering engineering communication.

1. INTRODUCTION

Before the industrial revolution, the manufacturing processes have been concentrated around a single individual – the master. Master builders were controlling the erection of buildings and bridges, “master blacksmiths” were in charge of the production of simple products made of iron and steel. Their key role in the manufacturing process was a consequence of their “mastering” of (1) the general knowledge required to build such products and (2) they also had the best knowledge about what a single product, that they were involved with at the time, should look like. Excellent examples of this are the great builders of the Renaissance, who were not only great painters and architects, but also had the engineering knowledge required to erect the structures. During the building of the cathedrals and palazzos, they would quite often, in person and on site supervise the building process. Technical documentation, as an instrument of information exchange, has been almost non-existent.

During the industrial revolution, the volume of technical knowledge has been growing rapidly. Several new technologies have been developed. This required specialisation in the profession – no longer could a single master builder handle the entire production process. Communication among the specialists was getting more and more important. It was in late 18th century that techniques needed to be developed, which would enable various specialists to efficiently communicate about the same product. Descriptive geometry provided the underlying fundamentals for the representation of 3D products on 2D paper and for under-

standing them. Precise engineering drawings, using a common graphical symbolic language enabled information sharing. Since then, we have been witnessing the fragmentation of all engineering disciplines. Efficient communication between all the actors involved has become crucial.

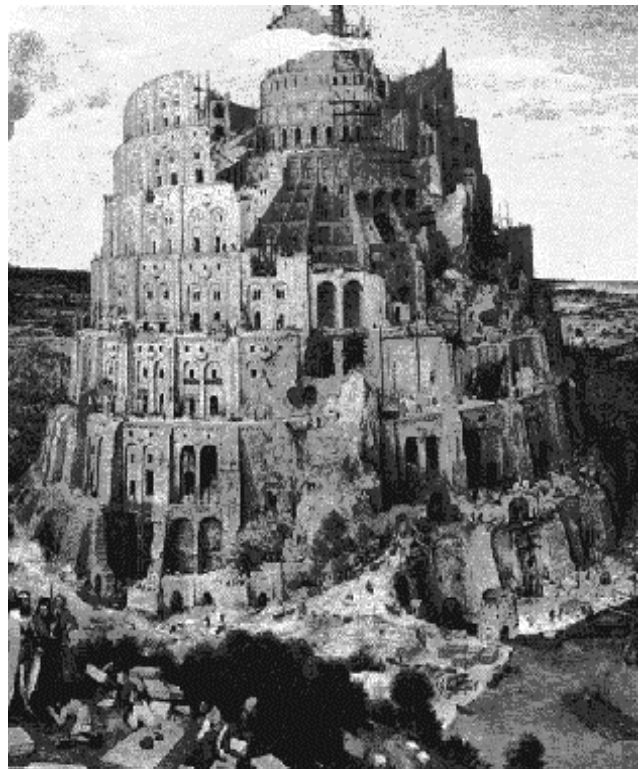


FIGURE 1: Role of communication in building.

Although the transport of engineering information is not as difficult as the transport of material objects, the profession has organised itself in such a way, that people who require common general information or who require to communicate, work together, in the same company or in the same floor. They talk to each other, consult the same books, read the same journals etc. Organisations such as design or consulting firms are examples of grouping people together with the information or knowledge they require. This creates a common orientation of these people, which, as it will be shown in section 4, facilitates communication.

