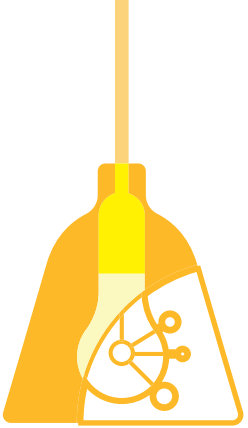


the system lens

A system is an interconnected set of elements that is more than the sum of its parts. Looking at your print from a system perspective means to look beyond the features it must have towards the patterns that it creates outside and within itself. The behavior of a system is the result of its structure.

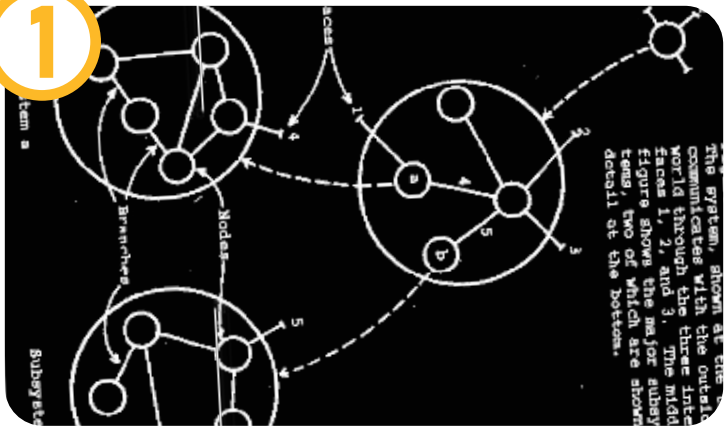
Using a system lens is looking at:

elements + interconnections + purpose

Is your existing system similar to other systems?

What are the most important flows in your system?

Do you find bottlenecks?



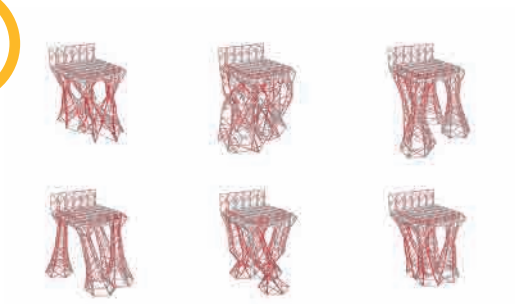
Conway, Melvin E. "HOW DO COMMITTEES INVENT?" Datamation 14, nr. 4 (1968): 28–31.

Functional architecture

The way functional elements are connected in a product is a mirror of the communication patterns in the organization that produces it. Elements that connect force the people responsible for their making to communicate with each other. The interfaces between these components reflect the agreements between them. These patterns expand beyond organizational boundaries and often determine industrial standards.

Changing the arrangement of components with 3D printing means changing the communication patterns.

Querbes, Adrien, og Koen Frenken. "Grounding the 'Mirroring Hypothesis': Towards a General Theory of Organization Design in New Product Development". Journal of Engineering and Technology Management 47 (1. januar 2018): 81–95. https://doi.org/10.1016/j.jengtecman.2018.01.001.



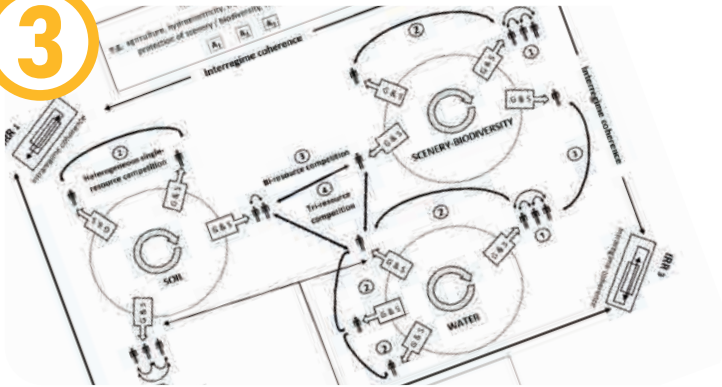
Meta-projects

Autodesk 2015

It is possible to take a step back and think of your product as a piece of code, a set of instructions to fabricate a product instead of a defined print. What are the variables that you are able to tweak in the design? What are the functions that translate these parameters into features? Can you include conditionals? Often, the reinterpretation of our design requirements as variables and functions allows us to see our products as a parametrized design space that includes variations of our products that appeal to different markets or different scenarios.

