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[make]SHIFT: Information Exchange and Collaborative Design Workflows

:abstract

This paper explores design processes requiring the invention and implementation of customized workflows for the optimization of design information exchange. Standard workflows in design software are typically dependent upon the use of proprietary file formats to communicate design intent across the design team. Software platforms promote “one-stop-shop” proprietary approaches to BIM where all team members and consultants ideally operate within a single model environment and store information within a single file format. While the ‘single model’ approach can be effective under some circumstances, this approach is often found to be limiting when the design process calls for the integration of other design toolsets and delivery processes. This is especially true for large complex projects where multiple participants with different software requirements need to collaborate on the same design. In these cases, various non-standard ways of working are often implemented, resulting in a new means of communicating design and building information across a team.

This paper will outline the impact customized workflows have on the design process at NBBJ and evaluate their potential for leading to more innovative design and integrated teams. The first study will explore and evaluate the communication and collaborative process that took place in the design development and construction documentation stages of the Hangzhou Stadium. The second study will be an overview of ongoing investigation and experimentation into customized workflows for team and data integration.

1 Introduction

Building Information Modeling (BIM) is currently at the forefront of the mainstream conversation regarding the use of digital technology in architectural practice. Through the use of single integrated models, the goal of BIM is to "positively impact the cost and schedule" through the optimization of communication and documentation workflows (Krygeil, 2010). Commonly used BIM software packages create models using proprietary file formats to store building information and communication among the team and is dependent upon the use of a specified platform.

While the ideal BIM scenario has many benefits, a fully integrated BIM process is still quite rare in everyday practice. The problems with an integrated process stem from the challenges associated with coordinating multiple participants with different technological needs, work scope, and decision-making processes (Figure 1).

These considerations are made even more challenging with international work given greater technological divides and communication differences. Several considerations related to this include:

1. Differences in preferred technologies between architects, collaborators, consultants, and local builders.
2. The contractual limitations of working internationally and the resulting production split between international architects and local architects.
3. The fluidity of the decision-making process and the possibility of major late-stage changes in design direction.

With respect to these factors, it often becomes necessary that the design team adapts to a given situation by developing and implementing various non-standard workflows into the design process. These workflows

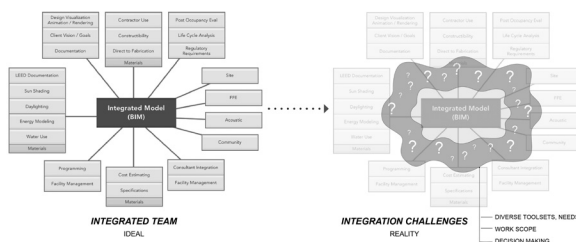


Figure 1. Challenges for team integration and building information coordination.

generally begin as highly specific solutions to immediate problems that cannot be solved with functionality given in out-of-the-box software packages. The process is tactical, responsive, and sometimes untested; however, the continued reuse of a particular solution can sometimes lead to optimized and innovative design and communication workflows.

This paper will outline the impact customized workflows have on the design process at NBBJ and evaluate their potential for leading to innovative design and integrated teams. The first study will explore and evaluate the communication and collaborative process that took place in the design development and construction documentation stages of the Hangzhou Stadium. The second study will be an overview of the ongoing investigation and experimentation into customized workflows for team and data integration.

2 Hangzhou Stadium and International Collaboration

The Hangzhou Stadium is an 80,000 seat multipurpose stadium located in Hangzhou, China (Figure 2). NBBJ partnered and collaborated with CCDI to design a vibrant, pedestrian-friendly sports and recreation development located in the midst of Hangzhou's expanding urban environment. The stadium is sited on the Qian Tang riverfront opposite of the new Central Business District. The entire sports park encompasses a site of approximately 400,000 square meters. For the city, the sports park is seen as an opportunity for creating picturesque and sustainable public spaces that are often elusive in the newly constructed urbanism of China.

