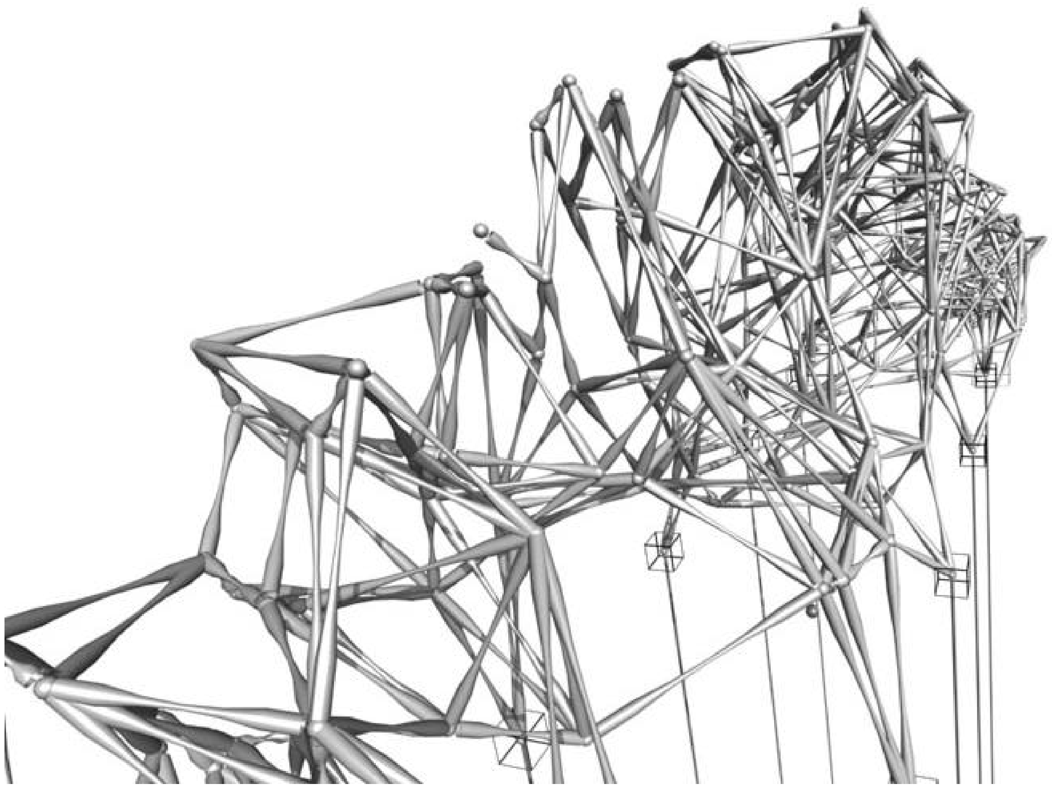
Short description of the project.

The context and long term goal of the project is to develop design environments in which the computer becomes an active and creative partner in the design process. The intention is to set up a system that enhances the act of design by suggesting possibilities and proposals to the user, instead of one that would merely be based in optimising an already existing design.

The work develops around the general concept of morphogenesis, the process of development of a system's form or structure. Besides the obvious example of embryological growth, biological evolution, learning, and societal development can also be considered as morphogenetic processes.

Drawing on D'Arcy Thompson's ideas and inspired by the successes in the field of Artificial Life, the project explores the possibilities of using a model based in bone accretion to develop structural systems. The mechanisms by which bone is able to adapt are relatively known and simple, and at the same time they address a sensible problem, such as that of the static performance of a structure. The problem is anyway approached not with the intention of finding optimal solutions, but challenging and creative ones. It is not answers the computer should provide, but questions about the problematic of the design. It is in this context of "problem-worrying" (as opposed to problem solving) that the work has been carried.

This enhancement of design through the computer touches also upon issues related to customisation of production. Instead of a fixed design, non-expert users or clients would interact with an open system and co-design together with it the desired product, adapted to their specifications and particular preferences. In this setting the new role of the designer would be to build systems that allow a multitude of possibilities, and to imbue those systems with the capacity for proposing feasible and sound suggestions to a user. This way, a creative process could also unfold from the back and forth interaction of the computer's proposals and the user's decisions and refinements on those proposals. Another implications of such design methods refer to aesthetics and the qualities that such "machine designed" objects may have, something that I believe, could eventually constitute a step in design of similar importance as the one between man-made and machine-made objects during the industrial revolution.