Using Additive Manufacturing allows us to fabricate all the sub projects available from the design code and expand our manufacturing capabilities.

Soddu, Celestino. "New Naturality: A Generative Approach to Art and Design". Leonardo 35, nr. 3 (1. juni 2002): 291–94. https://doi.org/10.1162/002409402760105299.



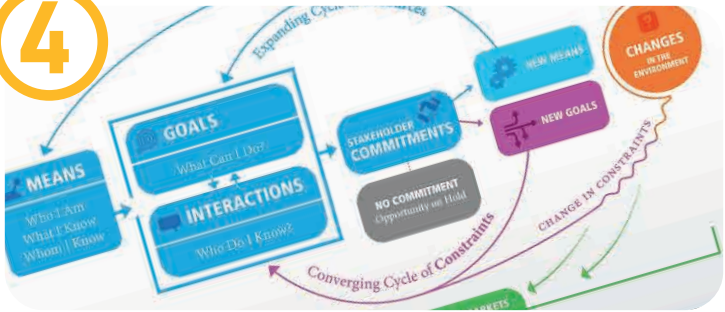
The territory

Nahrath, Stéphane & Bréthaut, Christian. (2016).

From a sustainability perspective a territory is a network of human and non human agents that collaborate to create value. A territory includes the flow of tangible and intangible resources. It also includes resource and energy stocks. What are the rhythms of stock depletion and replenishment in your territory? How do competing solutions relate to this territory?

Additive manufacturing can adjust the architecture of products to work as gauges for flows within a system. 3D printed products can adjust to available resources in different territorial settings.

Bagliani, M., Dansero, E., & Puttilli, M. (2010). Territory and energy sustainability: the challenge of renewable energy sources. Journal of Environmental Planning and Management, 53(4), 457–472.



Effectual networks

Effectuation.org (2022)

Research shows that market creation is possible when stakeholders collaborate and negotiate common goals. The effectual network is the set of stakeholders, their goals, and contracts that exist within a market. Effectual entrepreneurs learn to negotiate with other stakeholders using the resources they have at hand. This means leveraging internal capabilities to design a solution that includes the goals of external stakeholders as much as internal ones. The effectual network makes the success of a product a common goal.

The use of Additive Manufacturing gives more flexibility to effectual entrepreneurs. The design of a product can always be changed and therefore, it can help the negotiations without additional investment.

Sarasvathy, Saras D., og Nicholas Dew. "New Market Creation through Transformation". Journal of Evolutionary Economics 15, nr. 5 (november 2005): 533–65. https://doi.org/10.1007/s00191-005-0264-x.

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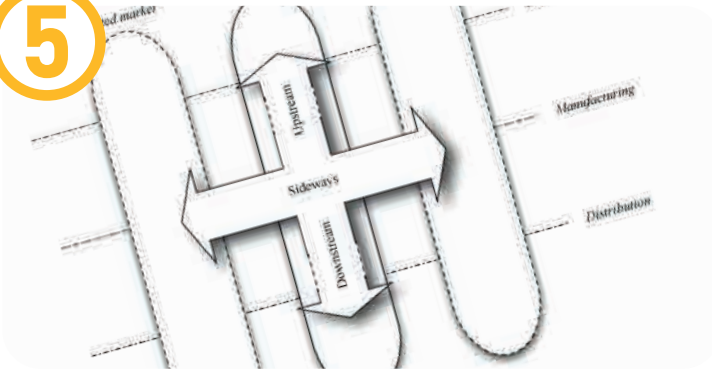


