3D Clay Printing: From Ceramic Sculptures to Architectural Buildings

مقال تفنى

* ياسمينة حيدر محمد عبد ربه
* أستاذ النحت المساعد، كلية الفنون الجميلة، جامعة الإسكندرية.
البريد الإليكتروني: Yasmina.Heidar@alexu.edu.eg

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الملخص:

3D printing pertains to rapid prototyping (RP) technology which is a versatile process for producing complex forms of different materials, including 3 dimensional art forms and Ceramics with intrigued and special designs. The Ceramic Sculpture in this study was manufactured using the 3D printer "Ceramic 3D printing | Delta WASP 40100 Clay", extruding Italian White ceramic Clay, 0-0.5 Chamotte, with layer height: 0,5 mm; and printing speed: 150 mm/s . The appropriate clay properties of the malleable paste have been obtained through the addition of 5% ethanol of 90%concentration to the clay paste. The paste was then inserted compactly in a column used for the extrusion through elected Nozzles, avoiding any air- immersion. The ethanol is used to facilitate the homogenization of the paste. Advanced Printers of the same project innovators include Printing Architectural Buildings, with the "Crane" WASP collaborative 3d printing system of Giants 3d printers designed for the construction of buildings with natural and various materials. The main objective of this study is to provide an adequate information for application of RP procedures of Ceramic sculpture Certain Designs, introducing the Printer, 3D modeling, 3D printing output to post-processing and kiln Firing in 1000oC.

الكلمات المفتاحية: Ceramic, Sculpture, Clay 3D Printing

INTRODUCTION

In our current digital age, Art is transforming... where technology and art merge and create new forms and identities… technology is transforming the traditional form of visual art. (Steele, 2022)

"Art" as defined by Johanna Drucker"In the modern era to contemporary period, the prevailing belief is that the distinctive identity of art derives from the unique ability of individual artists to give formal expression to imaginative thought."(Mitchell. 2010)

"Digit"noun is defined as (FINGER), OR (NUMBER. any one of the numbers 0 through 9. (Digit Definition. 2022), where "Digital" relevant definition is "of, pertaining to, or using digits… spec. applied to a computer which operates on data in the form of digits or similar discrete elements," The computer is only a medium to create an image using code, the code must be precisely definite, and repeatable, to be exactly planned out at the digital level to be to able produce always the same image at the level of encoding. Within this system, the material in which that information takes shape is actually non-atomic; it is information capable to travel across time and space.

In the process of digital mediation, travelling from artist's mind, to the digital code and process of computation, information conceived as pattern creates a certain dialectic, the dependence on pattern to convey information cancels out the role of randomness in artistic creation. (Tresp, 2022)

With the appearance of software for three-dimensional graphical representation, artists design 3D objects, and the possibility of materializing their work becomes possible by the emerging of Three-dimensional printing facilitates to transfer the digital representations from the virtual to the material world. In this way, digital art gets one additional site. (Grujović, 2011)

Digital art, according to the definition provided by the Austin Museum of Digital Art, is "an art that uses digital technology in any of three ways: as the product, as the process, or as the subject." Ultimately, digital art is art that could not otherwise exist without digital technology. (Tresp, 2022)

Nowadays, 3D- printing is a commonly used technology for rapid production of prototypes belonging to additive technology processes. (Grujović, 2011)

Review Literature: Rising 3D Printing Technology

3D printing or rapid prototyping first patent was filed in the 1980s, where Hideo Kodama, Filed the first 3D printing patent application, describing a photopolymer rapid prototyping system that uses UV light to harden the material. In 1983, Charles Hull invents the first stereo lithography apparatus (SLA) machine, then he is granted the first patent in 3D printing for SLA machine, in 1986, In 1987, Charles Deckard files a patent for a selective laser sintering (SLS) process.

In 1989, Scott and Lisa Crump file for a patent for fused deposition modeling (FDM). Scott Crump would go on to co-found stratasys, Inc. The progress of 3D printers continues over years, passing in 1997 through 3D metal printing using Laser additive manufacturing (LAM) that utilize high powered lasers to fuse powdered titanium alloys, to Organs printing in 1999 for transplant surgery… till In 2005 Dr Adryan Bowyer invents the RepRap open source concept to create a self- replicating 3D printer Process, opening the doors for creation of several new 3D printers. The progress continues and Makerbot launches and brings 3D printing into the mainstream by introducing do-it yourself kits for people that want to build their own 3D printers, and introduces the Thing-verse file Library that allows users to submit and download 3D printable files, becoming the largest online 3D printing community and file repository.(González, 2022)

