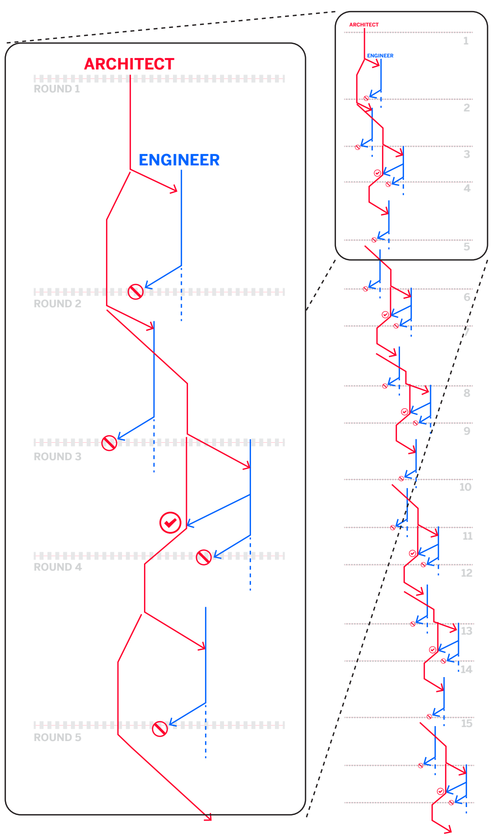
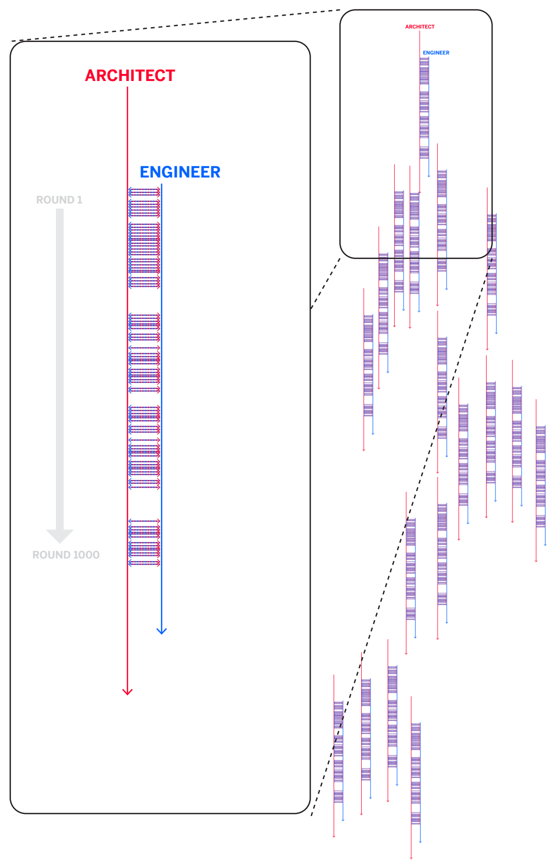
How can collaboration between engineers and architects be more productive in the early design stages?





The TRADITIONAL collaboration process often puts the architect and engineer at odds with each other by setting up a relationship where solutions are either a back and forth volley or a miss and wasted effort.

ARCHITECT: Parametric modeling has opened the possibility for digital models to respond to information, but the challenge is getting useful performance data in the early design stages. When this data is available it is often in a format that does not easily plug into the parametric model which effects how many iterations we can look at and the depth of understanding we can draw from the studies.

ENGINEER: The architect's design is constantly changing while we are in the middle of our design process. Even with the use of generative tools, if the design changes enough, the models have to be rebuilt, re-analyzed, and updated for documentation. All of this takes time, and it's important that we get it right.

The PROPOSED collaboration process looks to the dissolution of the architect-engineer divide during the formative stages of design by having the design team (architects + engineers) focus on the development of both project and process strategies.