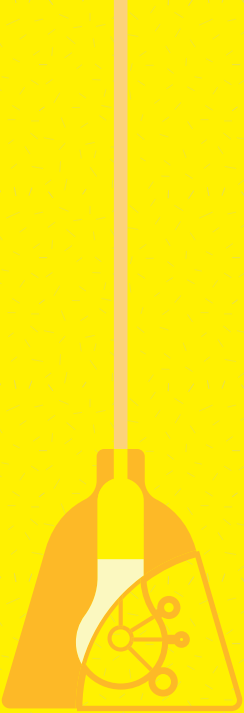
Market integrators

Effectuation.org (2022)

Value chains are often described in terms of vertical and horizontal integration. Integrating operations vertically or absorbing adjacent market niches is delicate because often it requires the acquisition of assets and knowledge. Therefore, good corporate strategy is the one that places business units in positions where they can control value creation without additional investment.

The use of 3D printing in small organizations allows them to think at a corporate level since making changes to integrate vertical operations or contiguous markets does not require extra investment. What valuable operations and markets could be absorbed by modifying your product architecture?

Sarasvathy, Saras D., og Nicholas Dew. "New Market Creation through Transformation". Journal of Evolutionary Economics 15, nr. 5 (november 2005): 533–65. https://doi.org/10.1007/s00191-005-0264-x.



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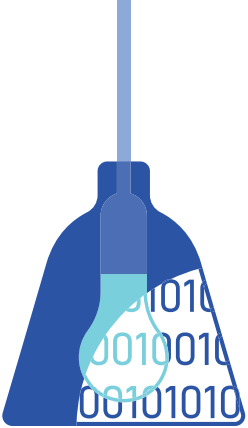


the digital lens

To design digitally is to represent, evaluate, and fabricate the material domain through computational means. Digital design uses a set of tools that calculate the location of points, surfaces, and volumes in space. Once the physical is mapped in a digital space, numbers can interact and be modified in new and different ways.

Digital design extends our capabilities to process information and explore design solutions.

What environmental factors could be represented digitally in your design space?

How could these factors relate to your design requirements?

How could your design be different if it was ruled by these factors?

Hyperganic. "Hyperganic | We Just Built the World's Largest 3D-Printed Aerospike Rocket Engine."

Functional surfaces

Computational tools can design components that fold in themselves and create features where traditional manufacturing can´t. Such is the case of minimal surfaces, a family of mathematical definitions that minimize their are in the same way soap films do. Architectures manufactured through a single changing surface integrate more complexity, functionality, and value to individual components.

Additive manufacturing is an ideal process to manufacture complex surfaces that manifest the effects of environmental factors.

Li Yuan, Songlin Ding, Cuie Wen, Additive manufacturing technology for porous metal implant applications and triple minimal surface structures: A review, Bioactive Materials, Volume 4, 2019,

EveryPoint. "EveryPoint Gets Hands-On with Apple's New Lidar Sensor". Medium (blog), 23. oktober 2020.

Minimal units

The digitalization of tangible materials creates the opportunity to reduce the represented matter to the minimum manufacturable unit. This reduction creates an opportunity for the manipulation of units according to environmental factors. Material properties such as transparency, hardness, and conductivity can be modified from unit to unit at the scale decided by the designer.

Different Additive Manufacturing technologies afford different sizes and shapes of minimal surfaces. The role of the designer is to match the available scale to the effect of environmental factors using CAD.

Oxman, Neri. "Finite Element Synthesis." Proceedings of VRAP: Advanced Research in Virtual and Rapid Prototyping in: "Innovative Developments in Virtual and Physical Prototyping" PJ Bártolo et al., published by Taylor & Francis, 2011.

University, Autodesk. "Generative Design for Architectural Space Planning". Autodesk University (blog), 10. januar 2018.

Simulation

Simulated factors inside the product can include structural, thermal, and conductive properties. Environmental ones depend on the context of use but can include illumination, water/air flow, public circulation, and interaction with other products that cause impact or friction. Simulation provides information that optimizes the properties of components using less material, energy, and manufacturing time reducing costs and maximizing performance overall.