A major component of the strategy was NBBJ's use of advanced parametric modeling techniques to design and document the complex geometries of the exterior stadium shell (Figure 3). The use of a parametric algorithm



Figure 2. The Hangzhou Stadium designed by NBBJ and CCDI.



created many advantages for the project such as enabling rapid response to design changes, documenting complex information, and optimizing the structural performance (Miller, 2009). However, while parametric technology enabled an efficient design and modeling process for the NBBJ team, there were several challenges in developing the proper workflow to ensure the successful transmission of design intent to all participants.

Before proceeding with design development and construction documentation, it became necessary to delineate an information exchange process which took into consideration the technological preferences and skill sets of the participants (Figure 4). These considerations were only made more urgent given the complexity of the exterior shell geometry in combination with an extremely tight production schedule. While a rough framework was established early on, the actual implementation of the workflow required trial and error and experimentation in order to achieve a robust communication system between participants.

The first challenge was establishing an information exchange procedure with the local architecture team at CCDI. Because the client deliverable for construction was 2D documentation, the local architect's team was organized for production using CAD drafting. However, the complexity of the 3D geometry made it necessary for NBBJ to design and implement a workflow that translated the 3D parametric information into 2D drawing backgrounds. In addition, NBBJ also had to provide comprehensive 2D documentation describing the geometric construction of complex 3D surface elements.

The NBBJ team utilized Grasshopper for the development of the parametric algorithm and implemented a workflow for translating the 3D geometry into Revit for documentation. This particular workflow utilized standard file formats, such as ACIS, to import and export key 3D geometry between the modeling platforms. (Figure 5) The modular geometry of the stadium made it easy to set up a lightweight export procedure for a single structural module. The module was imported into a Revit family editor and then loaded into the project environment. Instances of the structural module were then copied and placed relative to their corresponding gridlines. When a family component was updated from the Grasshopper model, the entire assembly of family instanced modules would also update. The strategic coordination of the import/export procedure allowed the team to adapt quickly to changes with a minimum amount of information transfer between programs.

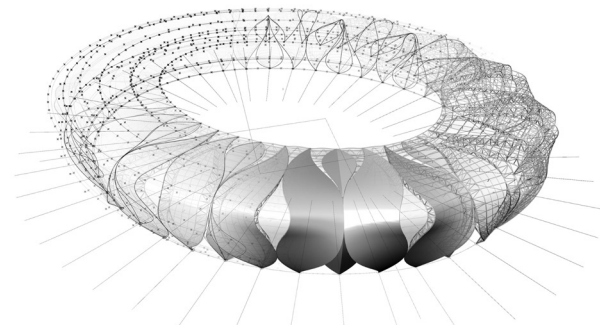
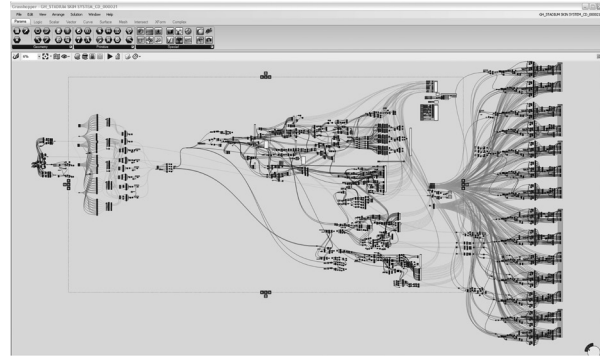


Figure 3. The Grasshopper algorithm used by NBBJ to design and document the exterior stadium shell.

