AMDay

Technion, 27 March 2019

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Session 1:

Shay Izhak Duvdevani, Inbal Michael, Ariel Szklanny, Ben Kaplan and Shulamit Levenberg

Sheba medical center; The Faculty of Biomedical Engineering, Technion – Israel Institute of Technology

Auricular Reconstruction for Microtia using 3D Printed Autologous Engineered Cartilage Tissue

Microtia refers to small, malformed external ear. The most accepted technique to repair it is autologous reconstruction using costal cartilage. However, it involves long-term donor-site pain and discomfort and the surgeon must have great artistic talent to achieve esthetic ear. Current tissue engineering techniques have been shown to be advantageous and a significant breakthrough in clinical translation of tissue engineered human ear-shaped cartilage was recently demonstrated. The successful regeneration of human ear-shaped cartilage using autologous microtia chondrocytes, compound biodegradable patient-specific ear-shaped scaffold, and in-vitro culture technique were achieved. Such engineered cartilages were used for microtia repair in five microtia patients and resulted in satisfactory aesthetical outcome with mature cartilage formation during 2.5 years follow-up. The current research suggests improving this technique by combining 3D-printing, co-culture of autologous microtic chondrocytes and adipose derived mesenchymal cells (MSCs), and use of a unique biomaterial combination. The engineered cartilage will first be evaluated in-vitro and then its characteristics and stability will be examined in murine model.

Initial results demonstrated microtia-chondrocytes and MSCs isolation, 3D printing of representative ear-shaped scaffold and rectangular scaffolds made of different biomaterials, as well as initial cartilage formation by the isolated chondrocytes on the different scaffolds 1 month post seeding.

Ariel Szklanny and Shulamit Levenberg

The Faculty of Biomedical Engineering, Technion – Israel Institute of Technology

Three-dimensional bioprinting for perfusable vascularized tissues

Living tissues require a vascular network to supply nutrients and gases and remove cellular waste. Fabricating vascularized constructs represents a key challenge in tissue engineering. Several methods have been proposed to create *in vitro* prevascularized tissues; however, creating complex vascular networks with varying vessel sizes has yet to be achieved. 3D bioprinting, the controlled and automatized deposition of biomaterials and cells, represents a very attractive approach to solve this issue. This technique allows for combining different bioinks (biocompatible printable materials) in an organized fashion to attain native-tissue mimicking structures. Here, we intend to fabricate vascular trees with decreasing vessel diameters using a combination of materials: printable thermoplastics, which provide mechanical support; sacrificial materials, which allow for creating hollow structures, and hydrogels, which provide the appropriate environment for cell growth and tissue development.

Ben Kaplan, Idan Redenski, Ariel Szklanny, Uri Merdler, Tsemach Bar-mucha, Noah Michael and Shulamit Levenberg

The Faculty of Biomedical Engineering, Technion – Israel Institute of Technology

Indirect 3D printing of biodegradable scaffolds for spinal cord injury

After sustaining an injury, severed axons in the spinal cord fail to regenerate. Failure of axonal growth is related to the formation of cystic cavities within the injury site. Unlike healthy extra-cellular matrix, the cavities do not serve as permissive substrates onto which axons can attach and grow. In the current study, we developed an implantable scaffold that mimics the spinal extra-cellular matrix to encourage axonal regeneration. The scaffold was fabricated by 3D printing water soluble constructs that were loaded with biodegradable polymer solutions. The solutions were freeze-dried-and the 3D printed constructs were dissolved in water. By utilizing 3D printing and an MRI scan of the lesion site, we were able to control the scaffold's microtopography and customize its shape to match the injury site. At the same time, the scaffolds were highly porous to support nutrient diffusion. The scaffolds maintained their structure over four weeks in vivo and supported in vitro growth of stem cells. Hence, 3D printing can be utilized to fabricate scaffolds that are designed particularly for spinal cord injury. Specifically, the described method generates a scaffold with optimized properties of stiffness and porosity along with the benefits of computer aided design.

Simon Dorfman, Shani Elias, Eliram Nof, Yan Ostrovski, Josue Sznitman and Arbel Artzy-Schnirman

Biofluids Laboratory, Biomedical Engineering, Technion-Israel Institute of Technology

3D printing for in vitro airway assays

3D printing continues to permeate into research labs at an accelerating rate due to the relative low cost and rapid prototypying capabilities critical at the earliest stages of exploratory research typical of the academic setting. Our lab focuses primarily on respiratory flows in association with targeted drug delivery and small-scale physiological flows using microfluidic techniques. Employing an on-site SLA printer (Form Labs), we've used 3D printing for a variety of needs ranging from auxillary supports and fittings, to bespoke moving components in experimental setups and finally in the intricate physiological models used in *in vitro* experiments. These include molds for the fabrication of silicone microfluidic airway assays and true-scale upper airway and mouth-throat phantoms used in particle image velocimetry (PIV) flow visualization experiments.

Moran Bercovici, Govind Kaigala, Boaz Mizrahi, Maxim Shusteff and Daniel Widerker

Science and Technology Department, IBM Research – Zurich;
Lawrence Livermore National Laboratory;
Biotechnology and Food Engineering, Technion-Israel Institute of Technology;
Mechanical Engineering, Technion-Israel Institute of Technology

Additive bio-functionalized microscale printing

Our team is collaborating on the development of a new technology for creating microscale 3D printed devices with integrated biological components. We believe that a 3D printing technology capable of combining mechanical structuring with biological patterning will be a game changer in the field of in vitro diagnostics – a rapidly growing field and market encompassing clinical laboratory tests and point-of-care devices (a $75 billion market). In the past decade, IVDs have shifted rapidly to biochips – miniaturized microfluidic devices integrating biological components which enable new capabilities and higher efficiencies in the analysis and control of biological samples. To date, the manufacturing of biochips has relied on processes that originated from the semiconductor industry, as well as on traditional machining – both largely incompatible with soft materials and the integration of biological components needed in biochips.