The use of 3D printing allows a more dynamic simulation process where different contexts can be reproduced resulting in a broad family of products without additional tooling investment.

Kusiak, Andrew. "Smart manufacturing". International Journal of Production Research 56, nr. 1–2 (17. januar 2018): 508–17. https://doi.org/10.1080/00207543.2017.1351644.

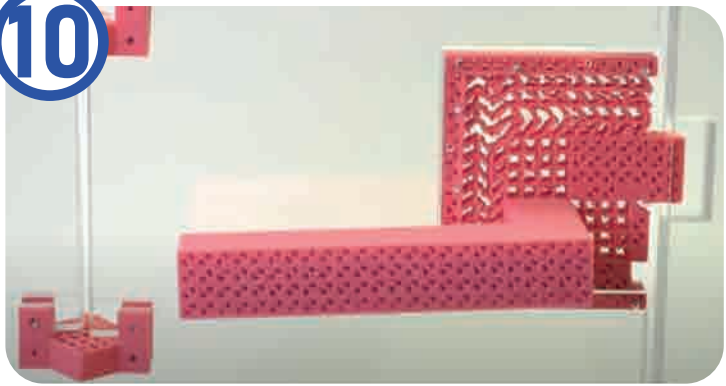
*Automated Antenna Design with Evolutionary Algorithms | AIAA SPACE

Genetic Algorithms

One computational search strategies is the use of genetic algorithms, functions that use the same dynamics of evolution to find the best solution for complex problems. Genetic algorithms create random populations of designs that vary features in the same ways genes vary in living organisms. Once populations are generated they are evaluated through a fitness function that determines which are closest to the success criteria and which aren't. Fit combinations are paired in a new generation. After several iterations it is possible to find the limit of the fitness function in a more efficient way than structured search.

Genetic algorithms can be used to generate families of products that satisfy criteria but are different in shape. Thus they help to create unique 3D printing products that otherwise would require the development of manufacturing tooling.

Vaissier, Benjamin, Jean-Philippe Pernot, Laurent Chougrani, og Philippe Véron. "Genetic-Algorithm Based Framework for Lattice Support Structure Optimization in Additive Manufacturing". Computer-Aided Design 110 (1. maj 2019): 11–23. https://doi.org/10.1016/j.cad.2018.12.007.



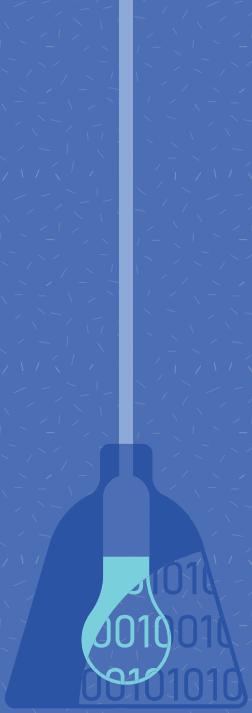
Ion et al. “Metamaterial Mechanisms”. I Proceedings of the 29th Annual Symposium on User Interface Software and Technology, 529–39. UIST ’16. New York, NY, USA: Association for Computing Machinery, 2016. https://doi.org/10.1145/2984511.2984540.

Meta-materials

The ability to select the scale of design allows the definition of the component in micro - meso - and macro levels. Therefore, the geometry of materials can be modified at lower levels to create new material properties in larger ones. Such is the case of structural or acoustic properties where surfaces can be designed to perform specific functions..

Through Additive Manufacturing it is possible to alter such properties in different areas of the printed product, therefore making a unique component with different structural properties.

Askari, Meisam, David A. Hutchins, Peter J. Thomas, Lorenzo Astolfi, Richard L. Watson, Meisam Abdi, Marco Ricci, m.fl. “Additive Manufacturing of Metamaterials: A Review”. Additive Manufacturing 36 (1. december 2020): 101562. https://doi.org/10.1016/j.addma.2020.101562.