In 2012, together with a group of young designers, Massimo Moretti founded **WASP** (World's Advanced Saving Project), a company that designs, produces and sells 3D printers Made in Italy all over the world. Massimo Moretti, taking inspiration from nature and from the observation of the Potter Wasp, which builds its own nest with material recovered from the surrounding environment, moves WASP to produce large 3D printers able to build houses with natural materials and available on the territory, at a cost tending to zero. (WASP. 2022)

WASP led experiments with clay, porcelain, aluminum, zirconium, and advanced ceramics and concrete, the machines also replicate large objects with never-before-used extrusion systems that employ multiple materials at the same time. Moving from physical and manual work to mental and intellectual work: the mind to think and design, a computer and a printer that can also be understood as robot. This is one of the most fascinating frontiers of the millennium, which is already a reality through 3D printers Cutting-edge technology. (Donati, 2014)

Related Studies

WASP has always focused its work on the development of 3D printing systems that allow the use of dense fluid materials. After developing the first extruder with flow control (LDM WASP extruder). A gear stepper motor enables the printing of harder mixtures and therefore faster prints by taking advantage of the entire printing volume of the Delta WASP 40100 Clay. The 3D printing with clay or other fluid-dense materials is an international research theme of the additive manufacturing. Polymers and thermoplastic are more simple to be printed, but, to set down fluid-dense materials like clay through LDM (Liquid Deposition Modeling) process, there are some limits due to the geometries, to the collapses,to the drying and to the retirements of the extruded material. (WASP CLAY. 2022)

Wasp with Mario Cucinella Architects innovated also the "Crane" WASP collaborative 3d printing system of Giants 3d printers designed for the construction of buildings with natural Dough and cements,with a maximum speed of 300 mm/s and a maximum printing area of 50 sqm per unit.….An experimental domed domicile in the rural outskirts of Bologna, Italy, is the first 3D-printed dwelling constructed using locally sourced clay, The clay itself is soil sourced from the build site mixed with water, rice husk fiber, and binders (Fig.1,2).

Fig.1 Domed domicile in Bologna, Italy, first 3D-printed construction named "TECLA" (Courtesy WASP)

Fig. 2 The Domicile interior (Courtesy WASP)

The project also marks the first time that two autonomous printing arms have been "synchronized as part of a construction. " (Fig. 3) (Hickman, Matt..2021)

TECLA (an acronym for "Technology and Clay, consist of two interconnected **"cocoon-like"** housing units, each covered by a dome. The thick raw earth walls of the units have a hollow structure consisting of several clay "waves", which makes them at the same time lightweight, resistant, and highly insulating. About 200 printing hours are required to build each unit, which consists of 350 clay layers, each 12 mm thick. (Bianchini, 2022)

Fig.3 The multi-printer Crane WASP system (Courtesy WASP)

Significance

In addition to the applications in the field of 3d printed Architectural Buildings; which can originally be designed and worked artistically as a small scale organic form sculptures, ideas develop towards applications in making giant art sculptures, printed like architectural Buildings, or assembled in various parts. And On a smaller scale, 3d printing of clay can be used to produce countless ceramic art forms, modifying the printing materials, in respect to all design specifications related to the material capabilities of its stable and durable standing form. In this research an originally hand sculpted element was freely created to be used in various compositions and construct a complex CAD model, which could be printed in small scale sculptures up to architectural buildings.

Methodology:

Practical application and investigation of technique procedures was used in this research, in parallel to collecting topic-related data.

This research proceedures Practically Experiments 3D Printer" Delta WASP 40100 Clay**" (**Fig. 4)

Fig. 4 Delta WASP 40100 Clay

This 3D Clay printer is Accurate and fast using all kinds of self-supporting ceramic clay, it is open and accessible to interact during the prints. It is possible to print directly on the floor or on printing surface removable steel. It may continue printing without waiting for the piece to dry simply by moving the printer using different materials of porcelain, earthenware, gres, refractory materials, clay. (WASP.2021)

Printer Information

Printing volume: Ø 400mm x h 1000 mm;Minimum layer height: 0,5mm;Maximum printing speed: 150 mm/s; Maximum travel speed: 150 mm/s;LDM WASP Extruder: 1.5, 2, 3 mm nozzle diameter (standard) (1 Tank 5L)LDM WASP Extruder XL: 4 mm, 6 mm, 8 mm nozzle diameter SOFTWARE Operative systems: Windows, Mac, Linux;Slicing software: compatible with all slicing software (Cura – SLic3r – Simplify3D®);File type: .stl, .obj, .gcode; INTERFACE SD Card – Schermo LCD;

Designing 3D Model

– To obtain a CAD design, A 3d Scan of a Sculpture (an organic shape resin originally hand modeled) was produced using a camera Nikon d5600 by shooting 360 still pictures from 3 levels (Fig. 5), the purpose of hand modeling of the main element was to freely create a soft and expressive organic abstract form, which could be used in numerous compositions repetitively and construct a complex digital intrigued CAD

model, which can be processed and printed from tiny size sculpture up to a sustained architectural building.

