REFLECTION

Investigating Principal Stress Lines: Optimization of Gridshell Structures

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REFLECTION: SCIENTIFIC RELEVANCE

The form finding methods outlined in this thesis were a success, and the application of a variety of form finding algorithms did yield more efficient structural solutions within the standard context of particle spring loading methodologies. These methods more accurately model real world loading characteristics to a digital form finding mechanism. Form finding via analytical solutions through determining the moment surface is also a viable option for most shells. The system yields results with average shell behaviors often high in the 90%+ range, as shown in Table 6.3, while dealing with complications that analytical structures have difficulties with, including mixed height supports. This form finding system was also shown to be viable for gridshells developed from this structure reaching scores averaging 81.7% from Table 8.1

The second part of the thesis, however, was less successful. There were several issues that occurred within the thesis. Firstly, streamlines even when mapped to a 2D mesh of the original shape to reduce integration step errors are not usable as a method of optimization. The streamline generation along principal stress vectors for gridshell development requires the result to become a discrete grid unlike most other engineering applications of streamlines. Typically streamlines are used for visualization of flow analysis rather than generating a connected network. Even through the use of mapping to a 2D surface and only working with orthogonal vectors, the system still did not efficiently work. The result yielded a messy and unrefined structural flow even in the event of a fully parameterized design.

While this paper does eventually develop a gridshell, it requires significant manual editing and development that is unsatisfactory for a fully parametric model for optimization. Some of the reduction was developed later on in the thesis, but would need to be more rigorously tested before implemented fully in an optimization algorithm. One of the designs chosen to compare against the base system was also in the end developed via black box methods. This was because the periodic global parameterization engine was not viable to run within the Grasshopper3D system. This would have needed to be fully rewritten from base discrete differential geometry in order to be implemented, which was unfortunately beyond my current capabilities and the time scope of this thesis.

Instead, this paper in turn explored multiple current methodologies with none being quite satisfactory from a parametric perspective. While this is in no small part due to my failure at understanding the complex mathematics of discrete differential geometry, it shows that this method is relatively impractical for the architecture student. This is confirmed by the primary papers in the field being a PhD thesis from civil engineering and other conformal mapping papers being co-written by mathematicians focusing in discrete differential geometry.

Instead, the research presented at the end of the paper that focuses on the plate behavior and utilizing structural theory may provide a better solution.

My belief is that this method of examining principal grid layout appears to be correct on the surface in order to generate grids for all forms, but is inherently flawed. Since principal stresses are a second order tensor and a directional derivative of derived stresses, these are often non-smooth. In order for the data to be viable either intensive smoothing processing or curl correction would need to be applied. Secondly, often times, principal stresses can be plotted far more quickly by hand than by utilizing this system, while slightly more difficult on more complex surfaces, often time engineering intuition will be faster than that of utilizing parametric systems.

RELEVANCE FOR SUSTAINABILITY

The thesis relates to Building Technology by attempting to map 2nd order tensor sets using computation to generate more efficient lightweight and thin structures. Thin, lightweight and open structures such as gridshells are becoming more common around the world by the year because of their high span to structural depth ratio due to their form. This therefore attempts to further discretize the issues of the structure and also optimize their topology.

Discrete mapping of principal stresses would be useful in a variety of structures, however, there are more efficient ways of developing such structure if loads are concentrated at a point. But for structural systems under continuous load conditions made of bar elements, further work is required and my belief is this thesis has highlighted directional areas for future investigation in order to achieve these objectives.

By reducing the mass of steel required to create gridshell structures of the same span, the CO_2 equivalence required in order to create these structures is further reduced. This, in turn, results in more affordable and more sustainable long span roofing structures creating more viable open spaces in protected environments.

RESEARCH PATH

The research method was unfortunately not well defined. The examination began at wanting to optimize along principal stress directions which took a turn into examining mappings and mesh parameterization, while also diverging to examine plate mechanics and shell mechanics at the same time. I believe that members of the academic community with more advanced mathematical knowledge will be able to derive a more useful surface, and in fact in some cases have done so as seen with Winslow's PhD Thesis. Had this thesis focused instead on only one singular direction and track, a clearer and more developed thesis would likely have been developed. The main issue is that there were far too many parameters to examine in the scope of one master's thesis and would make a much better doctoral thesis, as evidenced by Winslow's thesis from 2010.

CONFLICTS OF INTERESTS

There were no conflicts of interest during the thesis.