The project is in its initial steps, and in this meeting we intend to present the underlying technology and the ongoing work, and invite a discussion on specific applications. Our method is based on the concept of microfluidic probe (MFP) originally developed at IBM-Research – a non-contact scanning device that combines hydrodynamic confinement of liquids with precision motion control. The working principle of the MFP is depicted in Figure 1. The probe has at least two microchannels with outlets on the bottom surface (apex), one configured to inject and the other to aspirate liquid. The probe is placed in proximity to a surface and submerged within an "immersion liquid" (e.g. water, buffers, cell medium). By exploiting the unique fluid dynamics at low-Reynolds-number conditions, the probe enables the shaping of the injected liquid at the apex. Any reactants contained within the hydrodynamic flow confinement (HFC) make contact with the surface over a well-defined footprint.

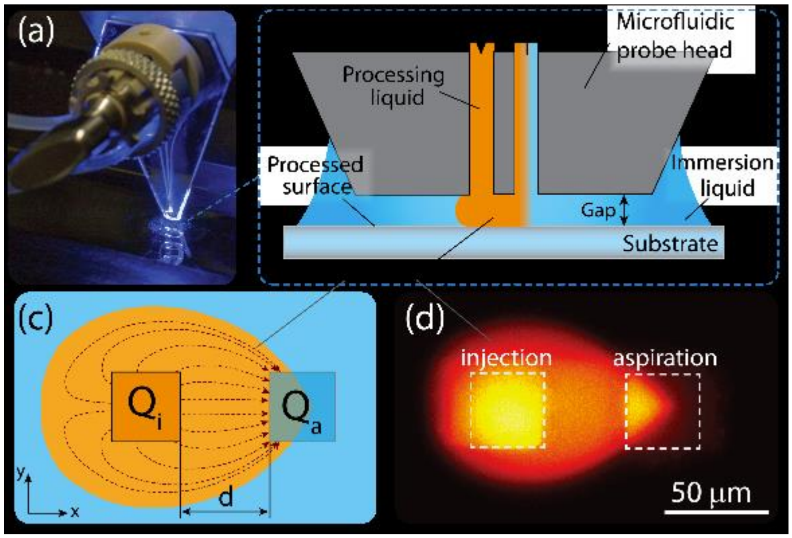


Figure 2. *(a) The MFP headis a 1.5 cm2 microfluidic chip. Two channels lead to an inlet and outlet aperture at its 1 mm2 apex. (b) Side view, and (c) bottom view of the MFP apex. The probe is immersed in the surrounding immersion liquid, and the processing liquid is simultaneously injected through one channel and aspirated from the other channel at a higher flow rate. The injected processing liquid is confined by the surrounding immersion liquid, enabling localization of the processing liquid on the surface of interest. (d) Raw fluorescent image of the flow confinement on top of a substrate, using aperture dimensions of 50 µm × 50 µm, with the apertures located 50 µm apart and 50 µm above the surface.*

Yair Herbst, Shunit Polinsky, Anath Fischer, Yoav Medan, Ronit Schneor, and Alon Wolf

Faculty of Mechanical Engineering, Technion-Israel Institute of Technology;
Faculty of Electrical Engineering, Technion-Israel Institute of Technology;
Haifa3D organization, Haifa 3303333, Israel

Scan-Driven Autonomous Personalization, Customization and 3D Printing Pipeline of Prosthetic Hands

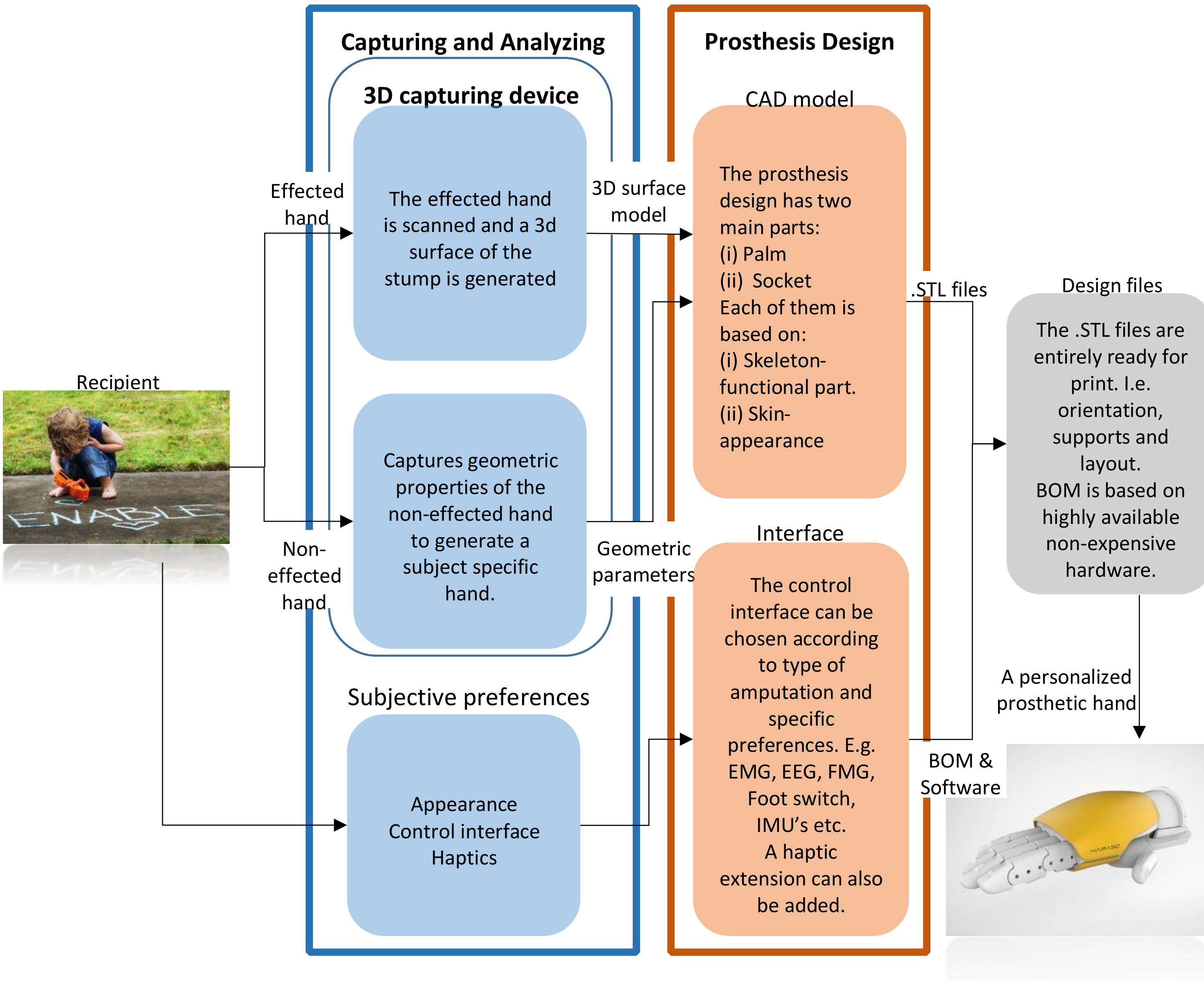
It is estimated that 16 out of 10,000 children are born with congenital anomalies of the upper limb [1]. While there are many solutions in the field of upper limb prostheses, financial resources play a crucial role in prescription of prostheses for children due to constant growth [2]. The cost of a prosthetic hand ranges from $3,000 for a body powered prosthesis, and can reach up to $100,000 for a neuro-prosthetic arm such as the i-Limb and the DEKA arm [3]. The very high price tag makes these devices inaccessible to large portions of the population. In many cases, the price is mainly effected by the time spent on manually fitting the device. Even when the financial barriers are surpassed, rejection rates of prosthetic devices are considerably high and are usually related to the following causes: age of first fitting, lack of social acceptance, weight, vulnerability of the electrical system and lack of sensory feedback [4]. Not using a prosthetic device could lead to degeneration of joints and muscles, inflammations and other complications [5].