Fig. 5 Scan of the used sculpture produced using a camera Nikon d5600 Courtesy of the Author

– pictures 24.2 megapixel TIFF 8 bit were imported via "Agisoft PhotoScan Professional" Sofware to Generate the Digital element converted it into a surface mesh (Fig. 6)

Fig. 6 pictures imported via "Agisoft PhotoScan Professional" Sofware Courtesy of the Author

– 3D max software was used to create the 3d digital model (Prototype) by gathering 5 repetitive forms of the originally scanned element (Fig. 7)

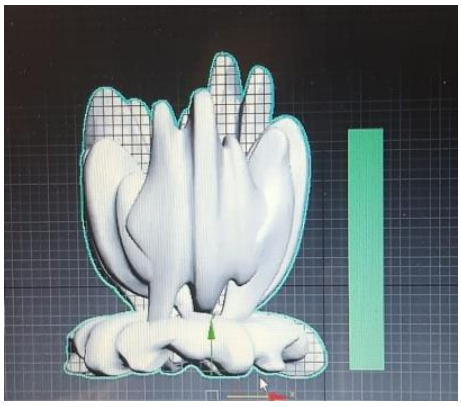

Fig. 7 using 3D max to create 3d digital (Prototype) of "The Blossom" Sculpture Courtesy of the Author

– further modified in ZBrush software (Fig. 8)

Fig. 8 further modification in ZBrush Courtesy of the Author

– Geomagic Wrap Software was used for exact surfacing, allowing easy transform of captured 3D data and imported files into 3D models for immediate use downstream (Fig. 9). (Geomagic Wrap. 2022)

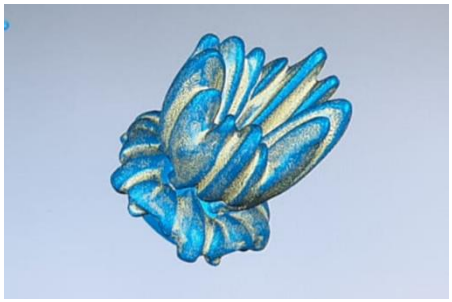

Fig. 9 Geomagic Wrap Software Model ready for printing (Courtesy of the Author) "Cura" Software applications was used for the prototype printing (Fig. 10).

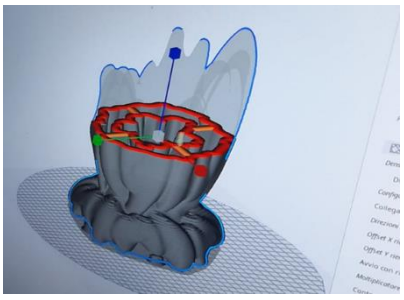

Fig. 10 Cura" Software applications used for the prototype printing Courtesy of the Author

Courtesy of the Author Cura is an open source slicing application for 3D printers. Ultimaker Cura works by slicing the user's model file into layers and generating a printer-specific g-code. Once finished, the g-code can be sent to the printer for the manufacture of the physical object. (Cura.2022) G-code (also RS-274) is the most widely used computer numerical control (CNC) programming language. It is used

mainly in computer-aided manufacturing to control automated machine tools, and has many variants. (G-code. 2022) The open source software, compatible with most desktop 3D printers, can work with files in the most common 3D formats such as STL, OBJ, X3D, 3MF as well as image file formats such as BMP, GIF, JPG, and PNG. (Cura.2022)

- 3D Printed models Preparation includes Keeping the 3D-printed objects fully gapless and closed is a must, therefore; 3DMax's STL Check function used to detect the model and close the model. As the 3D models usually exist in the form of patches, with no zero thickness in realistic models, the 3D printed models must have reasonable thickness.
- Due to the fact that the nozzle diameter of a 3D printer is constant, and that the minimum wall thickness that the printer can print and the strength properties of the printing material must be taken into account in terms of the wall thickness of the printed model, thus; the minimum thickness is 2mm, which varies according to different 3D printers.
- According to the technology used by 3D printers to determine whether design support is needed for the cantilever parts, when a 3D printer prints a model, any protrusions that exceed 45 ° require additional support materials to complete the model printing, so that sensitive details should be arranged in a vertical direction. The supports can set up for particular areas in need of sustaining.
- For the corresponding CAD model of the Ceramic Sculpture (height of 25cm and 25cm in length), and to enable 3D printing of this model, it was necessary to generate the STL file based on this model with parameters control (Fig 11).