ARCHITECT: More effort is involved up front, but the ability to look at performance data over a larger number of iterations offers new design potential. Instead of deliberating over one scheme which could be inherently flawed, we can test multiple schemes. This also allows us to more efficiently search for optimal solutions using test optimization scripts on a given set of parameters and fitness levels.

ENGINEER: We should be involved in the design process as soon as possible. Early integration of engineering knowledge has the potential to greatly inform the design by providing meaningful feedback, explanations, and design analysis. Analyses are automated where possible, and data is exchanged in near real-time, freeing the engineer to explore alternative approaches and provide meaningful explanations to the design team.

INTRODUCTION

Emerging computational tools have opened new efficiencies in the design process, and we seek opportunities to increase the value of designers (architects and engineers) as service providers. Of paramount importance is the generation of ideas, informed by both the iterative process and the unique results of human engagement through collaboration.

We are interested in the minimization of laborious production, and the use of analysis processes to enable a greater prominence of human instinct, intuition, whimsy, and will in shaping the design work. The reengagement of the engineer and architect is our goal, forging collaborations which are freed from the tedium of manual iteration and more fully immersed in a holistic and engaging design process.

First and foremost in our effort will be the need to define more rigorously what we as architects tend to liberally determine as 'performance criteria.' There are 'laws' by which our projects must be defined, and 'rules' which we subjectively determine and assign as designers. In this new process we will parse these, and send the 'laws' through a new automated workflow, freeing the design team to more intensively study and test many sets of 'rules' as ideas.

CONTEMPORARY CONTEXT

Enter performance driven design. By establishing quantifiable design performance criteria and measuring the corresponding performance metrics algorithmically, designers are able to provide explanations for what makes one iteration better than the next. Computation is used to measure and generate performance data, and the design team can act on this information in future design iterations. When realized within a generative modeling environment (like Grasshopper or Digital Project) this strategy opens the door to computational design optimization based on performance criteria and calculated fitness.

Even with BIM tools and performance driven design workflows at their advanced level of maturity, the schematic and pre-schematic design phases of an architectural project are usually completed before collaboration with consultants begins in earnest. There might be an initial meeting to be sure that a design direction is feasible, but there is rarely deeper collaboration. A problem that hinders tight collaboration during the conceptual phase is the fact that architects and engineers tend to work in different formats. Architectural concepts are usually delivered to engineers as 2D drawings or mesh models developed in 3D rendering programs. These models generate high quality visuals, but tend to be impossible to turn into structural 3D analysis models. Hence, the structural engineer spends a large part per each design revision to manually convert the architectural deliverables into useful analytical models.