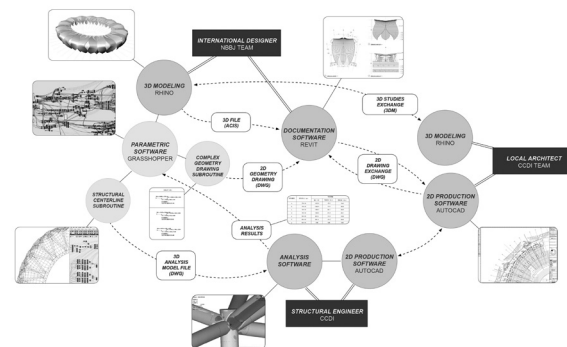


Figure 4. A diagram of the 2D and 3D information exchange processes used on Hangzhou. The framework was primarily peer-to-peer using model exchange for specific parts of the design.

The Revit environment made it easy to assemble the design components into a 2D document set and provide typical orthographic backgrounds which were handed over to the local architect (Figure 6). It became obvious, however, that conventional plan, section, and elevation documents produced in Revit were not able to fully describe the exterior ruled-surface shell geometry to adequately convey the design intent. A subroutine was created within the Grasshopper parametric algorithm. This provided the NBBJ team with the means to produce non-orthographic documentation such as unrolled

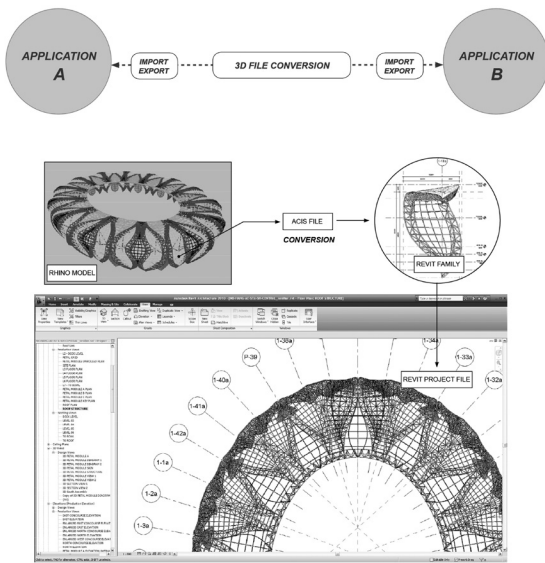


Figure 5. A diagram for using 3D file conversion to transfer model components across applications.

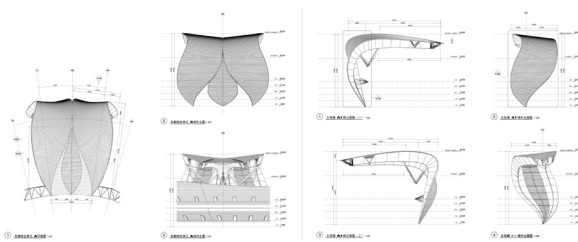


Figure 6. NBBJ's orthographic documentation from the 3D Revit model.

surface diagrams and geometry spreadsheets describing the curvature conditions along the ruled surface edges. (Figure 7) The geometric information could be used directly by the structural engineer, and façade consultant as a starting point for understanding the 3D surface curvatures for fabrication.

The second major challenge that needed to be addressed was the creation of an efficient way to coordinate the parametric form generation system with the requirements of the structural engineer's analysis software packages. With simpler geometry, the engineers would typically rebuild the structural geometry to analyze and document the design. However, the shortened schedule and the complexity of the exterior shell necessitated that the NBBJ team use their parametric model to generate an accurate analysis ready model which could be used directly by the engineer's software.

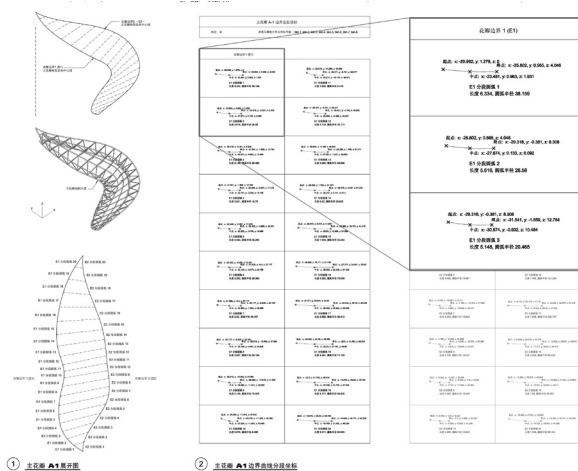


Figure 7. NBBJ's geometry spreadsheet documentation generated from the Grasshopper algorithm.

