**Zeitschrift:** IABSE reports = Rapports AIPC = IVBH Berichte
**Band:** 40 (1982)

**Artikel:** Closing address
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**DOI:** https://doi.org/10.5169/seals-30917

## Closing Address

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The activity of the structural engineer, or indeed of the civil engineer in general,can be summarized as the art of reconciling enviromental constraints, limited material and financial means and functional goals. This art is exercized as a dynamic process in which a certain body of knowledge must be brought to bear (either through a set of formalized rules,or by use of existing experience, i.e. analogy with past projects), certain data have to be obtained and processed, certain responsibilities fulfilled. Moreover, the flow and processing of data can be characterized - in successive steps - as the synthesis of a conceptual reality (design), the keeping track of a growing reality (construction), the monitoring of behaviour of an existing reality (follow-up of the completed structure during its service life). During each of these phases a running comparison must be effected between actual and expected properties, and corrective actions must be taken whenever the discrepancy exceeds certain thresholds.

And still,in each phase of this process the data will usually be neither complete nor acccurate enough to reach conclusions endowed with "absolute" certainties, so that at every step there will be - whether we are ready to recognize it or not - a risk of error in judgement and hazards to property or lives, as well as legal and financial responsibilities toward third parties.

Thus,the art of civil engineering - far from being the mechanical application of a body of rules, such as the layman is so often bound to envision it - is a largely personal gift born of and grown by experience,intuition and scientific knowledge, all of them applied in a flexible way so as to cope with everchanging, fuzzy contexts.

How can the computer assist the human designer in this complex endeavour?

The most evident feature of the computer is its capacity to handle, recall and process large amounts of data in a very fast and efficient way,provided these data are stored according to certain rules and provided the processing can be defined in a formally nonambiguous way. This explains in retrospect why the first applications of computers to structural engineering were in the field of structural analysis, where formalized set of rules can often be defined, at least as "first approximations".

Now the focus of interest is shifting to more ambitious goals. In the field of CAD and CAM it is now sought to secure the assistance of the computer system also in the more creative, ill-defined phases of design layout, construction drawings, planning, etc.

In a like manner the focus of the "Terms of Reference" of our W.C. is changing: besides cautioning the practicing engineer against improper use of the computer for structural analysis, we should endeavour to grasp comprehensively the full potential of computer application to the integrated process of civil engineering activities. In order to do this, we have to overview the mighty stream of information around and inside civil engineering activities.

I would like to mention that also in Italy, and in particular within my organization, ENEL (The National Power Agency), efforts are under way to set up a system of computer aided design for new power plants.

Also looking at the contents of the papers that have been presented and discussed, the novelty of this Colloquium as compared with the first edition

(1978), or even with the more recent Specialized Session of the Vienna Congress (1980), lies in a shift in emphasis from "structural analysis" to hardware and software systems for CAD and CAM on one hand, microcomputers and computer graphics on the other hand.

Many contrasting views have been expressed, ranging from deep skepticism to sanguine optimism.

Some people seem to think that a nearly complete automation of design activity is in sight (at least within the horizon of the next 10 years) if not just around the corner; they would like to include everything into "computer aided management": layout, preliminary design, structural analysis, quantity evaluation, costing, planning, construction management and accounting.

It is natural to be tempted along this way: the logic of the computer system is powerful and, once you have adopted it for one step of the process, there are very strong reasons for doing the same thing on the other steps as well. But to draw up a rational, feasible plan leading in a carefully thought-over way to complete (or nearly complete) design automation is indeed a formidable task, and we cannot even be sure that it is feasible with present-day means and techniques.

I think it more reasonable to envisage successive attacks on small, relatively well-defined "segments", or phases, of the design activity. In this way, successive advances can be incorporated, experience gained can be brought to bear, errors corrected and the transition from a completely "hand-made" design activity to a "completely automated" one will be made less painful and difficult. More flexibility can be maintained at every moment.

We should also keep in mind that analytical tools of different degrees of complexity are needed in the different phases of the design activity. Normally, just to make an example, a full 3-D F.E. analysis is neither warranted for nor economically justified at a preliminary design stage: simpler methods should be used at that moment, allowing the designer to modify and try again for optimization and making easier an "interactive" working mode.

To conclude, I would like to remark that what we are dealing with is a huge problem in communication between man and machine, and even between different kinds of machines. This reminds me that the dawn of the "Cybernetic era", in which we are now living, was marked by the appearance of a classical booklet by Norbert Wiener, titled "Cybernetics, or Control and Communication in the Animal and the Machine". In this booklet, the process by which either an animal or a cybernetic machine pursues its "goals" is described as a continuous comparison between aims and realization. This same comparison - as I said at the beginning - is central at every step of the design process: the designer is comparing its objectives (in terms of functions, aesthetics, strength, costs, behaviour, time schedule, structural damage or whatever else) with what is achievable or has already been achieved, and takes corrective actions whenever he detects a difference between aims and realizations. The concept is, of course, that of feedback, which is also at the core of "interactivity" and "adaptivity".

Now I try to jump on an other plane of reasoning, a "meta-level" so to speak, and to look - in the spirit of our W.C. - to the process of development of a CAD system. We should adopt the essential process of feedback even on this plane: to begin with the first step of an action, to watch its results and to correct our line of work accordingly. The so called "direct control" approach, in this case starts from complete specifications and runs straight for the complete objective, could well lead to an unstable process, as in a biological and cybernetic system without feedback. The step-by-step approach is not only easier: it is intrinsically safer.

This, I think, both the structural engineer and the "informatician" will have to keep well in mind while developing CAD and CAM.

Thank you for your kind attention.

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