In recent years, alongside with the growing availability of 3D printers, medical applications for 3D printing are expanding rapidly and in the future are expected to revolutionize health care [6]. One of the most commonly known groups when discussing 3D printed prosthetic hands is the e-NABLE community [7]. Using 3D printers allows its volunteers to personalize the devices for both functionality and appearance. While modifications are possible and are being done, they require many hours of work by experienced engineers. In addition, most of the designs are body powered and thus limit their use.

In this research we propose a novel, digital design process to create a personalized prosthetic hand. Our proposed fitting paradigm is entirely digital to minimize the design time, the high cost and dependency of trained professional throughout the process, while potentially achieving a low-cost, tailor made design that can be accessible from anywhere on the globe.

The process is divided into three main steps, the first is obtaining user data using a combination of regular and depth cameras, and user preferences. Next, according to the user preferences an interface is chosen. The available options range from simple body-powered hands to more advanced EMG interfaces, haptics and more. In addition, a CAD model is generated automatically according to the data, the model is based on a functional skeleton and a skin to customize appearance, this approach allows us to increase social acceptance. This step ends with files that entirely ready for 3D printing, a circuit board and a bill of materials based on standard off-the-shelf parts. The last and final step is assembly. This step is the only manual one in the process but is shortened significantly by optimizing the previous steps. The entire process is illustrated in figure 1.

As described and shown in the figure, the research is highly multidisciplinary and will require knowledge from different faculties to realize the suggested process. The core ideas behind each of the blocks are based on computer vision, signal processing, biomechanics, mechanical design, industrial design and material science. The proposed process and the final outcome will potentially help overcome the above-mentioned difficulties and could finally push the prosthetic hands field into the 21st century. The entire research and final design is uploaded and shared online for anyone in the world to use.



work-in-progress. Photo courtesy of Oded Katzman, Taga Industrial Design and e-NABLE

Figure 1: An illustration of the design process. Each of the blocks presents a component of our research, many of them are currently a

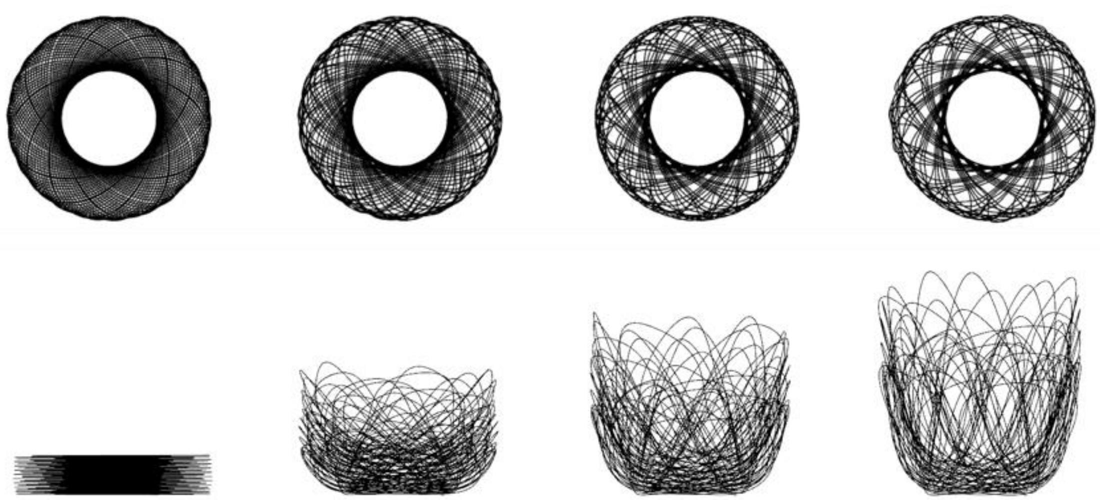
Session 2:

Tom Shaked, Haim Parnas, Nadav Shashar, Ezri Tarazi and Ofer Berman

DesignTech lab and Material Topology Research lab, Technion-Israel Institute of Technology; IUI Eilat

Freeform clay deposition in the service of marine biology

This research investigates an approach to designing and producing an artificial tabular coral by means of freeform 3D printing using natural clay. Most 3D printed artificial corals are formed by scanning natural corals and printing them with conventional layer-by-layer methods, often defined as slicing a model. Here, a freeform clay deposition method is used, which exploits the design opportunities of creating new morphologies of artificial corals, influenced largely by an industrial design perspective. The system allows the designer complete control of the pattern and deposition of the material in relation to the parallel natural coral. This method of designing crafty corals requires full understanding and control of both marine biology and machinery to achieve the desired functionality and aesthetics.