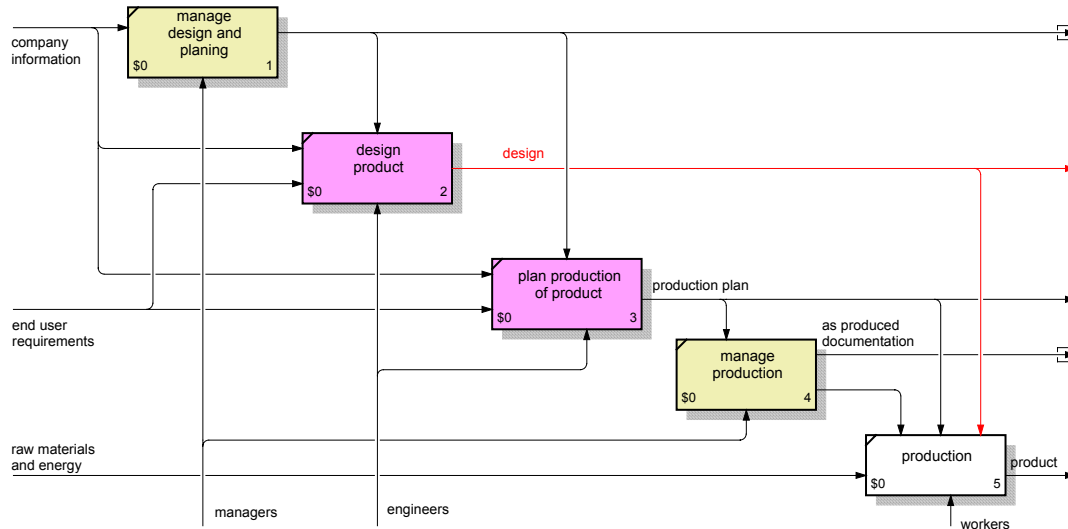


FIGURE 2: Information (shaded) and material processes. Legend: arrow from left denotes input, arrow to right - output, from top - control, from bottom - mechanism.

During the industrial revolution, machines have been invented that eased the transport of material goods. This caused the globalisation of the market for materials. No longer do we have to buy cars or chocolate that were produced near by.

In the late 20th century, technology is being developed, which facilitates the transport of the information. Not only information which is directed towards the masses, like TV, radio, newspapers or books, but of information for information exchange between individuals – phone, fax and, most importantly, computer networks such as the internet.

Therefore, the three organisational patterns of the manufacturing industries are:

1. Workshops controlled by masters, no clear separation between information and material processes
2. Industrial age, separation of information and material processes; organisations specialising in material or in information processes; specialists are organised around information
3. Post-industrial age: information is easy to move, no need to create fixed groups of people around the information; work from home; ad-hoc, per-project teams of specialists.

The transition from pattern 1 to pattern 2 has been enabled by the techniques related to technical documentation, such as descriptive geometry. The transition from 2 to 3 is being enabled by information technology, which includes geometric, product and process models, communication technology and document management systems.

2. AN ABSTRACT ENGINEERING PROCESS

To be able to identify the role of technology in engineering processes a methodology is presented first. In this section, an abstract model of engineering is proposed and information technology is defined.

2.1 Classification of human activities

A very natural classification of human activities in the industry is to distinguish between manual and intellectual work. Manually, humans are involved in different material processes. A process is an activity, which takes inputs and produces outputs, and material processes take mainly material items, such as raw materials, components, and energy, as inputs and produce more complex material objects as output. For example, building a brick wall, using bricks and mortar is an example of a **material process**.

Analogous to the physical works, the intellectual work is involved in the **information processes**. An information process takes information as input and produces information as output. For example the information about the expected load on a wall, mechanical properties of brick and mortar are inputs to the wall proportioning process, and the thickness of the wall is the output. Information and material processes are interrelated. Information processes, such as design and production planning, determine and control the material processes, such as construction (Bjoerk, 1997, Turk, 1997). This relation is depicted in Fig. 2 in the form of the IDEF0 process diagram.

The main information processes in manufacturing industries are product design, production planning, and the management of both the information and the material processes.

In addition to the information and material processes, some other kinds of processes have also been proposed ... e.g. business processes and financial process (Medina-Mora *et al*, 1993). Process oriented view on human activities, both manual and intellectual, has been dominant in this century. Economists like Taylor have built their theories on the improved productivity of the process paradigm. With the invention of computers, computer programs have been seen mainly as information-processing tools, which did fit nicely into the traditional process centred view. Input-processing-output model of computer programs prevails.