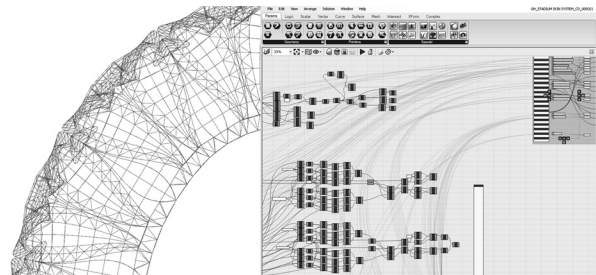


Figure 8. NBBJ's 3D centerline model generated from the Grasshopper algorithm.

The structural analysis software required centerline information formatted as individual line segments (for the structural tubes) and node points (for connections). In response to this, the NBBJ team developed a customized subroutine attached to the main parametric algorithm. The subroutine formatted the architectural geometry by segmenting the B-spline geometry into segments and ensured the alignment of all connections at the node points (Figure 8).

Because the curves had to be rationalized into segments, additional parameters were established to control line resolution for both basic and detailed analysis. The centerline model was exported as a 3D line file organized into layers corresponding to member type. The file was then analyzed to calculate structural member sizes and design the steel connection points. The structural engineers were able to perform various

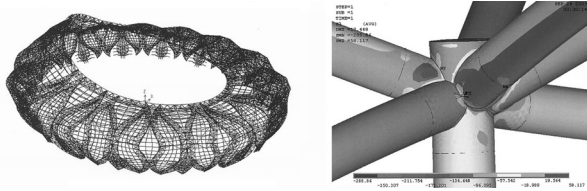


Figure 9. CCDI's structural analysis of the 3D centerline model.

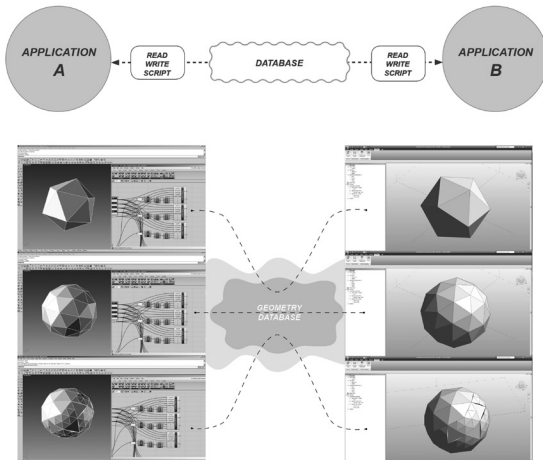


Figure 10. A diagram showing the coordination of two software applications via a geometry database.

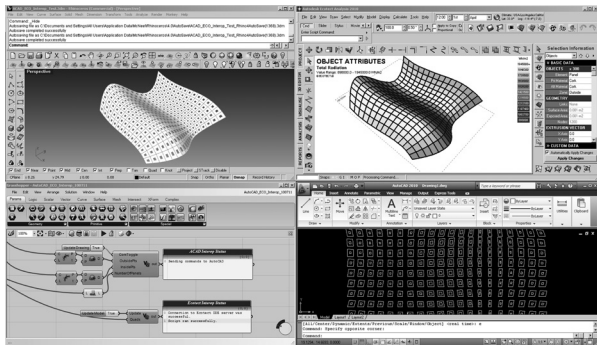


Figure 11. A diagram demonstrating inter-process communication to form direct links between different design, analysis, and documentation environments.

structural tests and identify structural problems as well as information related to structural member sizing (Figure 9). The information feedback allowed for the steel structure to be optimized for significantly reduced steel consumption when compared to stadiums of similar size and complexity.

