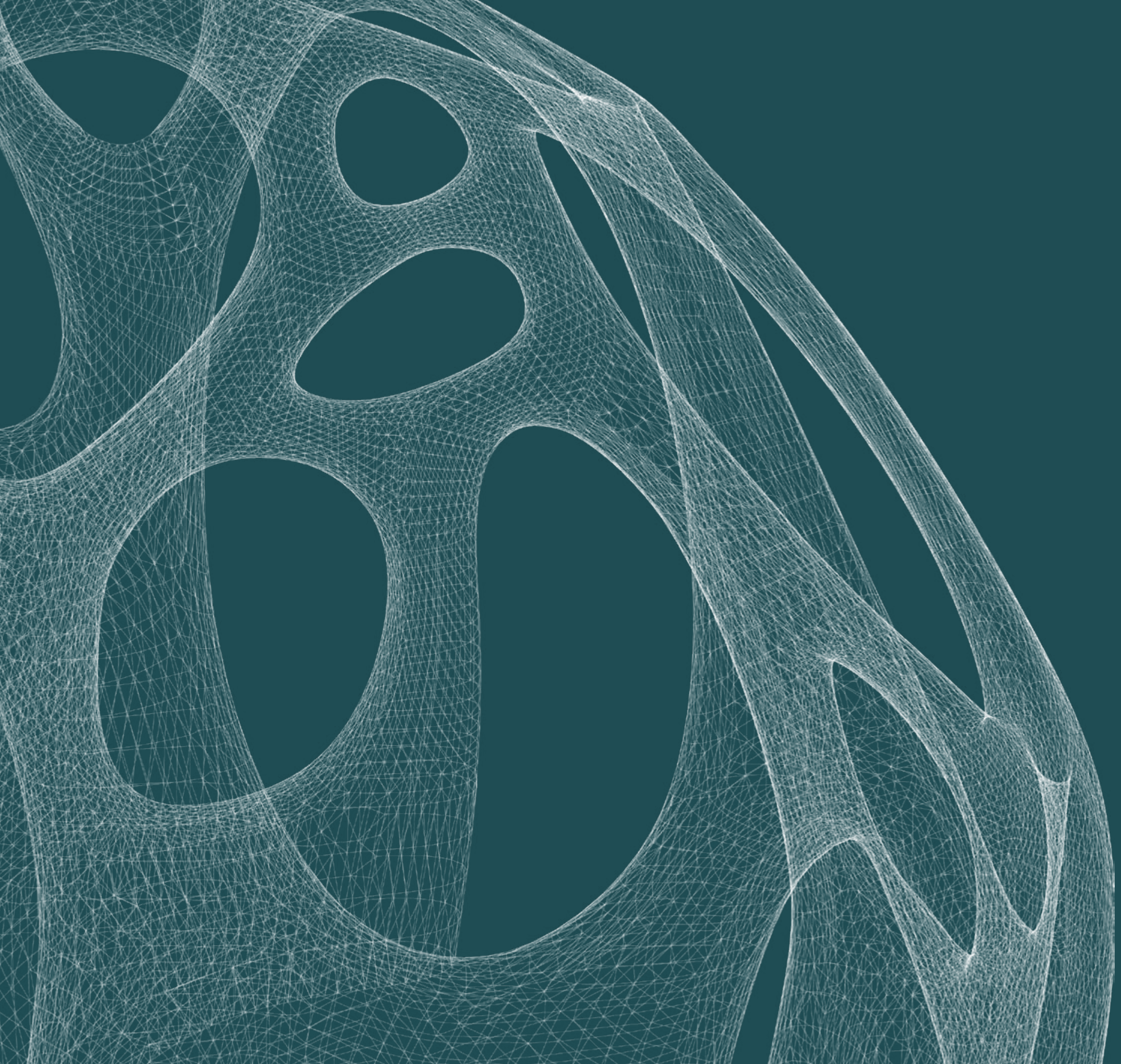


D-SHAPE

The 21st century revolution in building technology has a name.

D-Shape is a brand created by Monolite UK Ltd.