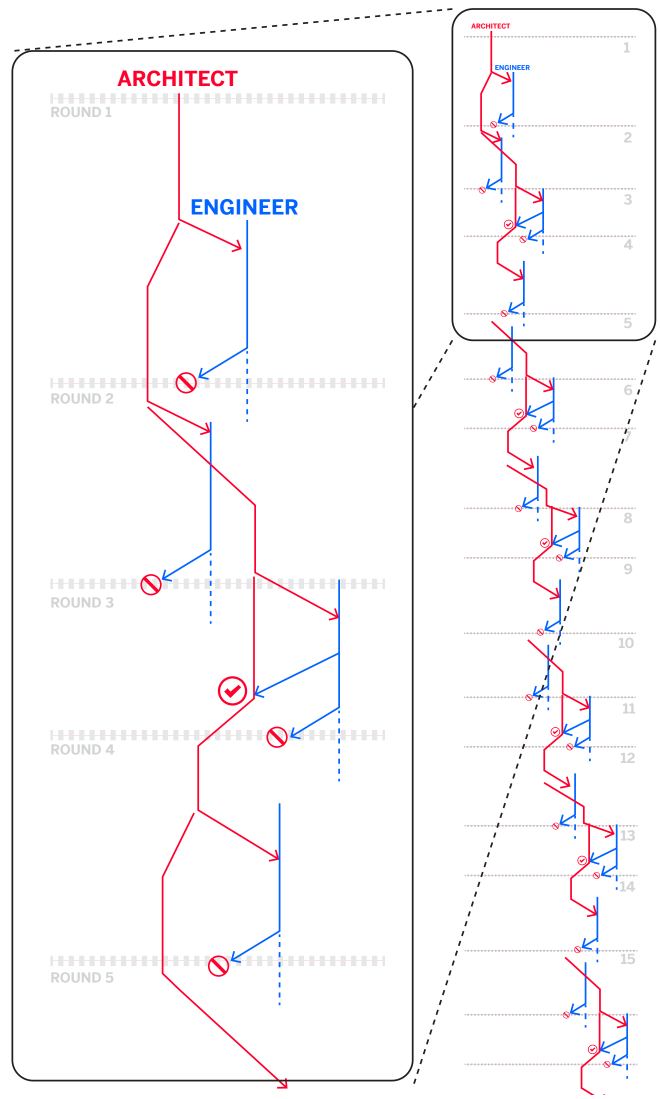


Figure 1. The contemporary collaboration process suffers from wasted effort due to rapid design changes.

This has something to do with the pace a project develops at during its early life. Competition work and feasibility studies usually happen in a matter of days – weeks at the longest. Hundreds (if not thousands) of design decisions happen during this period, decisions that have a profound effect on the later development of a project.

Analysis is usually not performed during this stage. Again, this has to do with pace. With so many design iterations happening so quickly, detailed analysis of any one iteration is usually moot by the time it is completed – the design has already evolved.

This problem is not confined to the earliest design stages. As a project moves into late schematics and design development, another facet of the same problem arises. For engineers to perform detailed analysis of a structure, the level of architectural resolution has to be high, but the design is still young and typically has low to medium resolution from a systems point of view. Engineers typically make educated assumptions to flesh out their analysis models, and tell architects where the

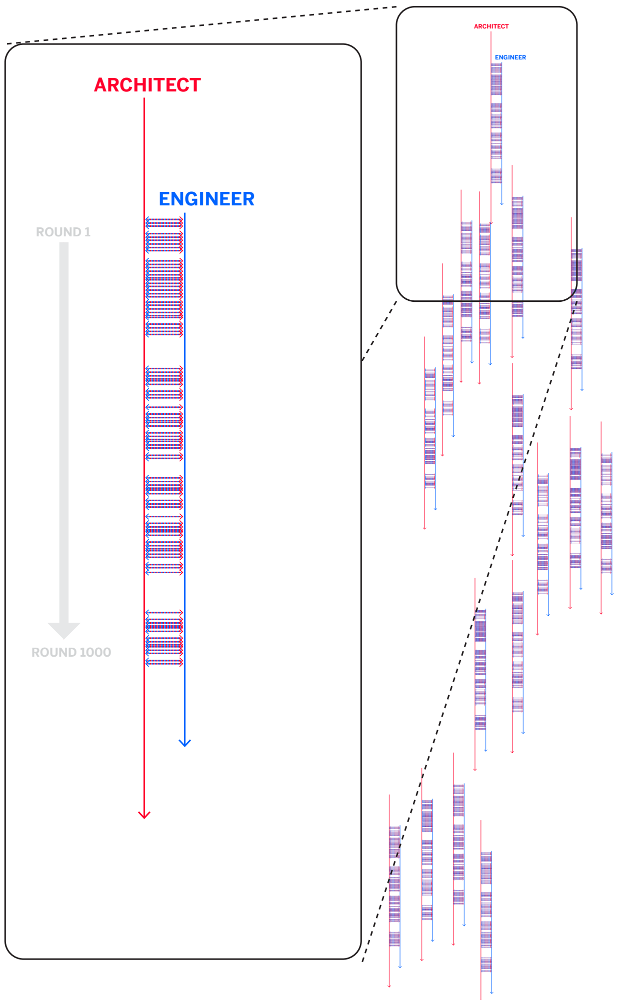


Figure 2. The proposed collaboration process ties together the workflows of the architect and engineer in an effort to explore a greater number of iterations

problem areas are. Again, by the time one cycle through this process is complete, the architectural design has evolved, and the engineering feedback might or might not be applicable to the most current design iteration.