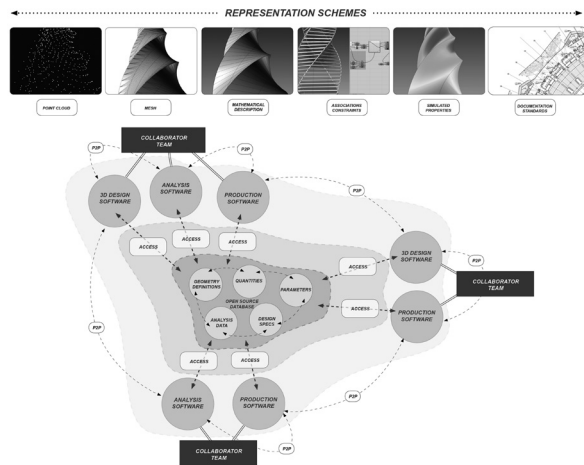


Figure 12. A diagram for a dynamic team coordination process leveraging multiple tools, workflows, and 3D representation schemes.

3 Feedback Cloud: Integration Methods and Workflows

The success of the Hangzhou collaboration was due, in large part, to establishing unique, rigorous working processes for information transfer. The processes enabled communication of critical information among a diverse team using multiple software platforms. However, the processes used during the Hangzhou Stadium project were not perfectly seamless and were the result of trial and error using primarily file import and export procedures and workarounds.

To build on the lessons learned from Hangzhou and to ensure successes in future collaborations, various tests and experiments have been devised to test the coordination of diverse skills and toolsets through the implementation of non-standard, customized workflows.

The main considerations are as follows.

1. **Interoperability:** Finding methods for coordinating multiple modeling environments and interfaces. The movement of information across a system takes primacy over any one interface or software solution.
2. **Design-Analysis-Documentation Feedback:** Setting up a dynamic framework for linking together different design, analysis, and documentation tools.
3. **Seamless Design Collaboration:** Connecting diverse participants together for minimizing redundancy and information loss.

3.1 Interoperability

The experience from Hangzhou shows that the biggest challenge for team integration was in the coordination of information coming out of different toolsets. Hangzhou primarily used file formats for transferring information. However, this process always resulted in a 'hiccup' requiring time to prepare geometry and send it using the proper conversion protocol. As an exploration in alternative methods, a system for transmitting raw geometric data through a database was devised (Figure 10). Information such as points and vectors are transmitted and exchanged through a database using custom scripts and API plug-ins. In contrast to emphasizing a single format or model to capture building data, this scenario streams information in an open, relational manner between software.

3.2 Design-Analysis-Documentation Feedback

In addition to general software integration, task specific workflows using direct inter-process links are also being investigated. Typically, the link between design, analysis, and documentation software is still not an optimized process. Usually, designers will use a design-analyze-rebuild working method when attempting to optimize their design using analysis software. Figure 11 depicts inter-process communication techniques being used to enable a direct and live design-analyze-document workflow between three different software

environments. The inter-process bridge allows for information to be transferred across application and forgoes the workflow hiccup of converting geometry to different file formats.

3.3 Seamless Design Collaboration

By developing and coordinating different communication techniques, the hope is to create opportunities for seamless collaboration regardless of the interfaces or modeling tools different participants would be using in the design process.

4 Conclusion

Team integration and the integrity of information are of the utmost importance in a industry made up of diverse trades and toolsets. Currently, out-of-the-box software solutions that promote team integration cannot fully account for the complexities associated with contemporary practice. As demonstrated by the Hangzhou project, inventing customized workflows are a necessary part of the design process and have a profound impact on the delivery of the architecture. Looking toward the future, various workflow methodologies continue to be explored for better team integration, collaboration, and the production of architecture.

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