Intro duction

Since the 19th century, the construction industry has been using Portland cement to cast concrete into a formwork containing a steel cage, cementing bricks and stones using masonry.
Despite the availability of construction machinery such as cranes, pumps, concrete mixers, moulds and form works, the building industry is currently reliant on the manual intervention of professional builders who are the hands which operate the machinery.
Today's construction technology lags behind the available computer design technology. The new 3D CAD software allows architects to conceive and design a construction easily but existing building methods prevent the full potential of the new design software from being achieved. Existing materials such as reinforced concrete and masonry are expensive and inflexible. To build a complex concave-convex surface, for example, would require the pre-fabrication of expensive formworks and cages, the mounting of complicated scaffolding and then the manual casting.
Furthermore, existing techniques require skilled personnel to continually refer to plans/blue-prints which is very expensive.
Stereolithography, also known as 3-D layering or 3D printing, allows the creation of three-dimensional (3-D) objects from CAD drawings. It is already used to manufacture small objects.
These scaled models of a building were created by a Z-Corp 3D printing machine operated using this method. To achieve

this building on a full scale will only require a machine of adequate size and the right binder.

Introducing *d_shape*, Dini has opened the way for application of this process on a large scale.

With *d_shape*, we will enable architects to make the buildings they design using a robotic building machine that uses CAD-CAE-CAM design technology. This will allow a level of precision and freedom of design unheard of in the past and the human limitations of master builders and bricklayers will no longer hamper architects' visions.

d_shape, the Copernican Revolution of conglomerate building construction

This picture shows how “Radiolaria” appeared just after breaking the self-built shell at the end of the two week building process and after one week finishing by hand. It is a two meter tall monolithic sandstone structure printed using approximately 200 -10 mm thick layers of sandstone rejects, aggregated by a new revolutionary inorganic binder.
It is the first ever example of classic stereolithography being applied to the building industry and it is a huge innovation of both product and process.

This Gazebo was designed by London architect Andrea Morgante based on a small micro-organism called ‘Radiolaria’ and was printed (scaled 1:4 in respect of final dimension) with a 3D Printer developed by the Italian Engineer Enrico Dini.

The material contained in the Gazebo cost just £60 (sand and binder).
The effect of this invention in the construction industry could be compared to the introduction of printers in place of typewriters in the office environment or to the invention of the car.

The first Daimler built in 12 series in 1892 had a capacity 1076 CC , developed a power of 2,8 horsepower at a maximum speed 18 km/h; less then half the speed of a horse running. Today, a Daimler Smart with the same capacity develops 85 horse power output at 145 km/h max speed. These two cars, apart having four wheels, have one important thing in common: an internal combustion engine.

The printer conceived by Dini is probably at an analogue stage of that reached by the car pioneer over one century ago, but the inventor believes that at least two concepts will be still present in the printers of the future:

• The principle of using inorganic ecologic cheap binders in the same way an inkjet operates on a sheet of paper.

• The principle of printing a containing shell, because this make the machine light with easy assembly.

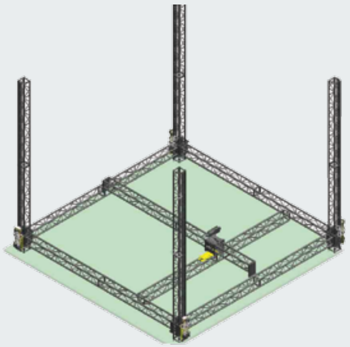
Dini believes that supported with adequate investment and the right partners development will be rapid.
Dini is aiming to develop a 'yard' printer and not a laboratory one.
A precise, but strong and reliable machine; sophisticated but user friendly; with a quick mechanical, electric, electronic set up, low encumbrance and light; easy to assemble and disassemble; low cost running, using cheap and ecologic binders and suitable for using with local sands to reduce environmental impact; a modular machine able to print small or huge buildings; based on a technology intrinsically open to quantity and quality improvements by future developers thanks to his simple working concepts; a machine capable of printing beautiful, strong amazing structures.

A technology conceived for a better mankind and environment, bringing together sustainability and beauty at an affordable cost. This technology could revolutionize the way architects design and construct buildings.