Alexander Geht, Yoav Sterman, Yasha Grobman and Ezri Tarazi

DesignTech lab, Technion-Israel Institute of Technology

The influence of Modulated Extrusion on design aesthetic and mechanical properties in 3D printing

Extrusion 3d printing processes are typically based on horizontal discretization of solid geometry and layered deposition of materials. The speed and the rate of the deposition are constant and determined by the material stability criteria, limiting technology possibilities. Manipulating printing speed and amount of extruded material, expands design and fabrication possibilities. This method known as Modulated Extrusion (ME).

This research explores the benefits of Modulated Extrusion method in big area additive manufacturing 3d printers, focusing on architecture and product design fields. Aim of this work is to develop new aesthetics language and mechanical properties of the printed products, expanding the range of possible outcomes, using the same 3D printing hardware. Outcomes of this research can dramatically affect on the extrusion printing field including bio-printing, product design and architecture.

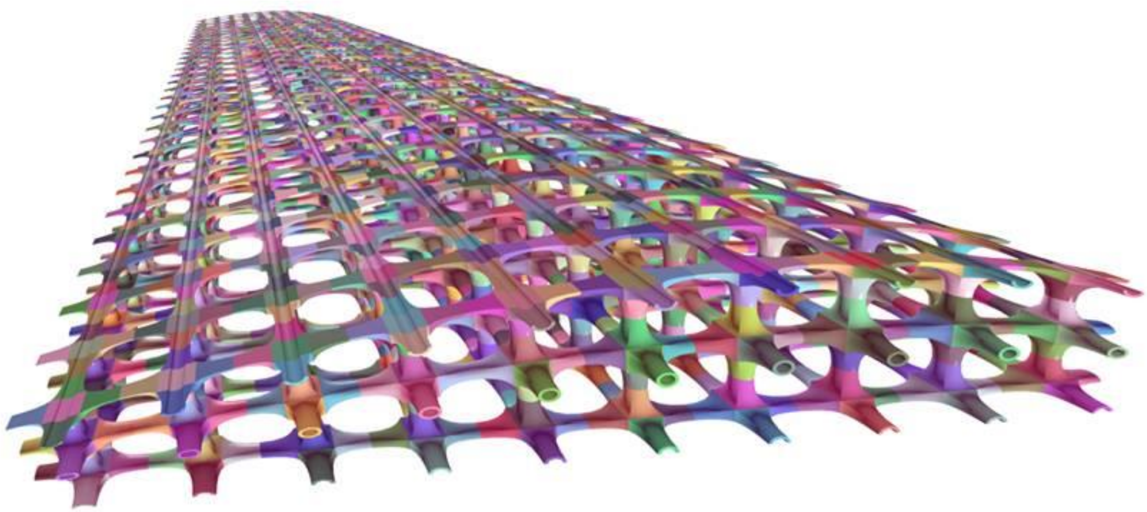
Pablo Antolin, Gershon Elber, Robert Haimes, Jinesh Machchahar and Fady Massarwi

Computer Science Department, Technion-Israel Institute of Technology
Department of Mathematics, École Polytechnique Fédérale de Lausanne, Switzerland
Department of Aeronautics and Astronautics, MIT, Cambridge, Massachusetts, USA

Hierarchical, Random and Bifurcation Tiling with Heterogeneity in Micro-structures Construction via Functional Composition

In recent years, we have developed a freeform volumetric representation (V-rep) that is compatible with modern geometric CAD's boundary representations (B-rep). With the aid of V-reps, we introduce a modeling constructor for freeform heterogeneous hierarchical micro-structures and porous geometry via curve-trivariate, surface-trivariate and trivariate-trivariate (symbolic/spline) function compositions. By using 1-, 2- and 3-manifold-based (possibly varying in geometry, topology and/or material) micro-tiles and paving them multiple times inside the domain of a 3-manifold macro-shape, smooth, precise and watertight, yet general, porous/micro-structure geometry might be constructed.

Such a decoupling of the micro and macro structures/shapes allows a simplified control over design parameters. Herein, we will demonstrate tight (iso-geometric) analysis coupling and compatibility with these V-rep microstructures on some applications, enabling a full design cycle where analysis and/or optimization tools affect the synthesized geometry.



Ben Ezair and Gershon Elber

Computer Science Department, Technion-Israel Institute of Technology

Volumetric Representations in Additive Manufacturing

In additive manufacturing (AM), slicing is typically used to manufacture 3D models, one planar layer after another. We present algorithms for the generation of general non-planar print-paths that can potentially be used to synthesize superior 3D models using AM and Hybrid manufacturing. We expect that the added flexibility and freedom in the specification of AM print-paths, as opposed to limiting them to planar curves, will enable the synthesis of 3D models (using AM) with superior properties (such as mechanical strength and surface finish).

In addition, the use of parametric volumetric representations allows the application of volumetric functions to an entire volume of the model, and enables, for example, 3D printing of multi-material objects. Parametric volumetric representations have advantages over discrete volumetric representations: they more closely couple design, analysis and manufacturing, and allow a more efficient (succinct) representation of multi-material objects.

Finally, and using the described algorithms, we present examples of 3D models manufactured with a full 3-axis (low-end) AM hardware as well as heterogeneous materials, courtesy of Stratasys Israel.

