Expanding Design Spaces

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Abstract

Current sustainability design practice is struggling to create design spaces that leverage advances in building technology, computer science, and human collaboration. But the methods for and interest in creating such spaces exists. This paper describes an evolving platform of tools to improve the design spaces that will enable a more sustainable built future.

Keywords: Design, Communication, Integration, Optimization

Introduction

Design research in the twentieth century oscillated between a view of design as a discipline and as science (Cross 2001). In the former, design synthesis is an innately human-centric process aided by technology for documentation and analysis. In the latter, technology is at the center of both synthesis and analysis—design is a technical process from which the best designs emerge. In both cases, design is broadly seen as a process in which stakeholders and computer tools construct interrelated design spaces of objectives, alternatives, impacts, and value in search of the best design (Clevenger & Haymaker, 2011a).

The previous century also saw a dramatic increase in awareness about sustainability—the ability of a designed system to be maintained over time without threatening the stability of other systems upon which it depends (Zhai & Pearce, 2011). In recent years, scientific and practical dialogue has actively sought design methods to enable the integrated sustainability of social, environmental, and economic systems at multiple scales and dimensions. In response, significant progress and convergence in design methods for sustainability are being made. New organizational and contractual arrangements and physical and virtual collaboration spaces make it feasible to assemble large, multidisciplinary teams. New rating systems, guidelines, and codes help define objectives. Building information models and parametric modeling help generate alternatives. Automated analysis tools can analyze energy, structure, schedule, cost, and many other performance objectives. Designers have at their disposal a rich and growing set of human and technological processes for constructing design spaces and understanding and maximizing multi-stakeholder value.

These developments come hopefully just in time. In the next decades, project teams will design unprecedented amounts of new and refurbished buildings and infrastructure. As resources become increasingly scarce, building technologies more numerous, and the impacts of the built environment more apparent, Architecture, Engineering, and Construction (AEC) professionals will need to make profoundly complex and difficult decisions. To find the best designs, they will need to construct and communicate very large design spaces, which help them fully understand the objectives, exhaustively search the alternatives, systematically do the analysis, and explicitly communicate the value of their projects. Even as government, industry, and academic leaders are calling for professionals to apply these new methods, however, successful adoption is proving difficult. There is still a large gap between the available and emerging methods, and the ability of design teams to reliably and successfully and consistently apply them in practice. The traditional precedence-based design processes still taught and in use today construct and communicate small design spaces that leave better designs undiscovered. Project teams lack socio-technical platforms and methodologies that allow them to relate all of these new methods and information to effectively and efficiently construct and explore larger, better design spaces.

Many research fields are relevant to developing this new platform, including organizational theory and social networking, design theory and methodology, building information and process modeling, model-based analysis, multidisciplinary design optimization, decision science, human-computer interaction, economics, and artificial intelligence. Numerous research methods involving ethnography, theory building, tool building, data analysis, and action research are relevant to understanding where existing methods fail and how to better fit and improve this platform. This presentation discusses one ongoing effort to develop such a platform for collaboratively constructing sustainable building and infrastructure design spaces.

The next section summarizes methods to describe the quality and clarity of design spaces and the efficiency and effectiveness of the processes used to construct them. These definitions are then used to illustrate how design spaces are constructed and communicated today. Subsequently, the paper summarizes work to construct an integrated platform of tools. Tests in the laboratory and in practice illustrate the ways in which elements of the platform can individually and collectively improve design space quality and clarity considerably over current methods. Nevertheless, significant opportunity remains to improve the performance of this platform. The presentation concludes with a discussion of future work.

How to Measure Design Processes

To improve design processes, it is necessary to model and measure them. Design theory and methodology, process modeling, lean construction, and decision analysis provide the foundation for methods and metrics for describing and measuring design processes.

Design integrates numerous processes, organizations, and products. To help designers and researchers model and understand this complexity, we develop graphical process communication methods to help teams formally describe and relate these components (Haymaker, 2006).

Design requires communication of processes, but it is necessary to know how to efficiently communicate them. The Mock Simulation Design Charette measures and compares the efficiency and effectiveness of process communication methods (Senescu & Haymaker, 2011).

Design involves the exploration of design spaces. The Design Exploration Assessment Methodology (DEAM) (Clevenger et al, 2010) provides metrics and procedures to measure and compare design processes in terms of the challenge addressed, the strategy implemented, and the exploration achieved.

Design is about making and communicating decisions. The Rationale Clarity Framework (RCF) (Chachere & Haymaker, 2010) helps teams measure how clearly they communicate decision rationale.

These methods for capturing and measuring the efficiency, quality, and clarity of AEC design processes, spaces, and decisions enable the assessment of current practice and provide key insights as to how to improve these processes.