Product and process overview

After four years research and development, Dini has recently tested the 6m x 6m prototype successfully. This new machinery enables full-size sandstone buildings to be made without human intervention using a stereolithography 3-D printing process that requires only sand and our special inorganic binder to operate.

Seen from the exterior, *d_shape* appears like a big aluminium structure inside which the building will be constructed. CAD-CAM software drives the machinery during the

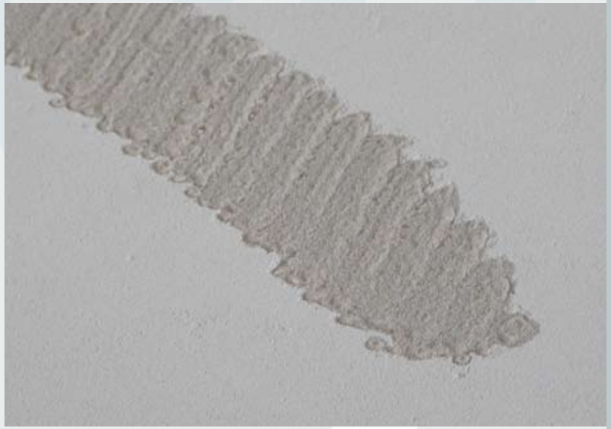


building process and this structure holds the printer head, which is the real core of the new technology. The machine consists of a rigid 6 x 6 metre plan that lifts along the four columns. The columns can be made longer adding parts up to 9 -12 meters. Each corner of the plan is provided of an electro-pneumatic climbing device controlled by an encoder with 0,1 mm resolution. On the lifting plan is mounted a bridge along which runs the printing head which is hung perpendicularly to the bridge.
The printing head holds 300 servo driven nozzles that drop a 'structural ink'. The nozzles are mutually positioned at 20 mm interaxis and can release a printed track as shown in the picture where the width is related to the speed of the printing head, to the ejecting pressure and nozzle diameter. Despite its large size, the structure is a very light and can be easily transported, assembled and dismantled in a few hours by two workmen.

The total stroke of the printing head (6 metres) could be extended almost indefinitely according to the bending resistance of the bridge to which it is hung.
The advancing speed of the printing head can be variated from 0 to 500 mm/sec. The printing head can slide laterally up to 20 mm to cover the gap between the tracks. This means that the full section picture is obtained by operating the printing head

forward and backward to cover the entire gap. Printing detail of completed printed after second backward stroke.

In the picture this full shape was filled by 10 mm width strips. The theoretical with of the strip was 5 mm, as per dimension of the pixel fixed in 5 mm, but the effective strip width was 10 mm plus an over material due to side adsorbtion.



d_shape 6x6 Data Sheet and performances

Overall plant dimensions: 7.5 x 7.5 m
Height: 3-6-9-12-18 metres
Maximum areas of printing (including the shell) : 6 x 6 m
Number of nozzles: 300 at 20 mm interaxis
Nozzle intervention time: 10-15 msec
Command and Control: by PC-PLC Siemens operating via Profibus communication protocol

Weight (not including the feeding equipment): 1.300 kg

Weight including the feeding equipment: 5000 kg

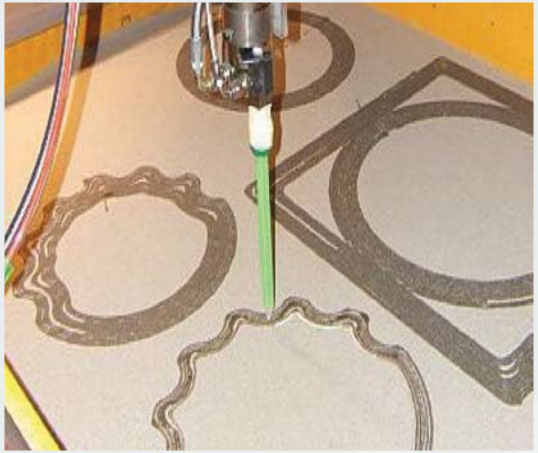
Power supply: 380 V-220 V - 50Hz
Power consumption (not including the feeding equipment: 2kW peak
Power consumption (including the feeding equipment): max 40 kW peak