Vladimir Popov, Evgeny Strokin, Alexander Katz-Demyanetz, Gary Muller, Aleksey Kovalevsky, Denis Zolotaryov, Alexander Fleisher, Jean Ramon, Haim Rosenson

Israel Institute of Metals, Technion's R&D Foundation

Additive manufacturing activities at Israel Institute of Metals (Technion R&D Foundation)

Additive Manufacturing Center at Technion is equipped with all the necessary facilities for manufacturing of metals, ceramics, composites, polymers; their post-processing, heat treatment, and characterization of microstructure, mechanical & physical properties. The presentation will show our development in AM application, materials, and process.

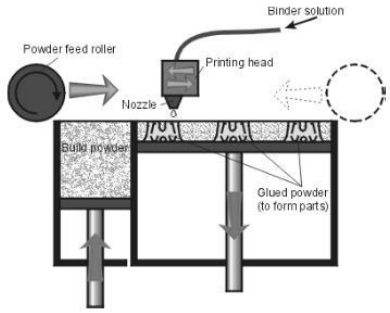
We conduct research activities in the frame of national and international projects with the focus on R&D of new materials for 3D-printing, hybrid manufacturing, and complex post-processing. The main technological approach used for these activities is Powder Bed Additive Manufacturing (PB-AM). PB-AM is a range of 3D-printing techniques where the powder-layer-spreading is used. The widely applied PB-AM with laser or electron beam as an energy source provides manufacturing of complex-shape objects from metallic alloys. However development of new materials (new alloys, powder blends, composite-like, multi-materials, hybrid structures, etc.) is still challenging and there is no any standard approach how new materials could be applied for PB-AM.

Binder Jetting (BJ) process is a unique non-thermal PB-AM technique that enables manufacturing of wide range of materials as there is no limitation of melting point of printed materials. BJ started with manufacturing of sand forms for casting, and was further optimized and developed for producing metal/ceramic based composites that could not be realized by other traditional and 3D beam-based techniques. Technion's ExOne M-Flex BJ machine is the only one in Israel.

Institute of Metals was first Israeli institution that was certificated by ISO 13485 for production of biomedical Ti-6Al-4V implants using Electron Beam Melting (EBM). With technological assistance of AMC were already manufactured titanium implants for canines and humans. The specific issues in this application are: shape / geometry; surface treatment; coatings / fillings; short lead time.

Application

Process



Material

<u>Anath Fischer</u>, Ronit Schneor

CAD laboratory, Mechanical Engineering, Technion-Israel Institute of Technology

Design, modeling and topology optimization for AM and 3D printing

Recent developments in the fields of scanning technologies, topology optimization in computational modeling methods, biocompatible materials and Additive Manufacturing (AM) processes have lead to advanced research in the field of designing complex geometries and developing/3D printing of materials with different mechanical properties.

Our research focuses on the following AM topics oriented to bio and engineering applications:

- Computational metrology using scanning technologies of AM models
- Reconstruction of 3D AM models including segmentation, classification
- 3D geometric analysis of AM models based on neural networks learning methods
- Design and topology optimization of 3D models for AM

One of the main bio research direction, in our lab, relates to **the design of bio-degradable bone scaffolds** which has lately become a prominent field in bio-engineering. Analyzing and assessing the scaffolds' mechanical strength plays an essential role in optimal scaffold design. The scaffold's strength is calculated over time as it degrades while living bone cells grow upon it. This geometrical change of the complex scaffold makes structural calculation a challenging task. An additional challenge is **modeling the process of cell growth on a scaffold**. The cell growth is influenced by many different factors such as stress, scaffold architecture, material platform and flow conditions, thus evaluation of cell growth imposes a complicated challenge.

We focus on both scaffold mechanical analysis and cell growth model. Our solution approach integrates CAD and mechanical computation tools along with progressive design methods such as topology optimization and learning algorithms. We invest optimization problems which involve material and biological constraints.

Additional AM related research:

- From scanning to AM model
- Semantic analysis of scanned data and 3D model reconstruction for AM
- Learning methods for geometric analysis that adapt to AM process
- Design for additive manufacturing
- AM oriented topology optimization based on mechanical analysis

Laura Levin-Bacari and Igor Verner

Faculty of Education in Science and Technology, Technion-Israel Institute of Technology

Fostering Applied Mathematical Skills through Learning Practice in Digital Design and 3D Printing

is study aims to explore the integration of digital design and 3d printing in middle school and teacher education. We explore an instructional strategy to promote digital making and applied mathematical analysis skills that are important in science and engineering careers, but are scarcely targeted in the school curriculum. Our study involves three groups of participants: 7th-grade students, technology education students, and informal education instructors. We developed an instructional unit which engages the participants in design and creation of 3d printed artifacts, using Tinkercad software and 3d printer Makerbot. The learning assignment is to create a spin-top toy which fits into a regular Kinder Surprise egg. When designing spin-tops, the learners are requested to do mathematical analysis of their geometric and mechanical properties at the appropriate level of difficulty. Pilot implementation indicated that the assignment inspired the participants to make different creative solutions and apply mathematics for their analysis.