Assessments of Current AEC Processes

My research group employs ethnographic-action research (Hartmann et al, 2008) and laboratory design charettes to understand the performance of projects. We build detailed process models that help us understand the design and analysis tasks that teams perform. We find that designer's tacit knowledge alone is insufficient to guide them for the challenges they face today, and yet they still perform narrow search of small design spaces (Clevenger & Haymaker, 2011b). We find design teams struggle to communicate process (Senescu et al, 2011) and design rationale (Haymaker et al 2011).

We use surveys to test our observations. For example, we found that leading high-rise design firms, consisting mainly of architects, spend many hours generating few options, and analyze them principally in terms of architectural and economic criteria (Gane & Haymaker, 2010). A survey of a leading multidisciplinary engineering firm confirms these observations, and finds that design teams spend over 50 percent of their time on non-value adding information management tasks (Flager & Haymaker, 2007).

In summary, we find in practice today that underrepresented teams develop inadequate statements of objectives and analyses and rely on potentially invalid precedent knowledge to perform limited and superficial search of poorly defined and communicated design spaces.

Platform to Improve AEC Processes

To address these limitations, we have developed and tested a collaborative platform of tools that assist building design teams to generate, evaluate, and develop consensus around far larger and better formulated design spaces than achieved in practice today.

The Process Integration Platform (PIP) provides highly visual and interactive tools to help teams communicate design processes (Senescu & Haymaker, 2011). PIP helps to communicate processes within a project team to improve collaboration between project teams to improve process sharing and across a firm or industry to promote understanding and to drive innovation and process improvement.

Collaborative design generation processes help teams create and manage alternative spaces. Perspectors help teams assemble graphs of geometric transformations that generate and manage dependent geometric designs (Haymaker et al 2004). Multi Attribute Interaction Design (MAID) helps teams conceptualize and relate parameters to discover synergistic interactions that help them tunnel through cost barriers and maximize multidisciplinary value (Ehrich & Haymaker, 2011). Design Scenarios helps them transform these initial parameters into parametric geometric design spaces suitable for multidisciplinary analysis (Gane & Haymaker, 2011).

Analysis processes help teams understand the impacts of their designs. Members of my research group develop, test, and industrialize advanced analysis and optimization processes. For example, ThermalOpt integrates a parametric BIM model (Digital Project) with energy (EnergyPlus) and day lighting (Radiance) simulation engines using an open data model (Industry Foundation Classes) (Welle et al, 2011) to provide an integrated thermal design optimization environment. Biopt is a method for shape and member sizing optimization of steel frame structures (Flager et al, 2011).

Management processes are needed to help teams set up and explore design spaces. For example, the Attribute Management Methodology for Multidisciplinary Optimization (AMMMO) gives designers control over how attributes of building objects are transferred and varied in optimization processes (Welle & Haymaker, 2011). The ability to represent and process so much information requires efficient ways to organize and leverage it to make complex multi-stakeholder decisions. After a design space is constructed, Importance Analysis reveals key parameters on building performance, helping design teams focus their exploration (Clevenger et al, 2008). Multi-Attribute Collaborative Design Analysis and Decision Integration (MACDADI) helps teams integrate objectives, alternatives, analyses, and values to efficiently develop consensus around decisions (Haymaker & Chachere, 2006).

Platforms for bringing multiple stakeholders and their tools together and to orchestrate their interaction are emerging. For example, Filter Mediated design investigates the feasibility of multiple designers and agents collaborating using various interaction protocols around a central model (Haymaker et al, 2000), whereas Process Integration Design Optimization (PIDO) enables the wrapping and orchestration of commercial tools in a workflow (Flager et al, 2009). Collaborative spaces, like the iRoom at Stanford and platforms like PIP, help teams configure an entire socio-technical infrastructure to meet project-specific challenges.

We actively test the tools and platform in the classroom, laboratory, and in practice. Building and communicating high quality design spaces can efficiently lead to improved design. Through this applied research, we are investigating how best to synthesize and use these tools and to train designers in the use of them. In an afternoon, it is feasible to work with a large group of diverse stakeholders to explicitly capture and communicate project objectives; investigate several hundred alternatives for energy, structural, daylight, and other implications; document qualitative analyses on a subset of these options; and clearly communicate which alternatives perform best and why; as well as provide instantaneous data about process efficiency and effectiveness and design space clarity and quality. This stands in stark contrast to the under sized and poorly communicated design spaces designers are able to explore today.

Conclusion

This presentation summarized one ongoing effort to develop an integrated process platform for efficient and effective construction and communication of design spaces. This, and research in other labs referenced in our papers, represents an emerging and exciting new paradigm in design for sustainable buildings. The two views of design research from the last century – discipline and science -- are merging, but there are many cultural and technical challenges ahead. Multidisciplinary engineering needs a common language, a platform of fully realized tools that allow designers to design and broadly communicate processes and results. I see several steps to creating such a platform: incentive structures that enable academic researchers and the software industry to invest the time needed to develop the platform; training and time for designers to use and perfect the platform; and case studies to validate the need for and further improve the platform. My hope is that the power of such a platform can transcend the current political, economic, and technical barriers that keep us from making sustainable decisions.

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