Min/max sand granulometry : 0,1- 60 mm (0,3 mm during first test)
Productivity: 15 cm/day (effective output during tests) - 30 cm (theoretical) with two turns.
People needed to run the machine: 2

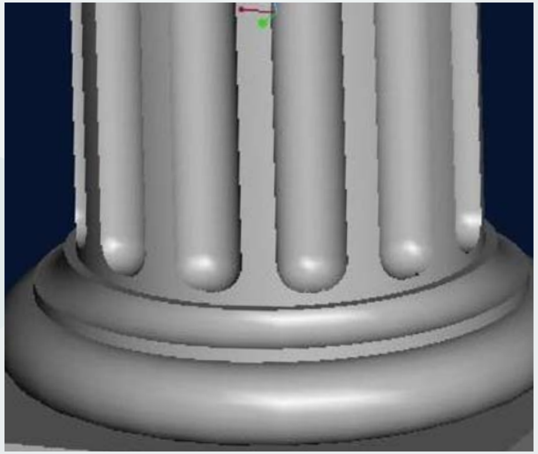
Pixel dimension: 5 mm
Minimum layer thickness: 5 mm +/- 0,5 mm
Maximum layer thickness: 60 mm

Theoretical output printing resolution: 25 dpi
Effective output printing resolution during test: 4-6 dpi

The Material



At the beginning of the research, Dini patented a system based on use of epoxy resins dropped by a nozzle on a layer of sand deposited inside a closed perimeter. He got pretty good results in terms of printing resolution but the final output was an expensive, flammable, non-ecological object.
Moreover, the machine operated very slowly using just an expensive high maintenance nozzle due to a mix of bi-component organic binder inside the operating head.
Epoxy or polyurethane resins, suitable for use as a binder, are not environmentally preferable, both for production and waste treatment reasons; they produce a flammable object product, and release toxic exhaust gas and vapour.
Resins also require a precise binder-to-granular material ratio, which remarkably increases production costs of the spraying head used for laying the binder. Furthermore resins call for accurate and frequent maintenance and cleaning operations, and for periodical replacement parts for the spraying heads where the granular material and the binder are mixed.



Another drawback of the use of resins as binders is the low elasticity modulus of the resultant conglomerate, which is the cause of too much deformability of the load-bearing parts of the structure, e.g. bending and tensile deformability.

Dini abandoned this system/material and

started searching for a binder system that might match his vision of a perfect material: inorganic, cheap, ecologic, low viscosity to be used as a common ink and capable of giving structural strength to the conglomerate.

Dini was unable to find anything on the market ready for use, but did find something close to his needs in the artificial stone industry.

Helped by chemical experts, it was developed a structural ink, low viscosity, hight superficial tension liquid with extraordinary reticulate properties if added to a catalyser.

This meant Dini was able to develop a bi-component liquid/solid inorganic binder in which the liquid fraction is released by a common low maintenance nozzle and the solid fraction is mixed to the inert.

The catalyst is a powder solid, which is dispersed among the granular material to form a mixture. In particular the catalyst has a granulometry finer than the granulometry of said granular material.
This helps to increase the hardness of the obtained conglomerate, since the granules of said catalyst partially fill the empty spaces existing between the granules forming the granular material.

The liquid component has a reduced viscosity. Furthermore, the liquid component has a high surface tension.
This allows a fast opening and closing rate of the distributing nozzles of the moving unit, according to an input signal coming from the control unit.

The granular material, for example quarry stone, has a granulometry set between 0.01 mm and 65 mm.

Materials with granulometry set in such wide limits are generally easy to find; furthermore, they can be derived from limestone sludge or from quarry waste material.

The granular material is not inert during catalysis reaction, and instead it is actively and deeply involved in the reaction. Therefore, the material obtained through this method is not an ordinary concrete material, i.e. a poor tension-resistant material in which inert granules are slightly bound together; instead it is a mineral-like material, which demonstrates a high level of hardness and a high tensile strength, due to tough microcrystalline structure.
Furthermore, the catalysis reaction is so fast it allows the conglomerate to harden in a short time and to achieve a tensile strength close to the final tensile strength in a few hours, thus speeding up the erection of the structure.