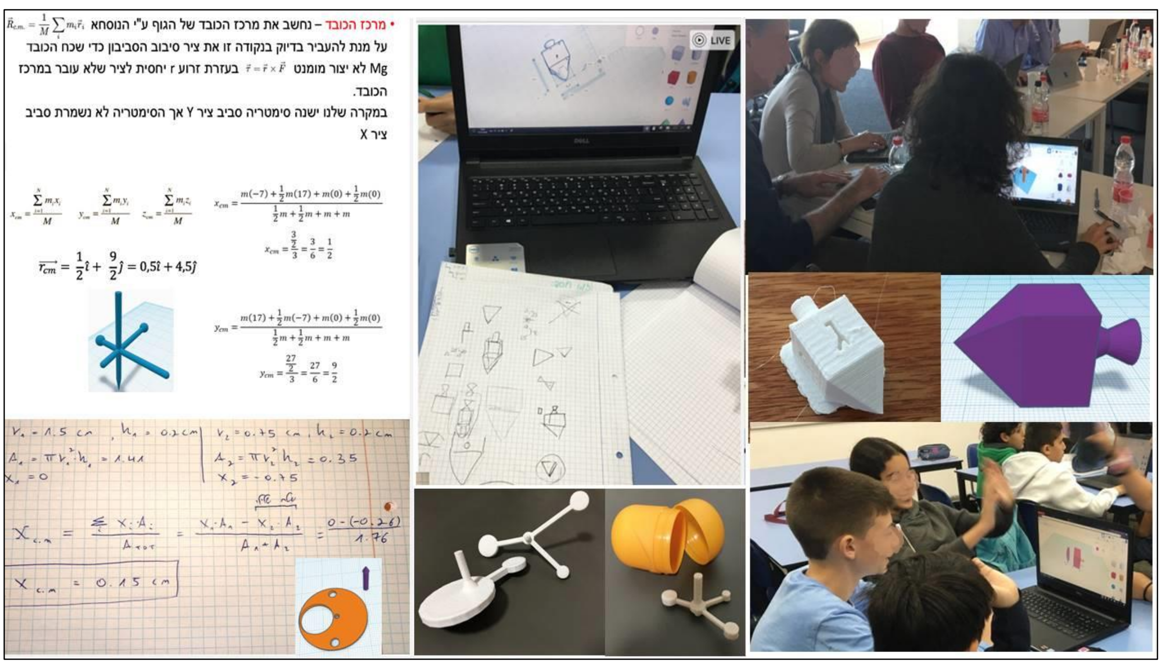


Figure 1. Results of pilot implementation of the instructional unit

Session 3:

Daniella E. Raveh

Faculty of Aerospace Engineering, Technion-Israel Institute of Technology

Printed Aircraft

The presentation will review recent projects of wind-tunnel testing of 3D printed elastic wing models, and an ongoing effort to design and build a 3D printed unmanned flying platform.

Wind tunnel testing is one of the most complex and essential aspects of aeroelasticity research. Aeroelastic wind-tunnel tests are used to assess the accuracy and validity of theoretical models, to study phenomena beyond the current reach of theory, to test new technologies, and to verify the safety and integrity of aeroelastic systems. Usually, wind-tunnel tests are performed on rigid models, and flexibility effects are accounted for in analyses. However, as flight configurations are becoming increasingly more flexible, there is a strong need to study the elasticity effects in wind-tunnel tests. 3D printing offers a new approach for the design and manufacturing of flexible models for wind-tunnel testing in a cost that is significantly lower than that of traditional models. The presentation will briefly review three recent experimental projects that were based on 3D printing of flexible wing models and testing them in a wind tunnel.

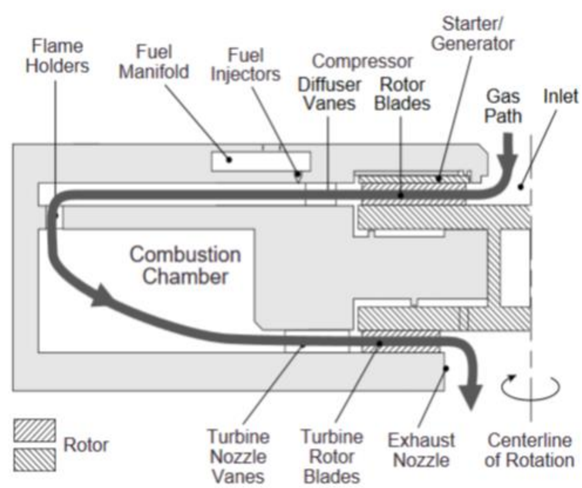
Building on the success of these projects, and the lessons learned on 3D printing for wings, there is an ongoing effort in the faculty of Aerospace Engineering to design, build, and fly a 3D printed aircraft. The aircraft is designed as part of an undergraduate students capstone project. It will be a flying wing configuration, 3m span, with an electrical propulsion system. The aircraft is designed as a technology demonstrator. First-year mission, other than the design and manufacturing of the platform, is to demonstrate the use of multiple (eight) control surfaces for optimized performance. The presentation will review the current state of the platform design and the way we handle constraints related to 3D printing.

Beni Cukurel

Faculty of Aerospace Engineering, Technion-Israel Institute of Technology

Printing micro gas turbnines for propulsion and power generation

In power generation applications, there exists an ever-increasing demand for ultra-micro scale compact systems that could be used as power packs for electronics, ultra-portable gas generators and propulsion systems for micro-unmanned aerial systems. This global need can't be fully addressed by modern batteries, which can only provide up to 720W/kg (for 1-hour operation). In comparison to energy density of batteries (~2.6 MJ/kg), hydrocarbon fuels offer much higher values (more than 40 MJ/kg) and thus a perfect candidate to use this source would be a small gas turbine, which has the highest specific power and specific energy among all other energy generation technologies on the market. Thus, there is a historic research trend of gas turbine miniaturization, with the ultimate aim to develop highly efficient turbo-machines that could produce power of tens of Watts, while only weighing tens of grams. Although prior attempts in the field resulted in some limited success, they were all plagued with issues of turbine to compressor heat transfer, viscous losses in the bearings, unstable combustion with common liquid fuel and limitations of micro-scale manufacturing capabilities. In order to address these difficulties, our approach detaches from the common gas turbine geometries and fuels (which are inherently not capable to operate in such small scales) and focuses on a novel micro-architecture in which radial compressor is coupled with a radial outflow turbine, manufactured together as a single component. This concept results in a flat, compact gas turbine, where the heat transfer problem is addressed by prolonging the distance between the heat sink and source, minimizing heat and pressure losses. The rotating disk will be mounted on high speed foil bearings, which are particularly suitable for high speed turbo-machines and need no lubrication. Highly suitable for such compact environments, hydrogen will be used as a fuel, while also serving as a turbine coolant. To gain additional cycle benefits, the coolant fuel will be used for secondary combustion between the turbine stages, further augmenting cycle efficiency.



