Prospects of Jewelry Designing and Production by Additive Manufacturing

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Abstract  Innovation in the designing process and its strategic implementation opens diverse possibilities. This concept in the jewelry and artifacts can reap enormous benefits when used with additive manufacturing (AM) technologies. AM has established its proficiency in various manufacturing sectors, medical fields, and art as it offers freedom, customization, and quick changes in design. This study investigates the use of additive manufacturing in jewelry modeling, jewelry design, and manufacturing. Additionally, modeling of ornaments has been carried out by using Rhinoceros software. We also provide a brief overview of the use of smart jewelry. These days, smart medical alert devices like smart watches could be developed as an ornamental and health device. These are used to check various health conditions like temperature, heart rate, calorie burn data, and sleep cycle. Furthermore, with AM, they can be customized and manufactured based on the individual customer’s requirement. Similarly, for other ornamental devices, this will open a new field with enormous scope.

Keywords  Additive manufacturing · Jewelry designing · Jewelry modeling · Rhinoceros software · Smart health care

1  Introduction

Today additive manufacturing is the most common terminology of the industry, while three-dimensional printing is mostly useful in the consumer market. The distinct benefits of additive manufacturing make it an accessible technology. According to the standard ASTM F42 Committee, additive manufacturing is defined as ‘process of joining material to make objects from the 3D model data, usually layer upon layer,
instead of subtractive manufacturing methodologies. There are extensive applications of three-dimensional printing technologies in aerospace, medical, engineering, construction, automobiles, architecture, etc. [1, 2]. In this paper, we have explored the area of jewelry design. Jewelry making has not changed a lot through time, despite various advancements. Jewelry design and model making are still time-consuming and labor-intensive tasks requiring a high level of drafting and handmade manufacturing skills. However, sometimes highly skilled technicians cannot create intricately and sophisticated geometrical shapes due to technological limitations, like the ones based on natural patterns, fractals or mathematical algorithms [3, 4]. So the process of three-dimensional printing can be used to meet these limitations. Moreover, for creating unique jewelry in varying sizes, different patterns are required, which causes the art of jewelry, making a very tedious process. With the modern CNC for every single item, machine parameters can very easily be varied. CAD/CAM/CAE can be used for improving the design and manufacturing processes [5–12]. It is the foundation of mass customization, which aids slight modifications in particular designs that are quite popular and in high demand [13]. Different software has been developed to design and create CAD jewelry models such as Matrix 3D, Jewel CAD, Rhinoceros 3D, Blender, ArtCAM, Jewel Smith, and Delcam Designer, and Jewel Space [1, 14].

The basic idea is to create designs using any of this software and then generate their STL files. An STL file is a standard tessellation language that stores information only about surface geometry of three-dimensional objects. This STL file is then transferred to a machine that converts the STL to G-code and gives the command to print the model. Moreover, when the models get printed, preprocessing operations are carried out. The different printing methods can be selective laser sintering, fused deposition modeling, or binder jetting [15]. There are two methods: either directly 3D printing them using precious metals or first creating a prototype using plastic, wax, or rubber as printing material and then using them as a pattern in investment casting. The former method is still not common because of the price involved. Nevertheless, companies like Shapeways and Immaterialize have started directly printing the jewelry using precious metal powders. One of the advancements of technologies like 3D scanning, 3D printing, and telemedicine are used to handle the COVID-19 pandemic [16–19]. These technologies are useful in tackling various ongoing challenges during this situation [20, 21]. Biosensors and multi-agent system also play an essential role for COVID-19 pandemic which is helpful for the better treatment of the infected patient [22, 23].
2 Additive Manufacturing in Jewelry Design: A Brief Review

Here we have presented a brief review of the role of additive manufacturing techniques in jewelry design. Furthermore, it can further revolutionize it by researching the area of material optimization in jewelry, design innovations, and trial productions of intricate designs. Table 1 presents a brief review of additive manufacturing in jewelry designing.