A step is provided of adding high tensile strength reinforcing fibres to said mixture of said granular material and of said catalyst, said reinforcing fibres selected from the group comprised of glass fibres, carbon fibres, nylon fibres.
This way, the conglomerate obtained through the method has a diffused tensile strength and a high stiffness, which compensates for a possible low tensile strength of the binding material or for a possible low elasticity modulus.

Effectively, the new process returns any type of sand, dust or gravel back to its original compact stone state. The stone is very similar to marble.

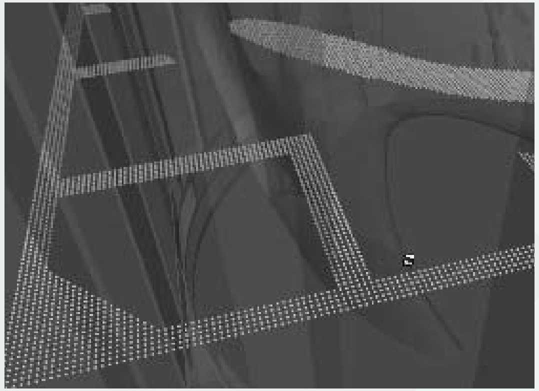
The Process

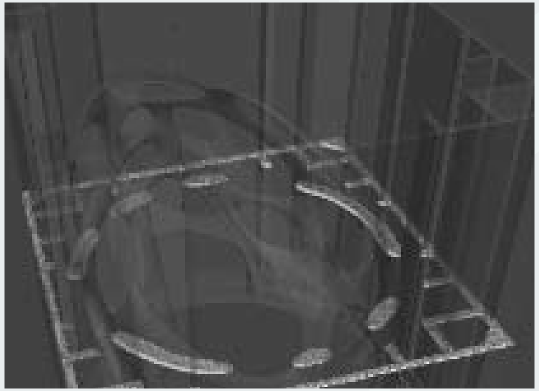
The process begins with the architect designing his project using CAD 3D computer technology. The computer design is then downloaded into a STL file (stereolitography) and is imported into the computer programme that controls *d_shape*'s printer head. To demonstrate how *d_shape* is the missing link between developments in the architectural world and the construction world, we have joined forces with the London Architect Andrea Morgante who has designed the first object to be printed by *d_shape*, Radiolaria, a sort of small Gazebo.

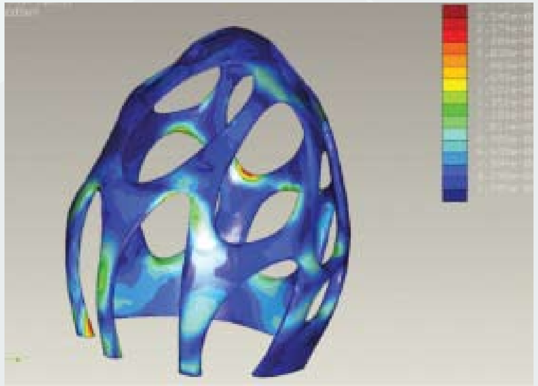
The *d_shape* building process is similar to the "printing" process because the system operates by straining a binder on a sand layer. This is similar to what an ink jet printer does on a sheet of paper. This principle allows the architect to design fantastically complex architectural structures.

The process takes place in a non-stop work session, starting from the foundation level and ending on the top of the roof, including stairs, external and internal partition walls, concave and convex surfaces, bas-reliefs, columns, statues, wiring, cabling and piping cavities.

During the printing of each section a *structural ink* is deposited by the printer's nozzles on the sand. The solidification process takes 24 hours to complete. The printing starts from the bottom of the construction and rises up in sections of 5-10 mm. Upon contact the solidification process starts and a new layer is added.







D-Shape Company Profile

D-Shape Ltd was set up in 2007 as Monolite UK Ltd, with the aim of producing and selling 3D Printers of Buildings together with related materials, products and services, directly or through associates.

D-Shape Ltd holds the patent on which *d_shape* technology is based and related know-how.

d_shape will be competing with the traditional construction industry which uses cement, reinforced concrete, bricks and stones. According to the vision of the inventor, D-Shape Ltd will become the holding company for companies domiciled in different countries around the world, and it will be substantially a services and R&D company.