1. tension members of first example.

The design context that has been chosen addresses a specific problem as it is the design of three-dimensional structures, but actually the general principles can be applied to a multitude of different problems. The algorithms can easily be adapted to other problematics comprising the design of networks (for example, layouts of buildings or cities, using for instance simple network calculations).

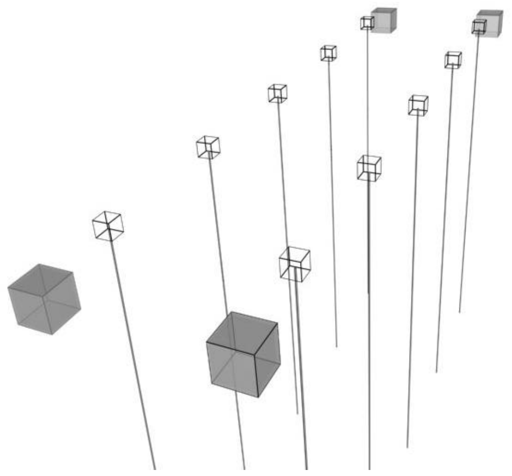
Current state.

The stage the project has reached so far is that of a first working algorithm, which was presented at the Generative Art International Conference in Milan, in December 2001.

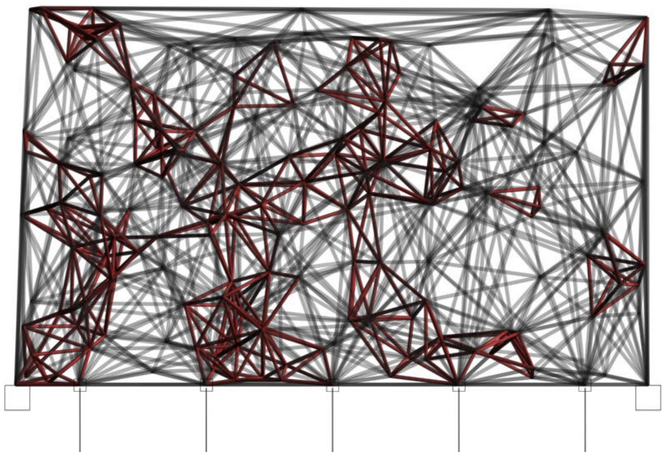
The steps of the algorithm can roughly be described as:

1. A 'problem' is presented to the program, in the form of certain loads and a number of supports.
2. The space around the application points of the loads and supports is filled with points distributed randomly.
3. The points are "tetrahedralised" (through a Delaunay tetrahedralisation) that is, a structure is generated made of tetrahedra, in which the points are the vertices of the tetras.
4. The resulting structure is evaluated through a simple Finite Element Analysis, and each node in the structure is given a score, according to the stresses of the bars converging in it.
5. Points with low scores will migrate to areas around points with high scores.
6. The algorithm iterates again from point 3, until a desired condition, in the current particular case a determined maximum/minimum score relation, is achieved.

The problem, abstracted enough, can also be viewed as different agents competing for certain commodity in a network. Each of them, going to areas where the commodity is more available (stress in this case), changes also the topology of the network and therefore the way that commodity is distributed. High densities of agents implies lower individual gains even if the availability of the commodity is high, and low densities may imply high individual gains even if the commodity may be relatively sparse. In relation to this mechanisms, S. Kauffman explains coevolutionary self-constructing communities of agents, as a system in which the adaptive moves of one agent deform the fitness landscapes of its partners. This process allows agents, each adapting it's own selfish "fitness", to tune their couplings and fitness landscapes, so the entire system achieves a specific self-organised critical state.



2. Initial problem: 4 supports 10 parallel loads.



3. Elevation of the initial random structure.

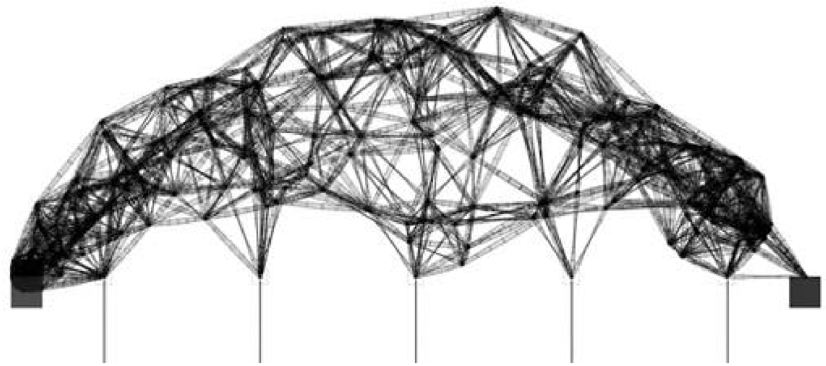
Future work.