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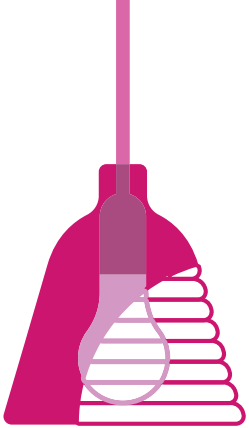

the material lens

Current CAD and Business modeling strategies are designed as flexible as possible in order to adapt to different scenarios. As a result they are often modeled as context free tools that prioritize form creation instead of material possibilities. However, there is evidence that shows how the consideration of material and technological affordances in ventures inform product design. **Considering material and technology creates more efficient ideation and manufacturing.** In the case of 3D printing, it also creates the opportunity to interact with the printer and extend venture capabilities.

What is the technology behind your printer?

What are your printer's limits?

How does the material behave?

How open is your printer's architecture?

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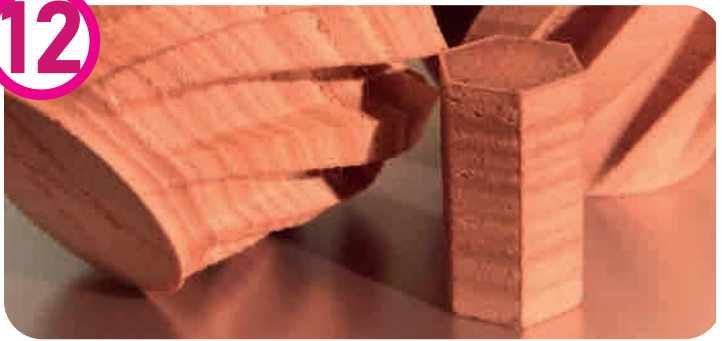
E3D Online. "Revo™ Hemera". Set 13. maj 2022. https://e3d-online.com/products/revo-hemera.

The extruder

The feature that creates complexity freedom in 3D printing is the head in charge of material deposition. In the case of FDM technology this is the extruder. It is composed by a nozzle, a heat block (containing the heater and temperature sensor), a heat sink, a material feed motor and a cooling system. Changing the arrangement and geometry of the components can create specific results.

The most impactful component in an extruder is the casing since it holds all components in place. Changing the shape of the casing using 3D printing can improve printing results without serious thermal and structural considerations.

Querbes, Adrien, og Koen Frenken. "Grounding the 'Mirroring Hypothesis': Towards a General Theory of Organization Design in New Product Development". Journal of Engineering and Technology Management 47 (1. januar 2018): 81–95. https://doi.org/10.1016/j.jengtecman.2018.01.001.



Wood filled fialment, All3DP. "The Best 3D Printer Filament Types of 2022", 27. december 2021

Printing material

The selection of printing material has a decisive impact on the performance of printed components. FDM technology works mainly with thermoplastic materials since it fuses the feeded material. However, a great variety of materials is available since the extruder can be modified to work with materials that solidify at room temperature. Such materials include wax, ceramics, concrete, gels, and edibles such as chocolate.

Thermoplastic materials in filaments can also be used as composite matrices if fibers of other materials are included. However, structural advantages of such composites often require post processing.

Soddu, Celestino. "New Naturality: A Generative Approach to Art and Design". Leonardo 35, nr. 3 (1. juni 2002): 291–94. https://doi.org/10.1162/002409402760105299.

13

nonplanar.xyz. "Non-Planar". Set 13. maj 2022. https://www.nonplanar.xyz.

Printing bed

Slicing software assumes a planar printing surface. However it is possible to modify the printing surface as a mold to avoid the use of support material or include additional functions. Printing beds can be modified in geometry and texture as long as material temperature and extruder geometry do not interfere.

Slicing processing is necessary to exploit modified printing beds. With proper pro gaming, FDM printers can use different materials such as PET or polyester meshes to create garments.