SOLUTION

In an ideal scenario, collaborative performance driven design is productive at every stage of the architectural design process.

The goal of the proposed system is to form a feedback loop between the architectural design ideas, and the performance analysis results. The structural analysis model, which is hosted and maintained by the structural engineering team, is directly informed with building parameters from the architectural team. In return, the structural results, which are generated within a matter of minutes, rather than weeks, ought to inform future design iterations such as daylighting analysis. This process loop extends further as the project progress, integrating more forms of analysis and continuing to refine the design direction.

With a rigid data exchange framework between architectural and engineering data, a building's design fitness can be accurately calculated at sufficient pace so to keep up with the design team. When using automated data input and extraction methods, this would happen at a pace fast enough that many design vectors can be explored in parallel, with vastly more [meaningful] data being exchanged along each vector.

The designers in this process, both architects and engineers, spend most of their time formulating the problems (fitness function and DPC development, what data do we need to exchange?) and evaluating their design decisions. By allowing the empirical calculations and data exchange to be performed computationally, more of the design team's time can be spent exploring design ideas and explaining why some ideas perform better than others.

Our research team has developed an information exchange technique that requires neither collaborative modeling, nor sharing of CAD data. Not even the same software platform is required for this proposal to work, though for this proof of concept, it was decided to utilize Grasshopper.

A database format has been established by the architecture and engineering team, which allows floor outlines, column and beam locations and grid lines to be exchanged seamlessly. The architect's database server 'deconstructs' their building geometry into vertices and information about order and type of connectivity. The engineer's database client reconstructs the information to produce an analytical wireframe model.

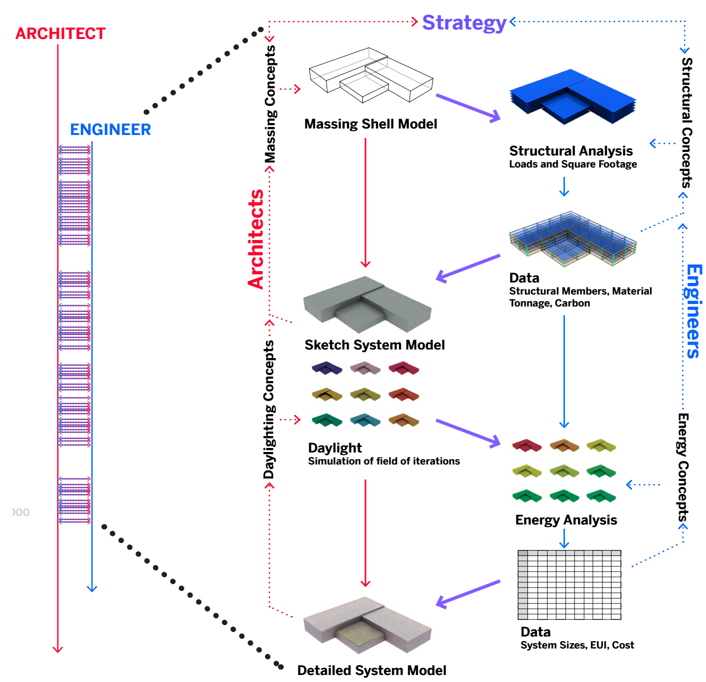


Figure 3. The design process continually builds on previous steps, retaining the ability to test new approaches from the beginning.