Information technology, as the name implies, is primarily concerned with the information processes shown shaded in Fig.2. These information processes can be further broken down into (Fig.3):

- **Base processes**, which create and document new information (e.g. by structural analysis programs, drafting packages, expert systems etc).
- **Glue processes**, which make already existing information available (e.g. transfer of information from an architect to an engineer, search for information on building elements, look up into design standards).

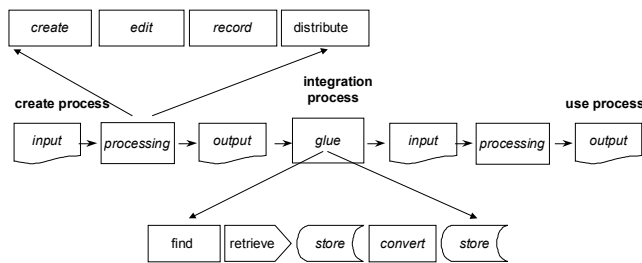


FIGURE 3: Base and glue processes.

The transition from workshop to industrial production pattern also included a clear separation between the base and the glue processes. In fact, printing press, technical standards, and documentation made the glue processes possible in the first place. The exchange of technical drawings that are drawn using certain projection rules and standard sets of graphical symbols is addressing the very same problems, as does the exchange of product data in CAD networks.

2.2 Information technology

Information technology is technology that is used to deliver data, information, and knowledge. It should not necessarily be affiliated with electronic computers, although today these provide the most powerful solutions. Technical drawings, descriptive geometry, copying machines, telegraph, telephone, fax etc. are information technologies as well.

Today, information technology is defined as something which includes equipment, applications, and services that are used by organisations to deliver data, information, and knowledge to individuals and processes (Mentor, 1997).

3. ROLE OF TECHNOLOGY

Technical drawings, descriptive geometry and product databases are the media which enable the information exchange between the different partners in the construction process. This media has the following principal roles:

- Assists in the information exchange between professionals.
- Designers use it to reason about their designs.
- Carries design information.

3.1 Technology to assist in information exchange

TABLE 1: Comparison of traditional and IT supported approaches to engineering communication.

	<i>item</i>	<i>traditional technology</i>	<i>information technology supported</i>
<i>information scope</i>	project	drafts, folders	document management, product and process models
	company	archive, micro-film	data warehouses
	country	library, building regulations	national construction information systems
	world	journals, conferences	global IT networks
<i>actors</i>	man with man	speech, phone, fax, mail	email, video conferences
	man with application		visualisation, 4D, virtual reality, graphical user interfaces
			...
	man with machine	direct manipulation	
<i>time</i>	application with machine		NC tools, robotics, remote sensors
	just-in-time	book look-up, library look-up, phone call to expert ...	database lookup, Internet search, discovery and search agents ...
	just-in-case	reading books, magazines, journals, visiting conferences	subscriptions to customised content
	once-in-time	watching TV, listening to radio ...	not-archived discussion systems, push services ...

The information exchange aspect of a traditional media and of the IT supported approach is summarised in table 1. The rows show the main aspect of communication - what information is transferred, who are the parties involved in the communication and when does the communication take

place. Columns list the traditional and IT supported approach.

3.2 Technology to assist in manipulating representations

In the process of using information, we need the skills to (1) read and understand it, (2) to reason about it and (3) to document and output it correctly. Engineers are required to know how to interpret 2D drafts as projections of 3D objects, they need to have developed skills of spatial reasoning and they must be able to create proper projections in order to share their designs. The role of technology is limited to first and last step:

TABLE 2: Technology to manipulate the representations

<i>task</i>	<i>traditional</i>	<i>IT support</i>
understanding designs	skills to correctly interpret projections	3D models, dynamic projections, virtual reality
spatial reasoning		limited
documenting designs	technical drawing, descriptive geometry, projections, shading	computer generated projections based on 3D models

3.3 Representation of design information

Drawings have been the prevailing method for the representation of the majority of engineering data, particularly in the so called 3D industries where products are solid objects, such as in architecture, civil engineering and mechanical engineering. Design information can be represented in the following ways:

- As drawings on paper, physically composed of dots of ink on paper.
- As electronic drawings, composed of neutral graphical symbols, such as lines, arcs and characters.
- As geometric models composed of faces and solids.
- As models composed of industry specific elements, for example of columns instead of cylinders.
- As product models. A product model is a totality of all information about a product and includes, as one part only, its spatial properties.
- As objects. An object is an abstraction of a real-world entity including methods and procedures and not only data.