The intention is to develop the algorithm further, to incorporate other features, such as the possibility of the number of points to vary, and to test different scoring rules (penalising compression, for example, would perhaps produce tensigrity structures). In the next stage of the project, anyway, it is crucial to be able to develop a whole manufacture system (at a prototype level) to be able to test the designs. The output of the program are not simple graphics, but specifications of how to build an object. Thus, many factors, such as economy or performance of the structures can be tested in reality. The future goals are:

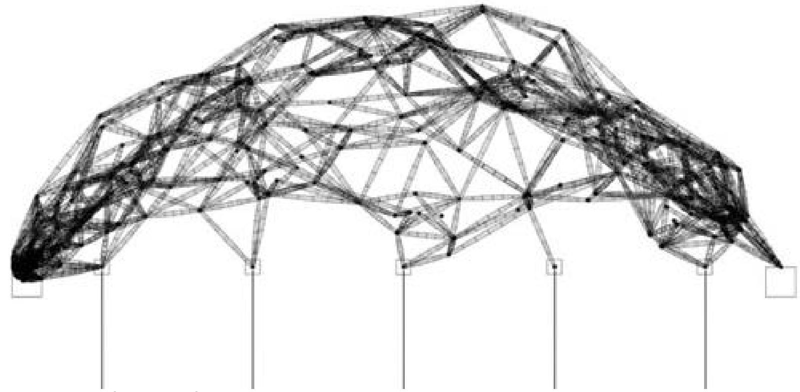
1. Improvement and development of the basic algorithms, from an structural point of view as well as improving its performance and general design. Introduce constrains that will reduce the "noise" in the current designs, related to an interaction with a user or to point 2.
2. Development of a prototype for a fabrication process, and adequate ways for testing the designs.
3. Study how the algorithms can be applied to other problems, mostly related to the design of networks (street patterns, road networks, distribution networks, building layouts, pipes or electric networks…anything that can be represented as a graph).

Example 1.

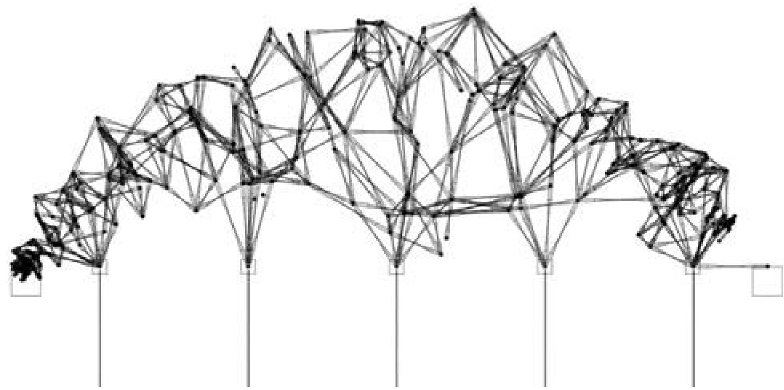
In this example the system is presented with a simple "bridge" problem (fig. 2), consisting of 10 parallel loads and four supports. First a random structure is generated (fig. 3), that slowly evolves in to a more stable configuration (figs.1,4,5,6). There are a few things to notice from the result: first how the points have organised to form an arch, composed of compression members in the direction of the arch (fig. 5), and tension members that work as braces and carry also the loads to the arch (fig. 1, fig. 6). Another thing to notice is that even if it was given four supports, the program has been able to realise that only two are essentially needed for this particular case, and has designed the structure accordingly. All of this 'knowledge' is not explicitly programmed, but an emergent property of the system, as it is believed to be in many natural and biological phenomena.