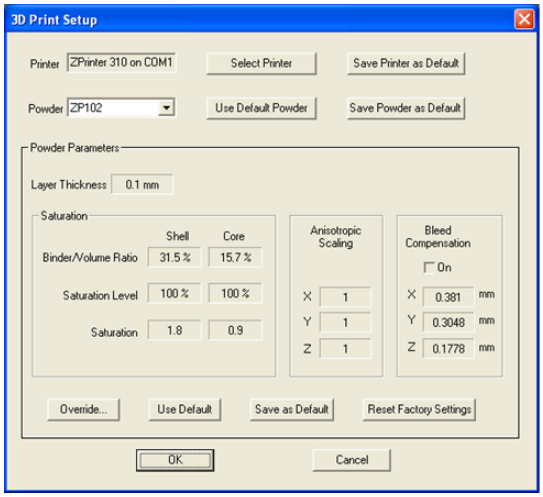

Fig. 11 Parameters for printing with ZPrint software

- The resulting STL file is loaded into a ZPrint software application. During the 3D printing process, layer thickness was set on 0.1 mm, and printing process lasted 2 hours. (Fig. 12)

Fig. 12 Printing Process
Courtesy of the Author

Printing Clay and Ceramic Processing

Basic processing includes removing excess material from the printing part during nozzle extrusion in a rapid schedule of time. (Fig. 13,14)

Fig. 13 Removing excess material
Courtesy of the Author

Fig. 14 PrintingContinues
Courtesy of the Author

Results:

As a result of the 3d printing procedure, a round physical clay model was obtained, and could be reproduced in numerous models with variable sizes and infinite variations, during short periods of time. After finishing the printing, only sustained objects can be carefully taken out of the working chamber. After that, post-processing process, excess clay shall be removed from the sculpture in green strength. (Fig. 15) The next process is slow drying in normal atmosphere, then in an oven at 90 ° C, as preparation of Firing in 1000° C (Biscuit Firing) to obtain full hard strength. (Fig. 16) Finally the fired sculpture can undergo Glaze application, and Second Firing, for obtaining desired visual effects. (Fig. 17)

Fig. 15
3d printing processing in PietraSanta Lab, Italy, October 2021 (Courtesy of the Author)

Fig. 16 Biscuit Firing (Courtesy of the Author)

in addition to the physical realization of the ceramic sculpture, a study of further implemntations to architectural project entitled “Dahab Blossoms” chalets compound was presented through 3dmax and autocad designing using the main sculptural model in various steps ready for realization represented in (Fig. 18) till (Fig. 25).

Fig. 17 Ceramic Glaze coat fired on 3d Printed Ceramic Sculpture Model, “The Blossom” Sculpture, Italy 2021 (Courtesy of the Author)

Fig. 18 Selecting 3d digital model upper section for architectural designing (Courtesy of the Author)

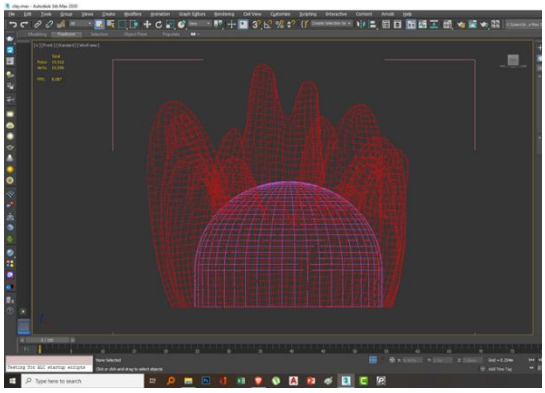

Fig. 19 inserting an interior domed space (Courtesy of the Author)

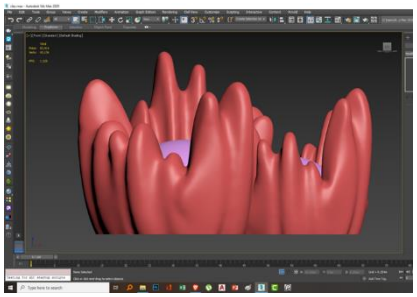

Fig. 20 merging another resized replica to introduce an extended interior space, redefining aesthetically the outer model to shape a Blossom like Chalet (Courtesy of the Author)