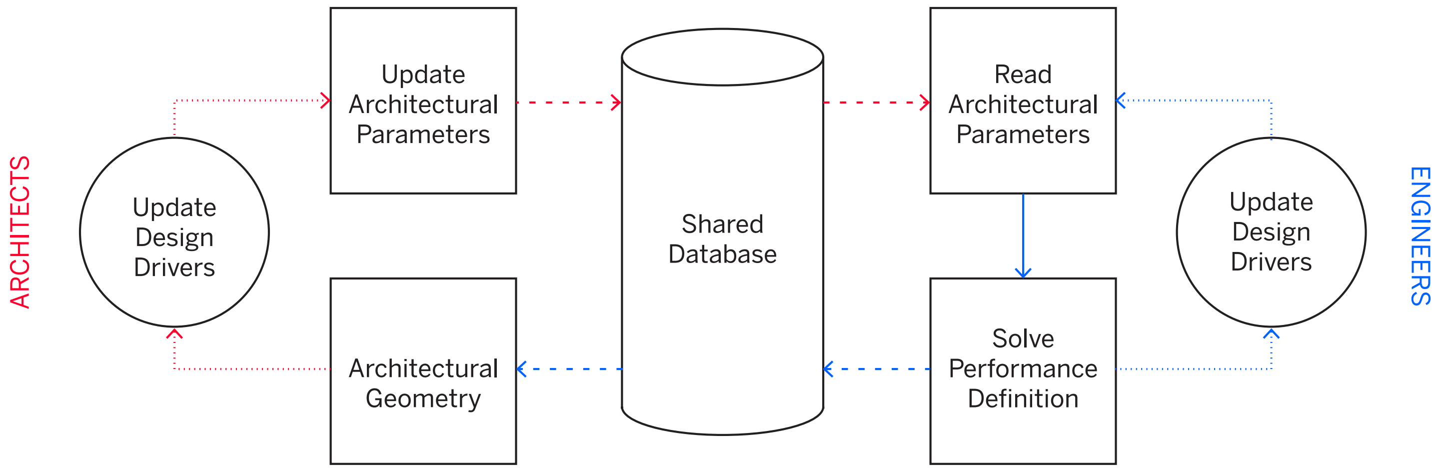


Figure 4. Analysis process is automated through the exchange of information takes place through a shared database

The information that is passed back and forth can be adopted to the specific building type, and based on the design focus.

Architect and engineering team have to decide on a number of key geometric parameters, which can seamlessly be exchanged via a web-hosted database. The architect sends the information that is necessary to describe their building geometry accurately to a shared database, and informs the engineer's machine when the upload is complete. The engineer's modeling software then constructs an analytical model, applies materials, loads and constraints based on building type and building code and triggers the structural analysis. Once completed, all structural elements have been sized, and overall material quantities have been determined. With this information, a rough material cost calculation, and embodied carbon content of the structure can be calculated.

This high level information is then written into the shared database, and the architectural design model is informed with accurately sized structural framing and performance data. The architects then review the model within minutes of sending it, which informs their decision about the next design iteration. Alternately, the structural data could inform further analysis such as daylighting, which can inform energy analysis, and so on.

In this way, analysis operations can be lined up so that each successive stage of analysis can be more accurately informed. The data is also used to inform further development of the collaboration process by looking for new simulation opportunities or approaches.

As part of our continuing research in this field, we plan to develop a prototype in the coming months, which will demonstrate this holistic approach to performance driven design.

CONCLUSION

A closer collaboration between architects and structural engineers will vastly improve our projects and professional practice. If we detach ourselves from the tedium of conventional consulting, we are given more time and flexibility to study our designs. With this improved process, the extra time provided will allow designers to focus more on the creative elements of projects. This enables intuition and sensibility... the conceptual generators which often get brushed aside in the name of production.

Instead of deliberating over one scheme which has the potential to be inherently flawed, this workflow allows multiple schemes to be more easily studied. The process enables the intuitive and the scientific, the qualitative and the quantitative.