The resulting unit can be used for both propulsion and for power generation by coupling a small generator to the compressor-turbine rotor. In order to realize this research effort and advance the project towards prototype manufacturing, the laboratory needs a suitable micro-nano manufacturing tool. Recently developed two-photon polymerization (2PP) methodology offers unmatched ~200 nanometer printing resolution at much lower cost than other available nanolithography techniques. The obtained parts could then be coated by metal and ceramic deposition and assembled into an ultra-small gas turbine with targeted power rating of less than 100W, ~5-10% efficiency and ~25gr in weight.

<u>Doron Shilo</u>

Department of Mechanical Engineering, Technion-Israel Institute of Technology

Additive manufacturing of shape memory alloys

Shape memory alloys (SMA) are smart materials that undergo a phase transformation between two solid phases, martensite and austenite. The phase transformation is associated with large reversible deformations, thus enabling the transfer between thermal and mechanical energies. This unique thermo-mechanical coupling results in three effects: (1) The shape memory effect, in which heating/cooling through the transformation temperature results in a mechanical work that is used in actuators. (2) The superelasticity effect, in which the phase transformation is induced by mechanical loading/unloading. This process results in large reversible deformations and is used in medical applications such as blood vessel stents and guidewires. (3) The elastocaloric effect, in which the latent heat that is emitted/absorbed during a load-induced phase transformation is used in elastocaloric cooling applications.

Existing technologies for manufacturing SMAs are limited to very few and simple structural shapes, such as wires and thin plates. Thus, a technology for additive manufacturing (AM) of high quality SMA can open the route for numerous new applications based on these materials. The main challenge in AM of SMA is the requirement of obtaining a combination of very high mechanical strength with small hysteresis of the phase transformation. In other words, it is not enough to print a desired structure with a predefined material stoichiometry; obtaining the desired set of properties is yet a significant challenge. In this talk, I will present our new research program that is aimed for addressing these challenges.

<u>Oded Amir</u> , Yoram Mass, Eilam Amir and Emad Shakour

Civil and Environmental Engineering, Technion-Israel Institute of Technology

Topology Optimization and Additive Manufacturing – our recent progress on methods and applications

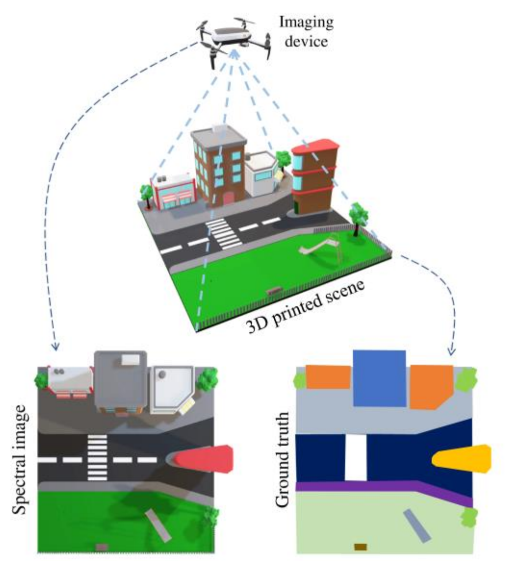
Structural topology optimization procedures deal with optimizing the distribution of material within a defined volume, subjected to external loads and boundary conditions. As these methods can generate relatively complex designs, additive manufacturing (AM) technologies seem to be the perfect match for producing topologically optimized structures. Despite the great freedom that AM can provide to designers, the technology still suffers from various limitations. One of these is the maximum overhang angle, meaning that one cannot manufacture overhang patterns without additional supports. The most immediate idea to alleviate this limitation is to integrate the supports in the design – meaning generate topologies that include supporting structures and can thus be printed without additional scaffolding. In the talk, we will briefly present two methods that our research group has been investigating in the framework of the MAGNET consortium AATiD (2015-2018) that aimed to additively manufacture critical load-bearing components in Ti6Al4V for aerospace applications. Finally, we will also present recent progress on 3-D printing of prestressed concrete beams that was achieved in collaboration with researchers from Ghent University.


Fadi Kizel

Department of Mapping and Geo-Information Engineering, Faculty of Civil and environmental Engineering, Technion-Israel Institute of Technology

Using 3D printing technology to create real scenes with reliable ground truth for intelligent study of spectral imaging data

Imaging spectrometers collect a big amount of information regarding objects by measuring the amount of reflected light from their surface in different wavelengths along the electromagnetic spectrum. Accordingly, each pixel in a spectral image holds a spectral signature that describes the chemical and physical properties of the measured surface. Thanks to this reach information, the analysis of spectral data helps for understanding a variety of geo-spatial phenomena. For this purpose, a great amount of research efforts was carried out and plenty of methods were developed for the analysis and extraction of significant information from raw spectral data. Among many other uses, spectral images allow for highly accurate results of important image-based geoscience applications, e.g. classification, target and object detection, mineralogy, change detection and unmixing. After several decades of research using spectral data, especially in the field of remote sensing, the evaluation of the developed methodologies is mainly applied using synthetic scenes or real data with limited filed measurements. This type of evaluation allows for basic testing of the different methodologies, but on the other hand, does not consider many effects that influence the acquired spectral data. One of these challenging effects is the bidirectional reflectance distribution function (BRDF) as a result of anisotropic reflection and viewing geometry. Due to this effect, the obtained spectral measurements, of the same object, will be inconstant under different conditions. This radiometric inconsistency bears undesired inaccuracy in the results of spectral-data-based applications. In this regard, the use of advanced 3D printing technologies will greatly help for creating real scenes that will provide a reliable ground truth for testing the developed algorithms. In addition, using these scenes for imaging under controlled conditions will help for understanding the different effects that influence the acquired spectral data, especially the BRDF. In the presentation we will briefly present the basics of spectral imaging of remote sensing. Then we will present some of the main research activities and show several existing challenges and the way that 3D printing can help in understanding and overtake them in order to improve the accuracy of application for the analysis of spectral data.