4. Elevation of a reached stable configuration.



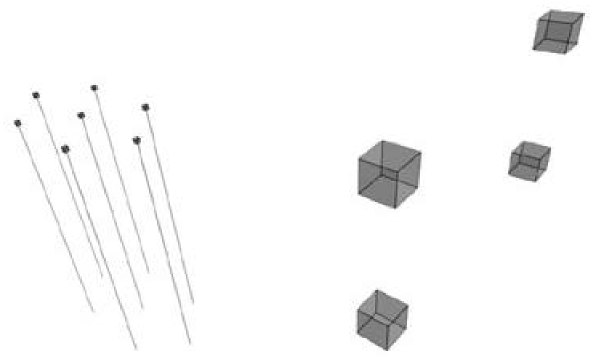
5. compression members.



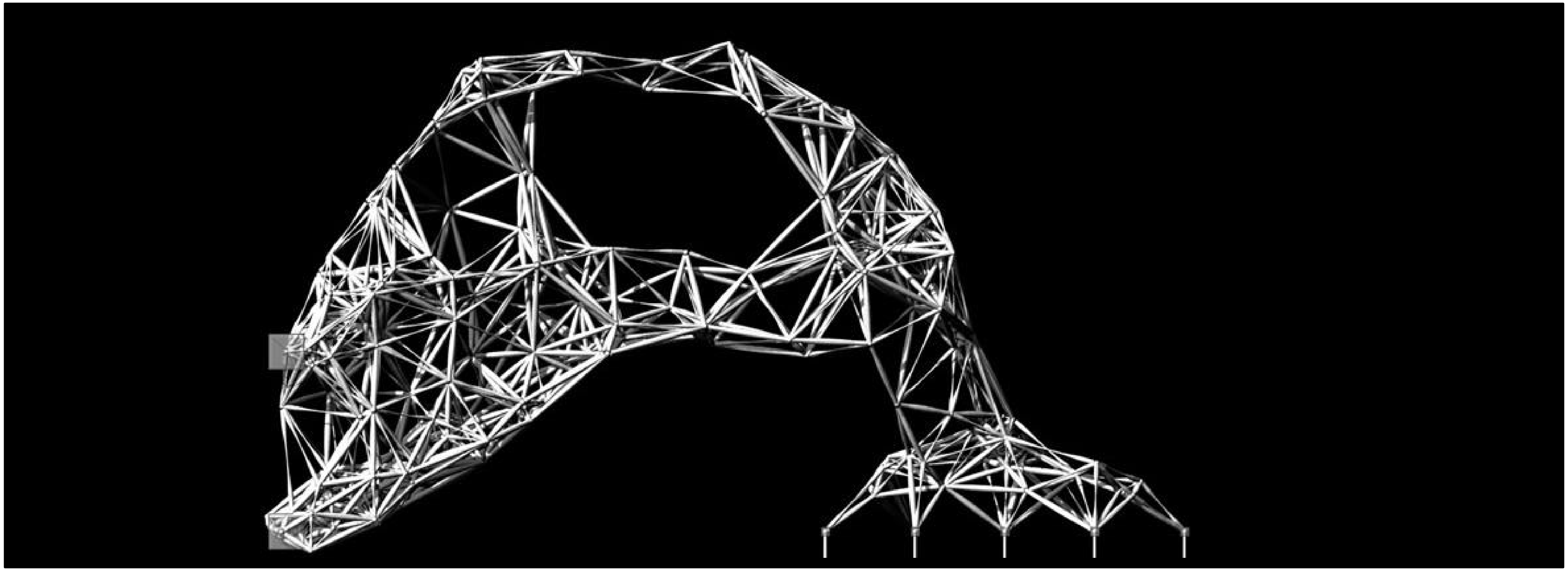
6. tension members

Example 2.