Hence, the area of jewelry making is now employing various additive manufacturing techniques. Here in AM, there are three types of significant technologies: scanning and imaging, software support, and 3D printing technologies. Furthermore, AM adds value to this process as it reduces the time, brings innovation, customization, and quick manufacturing.

3 Applications of Additive Manufacturing in Different Aspects of Jewelry Design

Figure 1 shows the major applications of additive manufacturing in different aspects of jewelry design. In the current scenario, people experiment a lot with their apparel and accessories [30]. Moreover, spend a considerable amount on designer stores for creating their signature looks. This involves much innovation in designing. The accessories may be objects imbibing nature. For instance, pendants are in the shape of snowflakes, or animals, or any intricate, beautiful natural pattern. Moreover, 3D modeling offers extensive freedom in creating intricate designs. These tools allow us to simplify the iterative design process. It also facilitates modeling of ornaments of any shape, type, and size. In general, while purchasing ornaments, the jewelers have already manufactured designs, and we have to choose among them or provide designs to make its replica. Presently, the customers have different demands and want their jewelry customized according to their apparels, and accommodating such freedom is not that easy in traditional jewelry making. The different ideas can be quickly visualized and improved through available design software by providing a digital platform. Furthermore, prototypes and actual products can be quickly manufactured with the help of relevant 3D printing machines. Thus, better use of additive manufacturing may revolutionize the process of jewelry and ornament designing and manufacturing.

While modeling objects, we can topologically optimize them. The topological distribution gives the best distribution of material when subjected to a set of constraints and optimization goal. It removes the excess material while fulfilling the given set of constraints such as stress and displacement. It prevents the wastage of material without comprising with the performance of the product. Since jeweler uses precious materials that involve high cost, if we use the material efficiently, aesthetic design is also not affected. Its load-carrying capacity at the joints is also
| Purpose | Methodology | Findings |
|----------|-------------|----------|
| Provides an insight into the future of 3D printing industries for jewelry and fashion apparel | Review of available literature on the 3D printing industry in jewelry design | Major AM techniques used in fashion industries are FDM, SLS, Polyjet, SLA, and Binder Jetting [2] |
| Creating innovative techniques for the insertion of gemstones in alumide (aluminum + nylon matrix) jewelry | The use of snap fits for smaller stones is mitigated by using variants in stone size coupled with the manufacturing process’s layer thickness resolution | It highlights the need to design for the material rather than carry over features from conventional manufacturing [15] |
| We are improving the design and processes by using CAD/CAM/CAE | CNC coordinate measuring machine (CMM) is used to acquire geometrical data and models constructed from digitized data to construct master patterns and make engineering drawings by converting acquired 3D data to 2D | Among the three methods of converting 3D to 2D, which are the use of CNC CMM for measuring polar coordinates, use of ‘development function’ of CATIA and slicing of the ring using radial, planar sectional cuts the latter method was used as it seems to provide a feasible solution [24] |
| Developing algorithms and mathematical models to provide computational support to traditional Indian jewelry design and simplifying the design methodology in this process | Mathematically modeling traditional jewelry semantics and combining different profiles to form clusters and then the prototype is generated through layered manufacturing technology | By combining modern mathematical design, computer-aided design tools simplify the iterative design process [25] |
| It presents a framework for primitive jewelry designs generation and provides a tool for designers to generate design alternatives according to the designer’s preference | Acquiring design considerations and factors by gathering information from interviewing jewelry designers | This system improves the product development process’s efficiency and enlarges CAD process to cover the conceptual design phase that can shorten time to gather information, and designers can rapidly transfer their conceptualized design ideas [26] |
| Demonstration of the effectiveness of procedural shape modeling for mass customization of consumer products | The generative modeling language is used for encoding the meta designs | It works as a blueprint that can be efficiently carried out also for other tasks of creating meta designs for mass-customizable shape domains [27] |