Dinitech will sell manufacturing licenses and exclusive use licenses on a regional basis. In the meantime D-Shape has become an integral part of "The Moon Factory: Industrial Short series Rapid Manufacturing Unit" which is a collaborative project uniting the best of Europe's R&D centres that aims at creating the capability to build on the moon.

Dini's mission is to contribute to making the Construction Industry more environmentally friendly, as well as providing low-cost access to building for people in need around the world promoting the use of environmentally friendly materials and very low levels of energy.

D-SHAPE

The Founder

Enrico Dini is the founder of D-Shape Ltd. He invented, developed and patented the *d_shape* technology. He works full time in the company in the role of technical person responsible for the project.

Enrico Dini was born in Pisa, Tuscany, in 1962 and graduated in Civil Engineering at Pisa University. His family is from a long tradition of mathematicians, scientists and engineers. His grandfather, Ulisse Dini is a famous mathematician who wrote various works on differential geometry such as Dini's surface, equations and theorems on infinitesimal analysis.

His father Egisto taught Automotive Engineering at Pisa University, and before this was Head of the Calculation Department at Piaggio factory from the end of the war. He was also a part of Corradino D'ascanio's team of inventors of the Helicopter, Vespa scooter and 3 wheel Ape that filled the Indian roads. To the message from both Enrico is grateful for that mix of creativity and science that made also him an Inventor.

Running his company Dini Engineering in Italy, Enrico has spent his entire career in the sector of mechanics, automation and robotics, manufacturing several automated machines, such as welding, milling, cementing and roughing robots, manipulators enslaved to injection machines, assembling lines and stereo digitizers.

He has been a specialist of robotics in the footwear industry and been involved in several research projects for the shoe industry funded by national and regional research bodies.

Enrico Dini cooperates with Scuola Superiore Sant'Anna, the technological branch of the famous Scuola Normale of Pisa, also with many high-tech companies and with the Department of Engineering "Ulisse Dini" of Pisa.

HORACE KIDMAN

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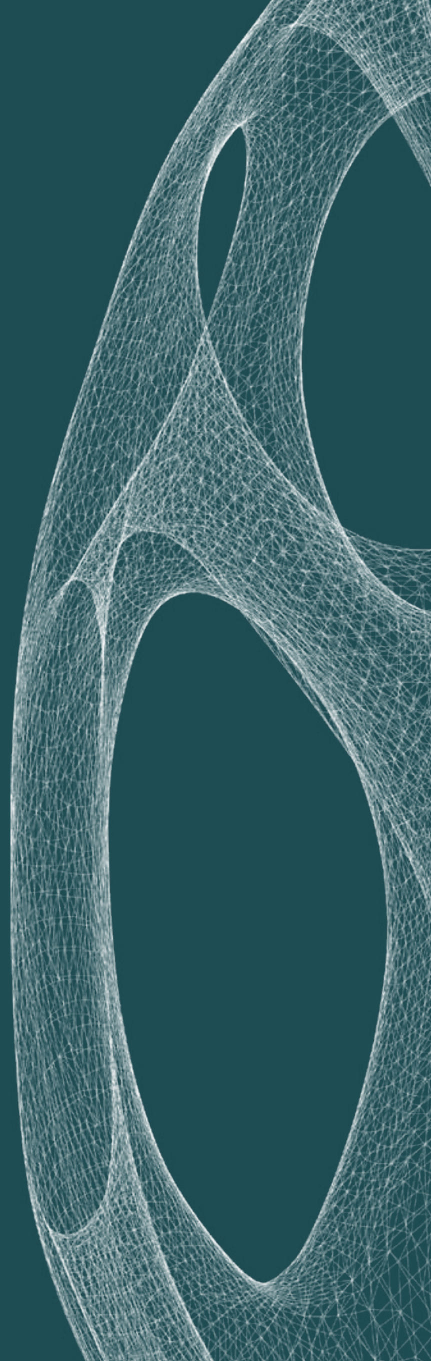

D-SHAPE

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