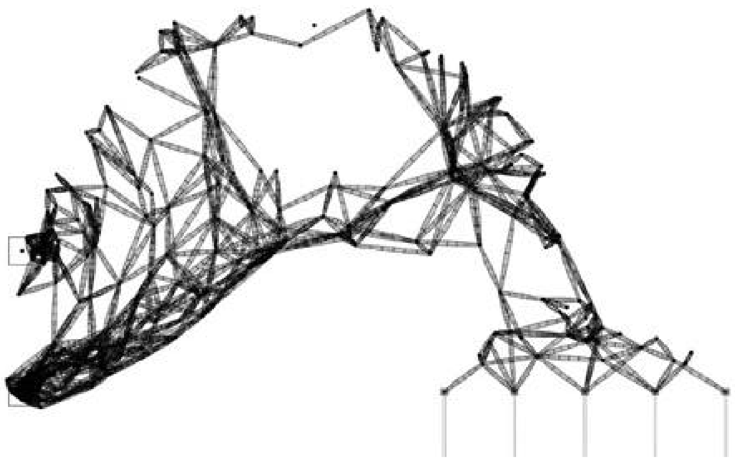
The task in this case is to provide ideas for a cantilever (fig 7). The proposal shown here (fig 8) is actually a relatively stable form, but not the final achieved configuration, which was much closer to a simple beam. This underlines the essential idea about the project, in which the production of ideas and concepts (problem worrying) is what is prioritised, and not necessarily optimisation. In a way similar to the previous example, only two supports of the supplied four have been used. What is remarkable in this particular case is the emergent organisation of the structure in clear compression and tension structural elements: a tension 'spine', and different compression trusses (fig. 9, fig. 10). It is also possible to observe how tension members work as braces in predominantly compression areas, and vice versa. There is also a clear a similarity with the organisation of trabeculae in the bone.



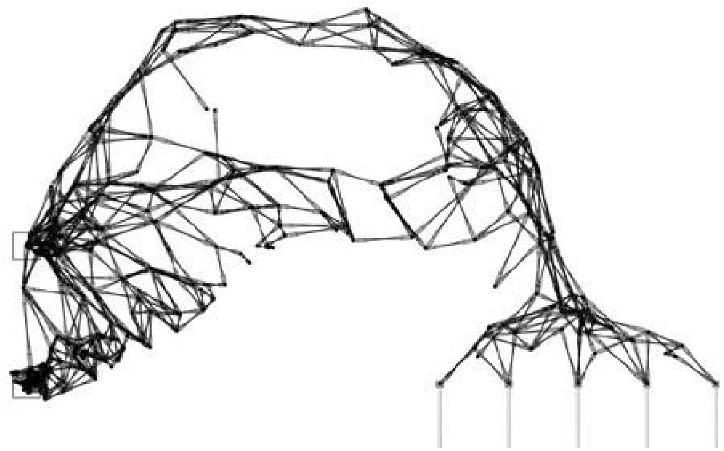
7. Initial problem: 6 loads and 4 supports.



8. the chosen relatively stable configuration. It represents a local minimum in the evolution of the structure.



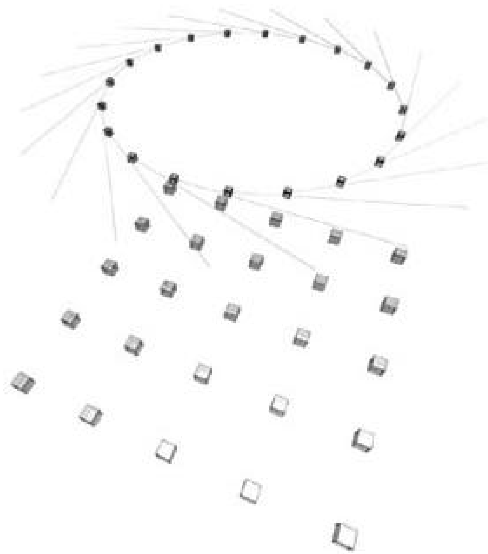
9. compression members, organised in to branch-like structures.



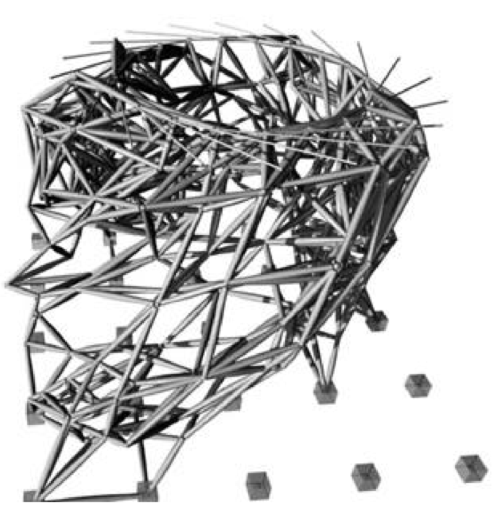
10. members working on tension.

Example 3.