Session 4:

<u>Wayne D. Kaplan</u> and Haim Rosenson

Department of Materials Science and Engineering, Technion – Israel Institute of Technology

Functionally Graded Composites by 3-D Printing

Additive manufacturing (3-D printing) of preforms is a possible method for producing composites with unique microstructures (and thus unique properties), which can't be generated using conventional manufacturing methods. Ceramic preforms can be printed with varying pore sizes by controlling the size of particles used in the ink during the printing process (and by mixing the type of ceramic particles). After printing, annealing processes can be used to promote "necking" at the particle contact points (which are capillary driven shape changes), resulting in changes in pre-form strength without changing the density. Infiltration of the preform with liquid metals can form a ceramic-matrix composite with unique properties.

The main printing parameters for optimization are the ceramic particle size, and mixtures of various particle sizes as a function of preform position. By controlling these variables, density gradients in the porosity can be controlled. The strength of the preform can be increased (to some extent) by post-printing annealing to increase the neck area. The final composite properties will depend on the preform microstructure, the type of ceramic particles, and the specific metal alloy.

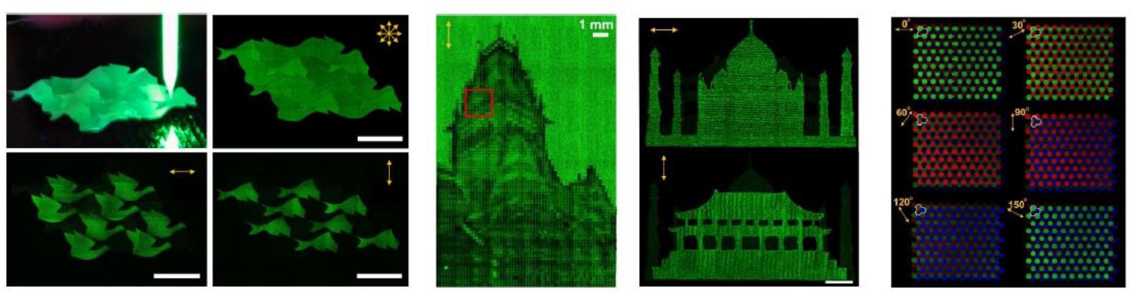
We intend to initiate a research project on this topic, focusing on alumina (Al2O3) and SiC particles as preform materials. Mixed particle sizes will be used to form concentration gradients. The microstructure of particle contact points will be studied as a function of annealing temperature and time, using scanning electron microscopy. Wetting experiments will be used to define dopants which adsorb to the metal-ceramic interface to promote wetting, needed for spontaneous infiltration into the preform by the metal alloy. The initial focus will be on Si and Ti alloys used for biomedical and aerospace applications. Shape changes at the contact points and wetting (relative interface energies) correlated to spontaneous infiltration and infiltration defects are the points for fundamental studies.

Yehonadav Bekenstein

Department of Materials Science and Engineering & The Solid State Institute, Technion-Israel Institute of Technology

Digitally Programmable Polarization Anisotropy via 3D printing of Nanowire-Block Copolymer Composites

Semiconducting nanowires possess unique anisotropic optoelectronic properties arising from quantum[1] and dielectric[2] confinement effects, making them attractive candidates for a wide range of electronic and photonic applications[3-7]. The ability to precisely pattern one-dimensional nanomaterials with controlled spatial orientation into planar and 3D structures that exhibit highly anisotropic properties[8] would open new avenues for the integrated design and assembly of optoelectronic devices. Towards this goal, we created stable nanocomposite inks composed of brightly emitting colloidal cesium lead halide perovskite ($CsPbX_3$, X = Cl, Br, and I) nanowires[9] suspended in a polystyrene-polyisoprene-polystyrene block copolymer matrix. Using direct ink writing, we programmably controlled the nanowire alignment within these matrices to produce photonic nanocomposites that exhibit highly polarized absorption and emission properties. Using this approach, we created several device motifs for optical storage, encryption, sensing, and full-color displays as exemplary demonstrations. The polymer encapsulated perovskite nanowires exhibit increased stability towards air and moisture degradation process, suggesting the methods and materials we use can be implemented in future devices.



Noy Cohen

Department of Materials Science and Engineering, Technion-Israel Institute of Technology

Programming the non-linear response of periodic elastic lattice structures

Periodic elastic lattice structures are a class of cellular materials with unique properties that cannot be achieved with fully uniform solids. Thanks to these attributes, lattice materials are used in modern applications such as, for example, airless tires technologies and customizable shoes. Modern 3D printing technologies enable a relatively easy realization of lattice structures with various micro-structures, characterized by different topologies and geometries. With the aim of programming the response of these materials, I will present a model that captures the linear and the post-buckling non-linear behavior of infinitely periodic elastic lattice structures. The model is based on moderate-rotation theory, which is an expansion of linear elasticity that takes into account moderate displacements and rotations. I plan to use additive manufacturing methods to experimentally validate the predictions of the model.

Ekhlas Homede, Anna Zigelman, Ludmila Abezgauz and Ofer Manor

Department of Chemical Engineering, Technion-Israel Institute of Technology

Signatures of Van Der Waals and Electrostatic Forces in the Deposition of Nanoparticle Assemblies

We evaporate aqueous suspensions in a micro-chamber to explore the connection between the morphology of the nanoparticle deposits at nanometer resolutions and at micrometer and hundreds of micrometer resolutions. Repulsive or weakly attractive electrical double layer and van der Waals surface forces support the deposition of detached particles and small aggregates at nanometer resolutions. However, strongly attractive surface forces render the dense deposition of large aggregates. At greater length resolutions, the deposit morphology is further governed by evaporation-mediated transport of particles in the volatile suspension. We use experiment and theory to show that the contributions of the different mechanisms to the deposit morphology are mediated by particle coagulation and by particle adsorption to the substrate. The nanometer deposit morphology and particle transport determine the morphology of the deposits at greater length resolutions, where it may take the shape of crude or smooth particulate micro-patterns or continuous particulate coating layers.