The representations have been listed from simplest to most complex form, however, we should bear in mind that they differ in the complexity of the representation and the level of the semantics built into a representation and not in its ultimate power of expression that they can convey. Conceptually, the role of the drawings and that of the product models is the same.

The tendency of the development in the area of the exchange of design information has been towards increasing complexity of the representations. The increased complex-

ity called for elaborate standards. If the drawing standards need to specify the types of lines used to represent a certain design detail, requirements towards the standards are much larger when it comes to the exchange of electronic drawings and models.

In the area of electronic drawings and geometric models, standards such as IGES have been proposed. Because the items discussed by IGES are relatively simple geometric data, there was not much need for the separation of the definition of the concepts and that of the physical formats for information exchange. Based on the ANSI-SPARC work, however, the development of the STEP standards went at great length to separate the application, conceptual and physical layers of information. Within various technical bodies that are developing conceptual models of engineering data, such as buildings, the modelling of engineering data has proven quite complex.

Current directions of information exchange in engineering are towards the collaboration of objects. It is no longer believed that it is enough to move some data from one designer to the other. Instead, the object - representation plus its functionality - should be available to all who are involved in the design of the product. Additionally, more attention should be paid to the design process itself.

4. DISCUSSION

The role of computers in engineering depends a lot on what we believe that humans actually do. The mainstream philosophical tradition, which has its roots in the works of Plato and Aristotle and provides the foundations for the work in cognitive science and artificial intelligence (AI) claims the following:

- Humans do decision making which is in fact a search process in the space of possible solutions.
- Human reasoning is symbolic manipulation of mental images that represent real world objects.
- Reading, writing and talking - communication - is an information exchange process.

Based on these premises the so called strong AI claims that computers are symbol manipulating machines as well and that therefore they could in perspective replace humans in decision making, reasoning and problem solving. They see the role of computers as of that of assistants. Understanding communication as an information exchange process considers information exchange as a key to integrated computer aided design.

It was as late as 1986 when Winograd and Flores (1986), based on earlier works in philosophy, linguistics and neurobiology exposed yet another, perhaps crucial human activity – co-ordination of workflow. In this light the technical drawings or computerised representation of the products cease to be abstractions of some objective reality, which would carry its own meaning or semantics, but merely parts of the speech acts in which humans would request or accept commitments. The design information on paper or on disk

becomes meaningful only in the context of this conversation. The theory they developed, sometimes called "hermeneutic constructivism", is based on the philosophy of Martin Heidegger and linguistic speech act theory of Austin and Searle.

The idea that meaning to "data" is only given to it at the receiving end, is one of the central ideas of hermeneutics. This puts the discussions on the increasing semantic complexity of the design information into entirely new light.

5. CONCLUSIONS

Efficient communication about the designed products is a very important activity in which engineers and other designers are involved. In the 3D industries, drawings and geometrical information constitutes a large portion of design data. Traditional means of communication involved technical drawings and the representation was based on the principles of descriptive geometry. Information technology provides new ways to exchange, manipulate and represent design information, however, only the technology itself is changing, but not the fundamental mechanisms and structures of the problem.

Therefore the author believes that on one hand the teaching of technical drawing and descriptive geometry should be placed within a broader context of communication technology in engineering. On the other hand we should be warned against the seemingly superior representations offered by product models and computerized information exchange. The meaning and the intent of the design does not depend as much on the complexity of the data structures in the product model but on the humans ability to grasp the design ideas quickly and to handle the representations fluently.

These issues have been addressed by the millennia long tradition of technical drawing. Modern IT based research should try to learn from that history.

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