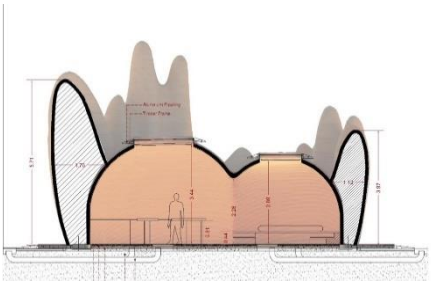

Fig. 21 Section Study of the "Blossom" Chalet (Courtesy of the Author

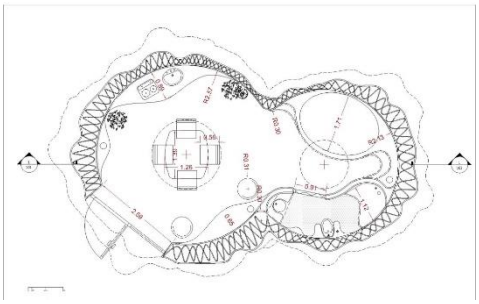

Fig. 22 Plan Study of the "Blossom" Chalet, defining double walled building and interior space use(Courtesy of the Author)

Fig. 23 The 3d printed "Blossom Chalet" side view representation(Courtesy of the Author)

Fig. 24 The 3d printed "Blossom Chalet" front view representation (Courtesy of the Author)

Fig. 25 The 3d printed "Blossoms" compound Site digital representation in Dahab Lagoon (Courtesy of the Author)

Conclusion:

Applications of 3D printing have two limiting factors, these are; the artist's imagination, and material potentials. It is possible, with adequate design preparation, printing different shapes from customized art forms and different Ceramic sculptures, up to buildings and large scale monuments. Art forms can be either kept with printers' impressions or further elaborated to hand expression or totally polished… they can be biscuit fired or glaze coated, etc. This field will be powerfully developing and crossing new artistic and creative borders being a multidisciplinary field between Mechanical Engineering and Fine Arts including both Architecture and Sculpture disciplines… creating complex forms of Sculptures up to Unlimited Creative Architectural buildings.

This Research is useful in reproducing sculptural models by printing clay or various materials, saving time and effort whenever the technological possibilities are available, which can be brought to Egypt by constructing a WASP like 3d printer.

The Study emphasizes the importance of developing artistic ideas, creating sculptural forms, using modern technology, to keep artistic expression as the most important value in art production, to extremely benefit of technological advances in a project execution.

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References:

1. Bianchini, Riccardo. https://www.inexhibit.com/case-studies/sus tain able-house-in-italy-is-made-by-3d-printing-locally-sourced-clay. 2022
2. Cura (Software). http:// en.wikipedia.org/wiki/Cura_(software) .2022
3. Donati, Francesco. Ceramiche artistiche con la stampante 3D, http://www.corriereromagna.it/news/ravenna/6795/Ceramiche-artistiche-con-la-stampante-3D.html. 2014
4. DigitDefinition.https://dictionary.cambridge.org/dictionary/english/digi t. 2022
5. González, Carlos M. Infographic: The History of 3D Printing.Jan 30, 2020. https://www.asme.org/topics-resources/content/info graphic-the-history-of-3d-printing. 2022
6. Grujović, Nenad and others. ART AND DESIGN OPTIMIZED 3D PRINTING. 34th INTERNATIONAL CONFERENCE ON PRODUCTION ENGINEERING. University of Niš, Faculty of Mechanical Engineering. Niš, Serbia. 28. - 30. September 2011
7. G-code. http://en.wikipedia.org/wiki/G-code. 2022
8. Geomagic Wrap. http://www.artec3d.com /3d-software/geom agic-wrap...2022
9. Hickman, Matt. Mario Cucinella Architects and WASP complete TECLA, a 3D-printed earthen abode. https://www.archpaper .com/2021/0 4/mario-cucinella-architects-wasp-complete-tecla-3d-printed-earthen-abode/ 16 April.2021)
10. Mitchell, W. J. T. and Hansen, Mark B. N. Critical Terms for Media Studies. University of Chicago Press, 2010
11. Steele, Cassie. iS THE DIGITAL AGE KILLING ART?. https://www .culturepartnership.eu/en/article/is-the-digital-age-killing-art. 2022
12. Tresp, Lauren. Digital Art. https://lucian.uchicago.edu/blogs/ medi atheory/keywords
13. WASP. https://www.3dwasp.com/en/massimo-moretti/.2022
14. WASP CLAY.https://www.3dwasp.com/en/ceramic-3d-printing-wasp-clay/. 2022
15. WASP. Ceramic 3D printer | Delta WASP 40100 Clay - 3D Printers | WASP (3dwasp.com). 2021