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The Validation of Integrated CAD in Building Engineering Design

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Abstract

The need and the urgency to develop integrated CAD software for building design are well established in industry and academia alike. The means and the approach to achieve this objective are however not so clear and do not meet with general agreement. Even the final product itself - integrated CAD - has different meanings for different people. Like other research groups in building studies, we have developed a number of integrated building design systems in the last few years that effectively combine different activities and types of expertise in a unified approach. For these successful research initiatives, the fundamental issue of validation remains a very difficult one to answer properly. On the one hand, reference cases do not exist to benchmark the operation of an integrated system, as in the case of experimental or empirical processes. On the other hand, no clear guidelines have emerged yet from commercial software developers in the construction industry that claim to have achieved 'integrated CAD' as soon as some form of file transfer exists between an application software and a CAD package. From the study of some integrated CAD systems for building design recently developed in industry and at the CBS, this paper will attempt to circumscribe the main aspects of the validation issue, e.g. what are the characteristics of integrated CAD ? what kind of performance is expected from such systems ? are current systems delivering what building design practitioners need ?

Introduction: Need of ICAD

- For several years, the need and urgency of accounting for integration in the construction industry has been stressed due to [Bédard, Gowri and Fazio, 1991]:
  - lack of productivity
  - loss of competitiveness
  - numerous building failures leading to litigation.

- This has promoted the development of integrated computer-aided design (ICAD).

- In response to this need,
  - concepts
  - approaches
  - products

  have been proposed.

Context: ICAD at CBS

- As an academic institution dedicated to the needs of the construction and building industry, the Centre for Building Studies (CBS) has developed specific
  - courses
  - research projects

  to further the cause of integration.

- Because of the multidisciplinary nature of its faculty and their activities, it is 'natural' to focus on specific technical problems and to develop computer-integrated solutions since the technical knowledge in different aspects is available.

- Numerous examples of ICAD can be given in various areas, some of which are mentioned in the following.

- Leaving aside the development process, <u>how can ICAD systems be validated ?</u>

ICAD Validation Depends on the Nature of the Reference Problem

Case I Integrated design as simulation of a natural phenomenon

- Validation is relatively easy.
- Validation amounts to comparing ICAD results to experimental evidence.
- Validation is easier if
  - only a small part of the entire building design process is covered;
  - that part is amenable to an algorithmic solution and/or backed up by experimental data.

Measure of success: how close to reality ?

Warning:
are scale-down models, algorithms and experimental techniques faithful to reality ?

Example: DEWEN (Discomfort Evaluation in Wind ENvironment)
[Wu, Stathopoulos, Bédard, 1991].

Case II Integrated design as simulation of a human process

- Validation can be inconclusive as there is no indisputable reference concerning human activities, e.g. building envelope design.

Measure of success:
is ICAD capable of producing the same results as human designers ?

Warnings:
- careful not to become case-driven;
- are results produced by human designers the best that can be achieved for this problem ?

- Validation can often be achieved in relative terms only i.e. by comparing relative merits of different solutions against each other.

- Optimum then represents an 'overall tradeoff' solution: in general, the more criteria considered and the larger the number of feasible solutions generated, the better the final solution.

Warning:

For many building design problems, the generation of multiple solutions is not merely a combinatorial process.

- Validation can also be achieved by submitting ICAD results for evaluation to recognized designers.

Warning:

individual styles, local practice, personal preferences and priorities.

Example: BEADS (Building Envelope Analysis and Design System)
[Fazio, Bédard, Gowri, 1989].

ICAD Validation Depends on End-Users and the Meaning of Integration

Case III Integrated design as developed by industry

- There is ICAD as soon as one software can communicate with a CAD (computer-aided drafting) package.

- Variations:
  - some ICAD are poor, inefficient, based on exchanging .DXF files;
  - others are embedded within drafting packages;
  - some integrate across different kinds of software e.g. CAD, KBS, DBMS, or across different disciplines, or across design stages.

Measure of success:

- is ICAD adopted (purchased) by a large number of practitioners ?
- does it make the building design process more efficient ?

Warnings:

- the category of ICAD that is built around existing software tends to be short-lived and idiosyncratic unless the software is basically remodelled to account for integration;
- designers become frustrated with ICAD if it negates their own way of working.

- Not the concern at CBS for now. However issues like portability, user interface, compatibility with hardware and software, documentation can affect the validation process more than the technical merits of solutions.

Example:

Evaluation of integration between structural analysis and design software (AutoCAD). [Bédard, Di Roberto, Rastan, 1992].

Case IV **Integrated design as considered by researchers in building engineering**

- ICAD allows different technical viewpoints to influence the design process.

- Completeness and technical merit are the main objectives.

Measure of success: Total building performance, i.e. after Rush [BSIH, 1985]:

- for all building subsystems (structure, envelope, mechanical, interior);
- accounting for human needs (physiological, psychological, sociological, economic);
- according to all performance mandates (spatial, thermal, indoor-air quality, acoustical, visual, building integrity).

Warning:

- most difficult case for validation as there is no mechanism to exhaustively identify all interactions and their impact among - components - participants - at different times [Bédard, 1989];
- validation can only be accomplished to a certain extent by means of documented evidence, similar case studies from literature, based on subjective evaluation.

Example: Integrated design of multistory office buildings
[Bédard and Mathi, 1991].

Conclusions

- With multidisciplinary knowledge about different building aspects, it is possible to develop ICAD with confidence.

- However as ICAD tries to capture more of the building design process, it becomes very difficult to validate such software.

- A number of issues should be considered to increase the chances of success of the validation process:
  - availability of experimental evidence;
  - relative instead of absolute evaluations;
  - adopted by practitioners;
  - documented evidence.

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