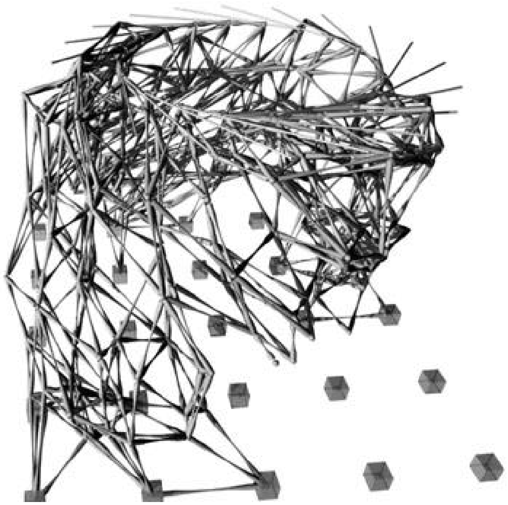
In this example the algorithm has to deal with forces producing strong torsion, and an over-abundance of supports (fig 11). The achieved configuration has some particularities: As it could have been predicted, the chosen supports are the ones further from the centre, and the central area has been left void (fig 14). The compression and tension members (fig 12 and 13 respectively) form a sort of basket, with compression members working in one direction and tension members in the other. There also observable a few bugs, that account for the early prototype stage of the project: the forces in this case, and opposed to the previous examples, work towards their application points. There are also observable bars between supports. This is a result of the triangulation algorithm and the FEM model. Even if they are shown as carrying loads, their stresses are very close to nil.



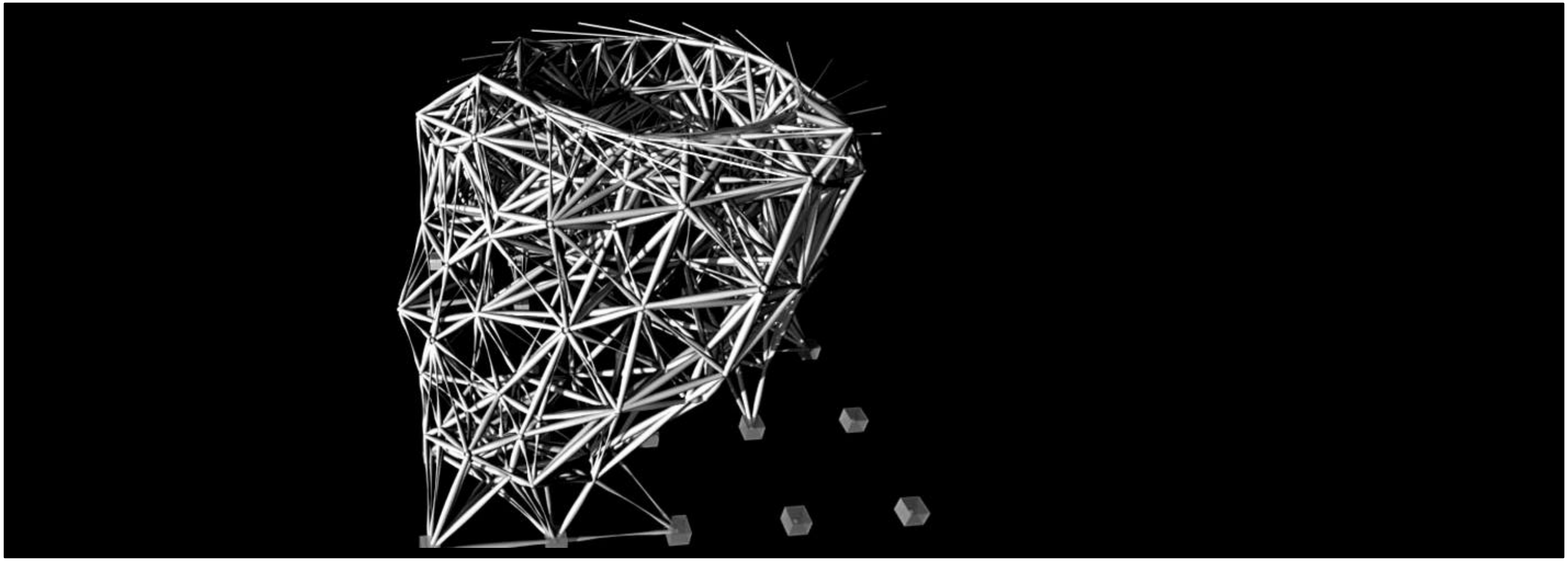
11. torsion example, with 100 possible supports.



12. compression members.



13. tension members.



14. resulting structure of problem 3.