Shembekar, Aniruddha V., Yeo Jung Yoon, Alec Kanyuck, og Satyandra K. Gupta. "Trajectory planning for conformal 3d printing using non-planar layers". I International Design Engineering Technical Conferences and Computers and Information in Engineering Conference, 51722:V01AT02A026. American Society of Mechanical Engineers, 2018.

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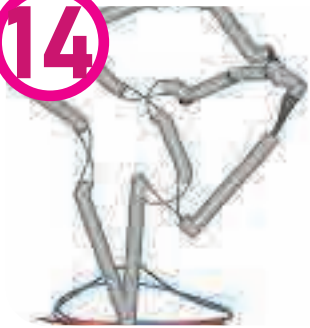


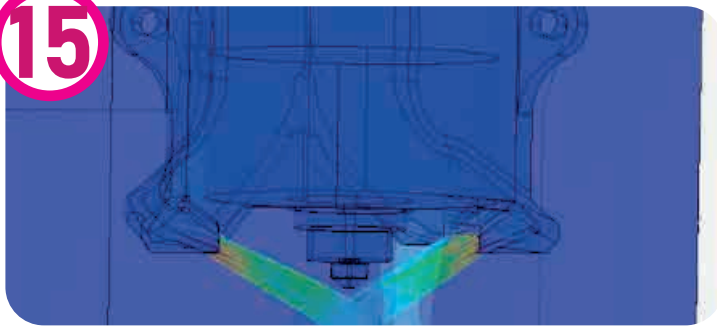
Megaro et al. "A computational design tool for compliant mechanisms." ACM Trans. Graph. 36, nr. 4 (2017): 82:1-82:12.

Compliant mechanisms

Shape and size affect the resilience of materials. Resilience is the amount of energy that a material can withstand without permanent deformation. This means that proper design can produce components that move without deforming permanently. Compliant mechanisms are single components that are designed to move without permanent deformation and produce the same result as assemblies. Material properly understanding can guide the design of single components that outperform assemblies of traditionally manufactured components.

Compliant mechanisms are 3D printable since they often rely on surface design.

Moritoki, Yukihito, Taichi Furukawa, Jinyi Sun, Minoru Yokoyama, Tomoyuki Shimono, Takayuki Yamada, Shinji Nishiwaki, Tatsuto Kageyama, Junji Fukuda, og Masaru Mukai. "3D-printed micro-tweezers with a compliant mechanism designed using topology optimization". Micromachines 12, nr. 5 (2021): 579.



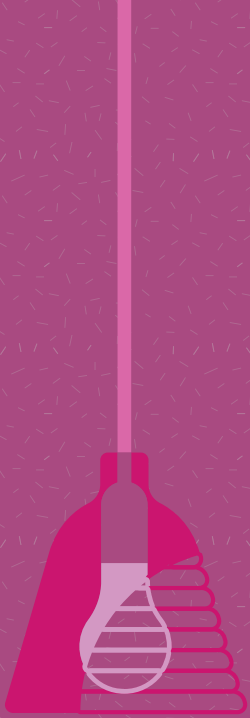
re:3D. "GBX Update September 21 2021". Set 13. maj 2022.

Flow and temperature

Besides controlled movement, 3D printing can manipulate the geometry with parameters that interact with the printing environment such as flow and temperature. Material flow can be modified to extrude/melt more material and create more adhesion between layers or spillover effects. Material temperature can ease or restrict the flow, adhesion, and performance. Additionally, cooldown temperature can be controlled through fan direction and speed to fabricate experimental effects during printing.

Flow and temperature control are parameters that produce effects in printing and can introduce unplanned results into the finished surface.

Ceretti et al. "Multi-Layered Scaffolds Production via Fused Deposition Modeling (FDM) Using an Open Source 3D Printer: Process Parameters Optimization for Dimensional Accuracy and Design Reproducibility". Procedia CIRP, 3rd CIRP Conference on BioManufacturing, 65 (1. januar 2017): 13–18. https://doi.org/10.1016/j.procir.2017.04.042.



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