(continued)
Table 1 (continued)

| Purpose                                                                 | Methodology                                                                 | Findings                                                                                                                                                                                                 |
|------------------------------------------------------------------------|-----------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Study of the use of computer-based tools for jewelry design and manufacturing with the advent of stereolithography technology | A review of Singapore jewelry manufacturing practices, show an improvement in the quality and quantity of production | Good RP facilities can increase both the quality and quantity of jewelry production. The designer gets free of mundane tasks (e.g., dimensioning, creating standard parts, etc.), and he can gainfully utilize this time to detail his designs [4] |
| Proposed a procedure to automate designing and manufacturing for producing ornamental products (jewelry, wooden carvings and stamp blocks, bottles) of different types | By integrating the process of product development, creativity, innovative design, and agile manufacturing can interact with each other by transferring the product information from virtual tools to CAM | Algorithm to generate Islamic geometric patterns, Zillij patterns for wooden carvings and Indian traditional floral patterns are created [28] |
| Comparative study between investment casting and direct metal laser sintering and making a customized jewelry design application | Experimental work has been carried out using SLA, DMLS, and 3D Printing to develop the contrast between the models created | DMLS consumed 30% of excess material for creating a support structure, whereas, in the lost-wax process, it is 60% [29] |
| Comparative study between investment casting and direct metal laser sintering and making a customized jewelry design application | Experimental work has been carried out using SLA, DMLS, and 3D Printing to develop the contrast between the models created | DMLS consumed 30% of excess material for creating a support structure, whereas, in the lost-wax process, it is 60% [29] |

Fig. 1 Major applications of additive manufacturing in different aspects of jewelry design

![Diagram](link-to-diagram)

not compromised; then this can significantly reduce the cost. However, this requires much research as the software available for material optimization does not consider the component’s aesthetic look.
4 Smart Jewelry for Wellness Purpose—A New Application Area for Additive Manufacturing

Human health is susceptible to many factors and to keep them in check that people usually take tests. However, these days, wearing smart devices is becoming a popular trend. There are smart watches, fitness trackers, and aids for different organs. However, these devices are aesthetically appealing to serve the purpose of both well-being and a wearable accessory [31]. Orthodontists are known to improve facial aesthetics.

Moreover, it may sound odd, but people prefer tooth jewelry also like teeth jewels and tooth ring [32, 33]. Allergies are also one issue which can be addressed through this. The allergy alert information can be used to mitigate health risk [34]. Further, they can be used to improve the design of hearing aids. These devices track the body signals and help us keep in shape. Hence, these wearable serves the purpose of both tracker and an accessory. Research on improving their designs and effectiveness is being carried out at many medical facilities. Customized smart jewelry could be developed and produced by using 3D printing technology of additive manufacturing.

5 Process of Jewelry Making

The initial step is to create a design. The blueprint design process is carried out by proficient craftsmen using techniques and methods handed down over generations. Traditional hand-drawing and drafting methods are still utilized in designing jewelry at the conceptual stage. These days designing software are also being used. Jewelry designing is an art. However, with recent advances, various computer-based tools have been developed, which people can access and use. They do not have to master this art; only a little practice and creativity can generate innovative and beautiful designs. These designs may be inspired by various geometrical shapes or imbibing real nature objects like making snowflake pendants or flower patterns. One such interactive modeler is Rhinoceros 3D. It is a commercial NURBS-based modeling tool, developed initially by McNeel and Associates as a plug-in for Autodesk’s AutoCAD. According to McNeel and Associates, Non-Uniform Rational B-Splines (NURBS) are mathematical representations of 3D geometry that can accurately describe any shape from simple 2D elements (line, circle, arc, or curve) to the most complex 3D organic free-form surface or solid. There is plug-ins to the Rhinoceros 3D application, making it all-inclusive computer-aided design (CAD) software for industries.

Grasshopper plug-in used for parametric modeling has also been used in this paper for flower pattern design. The modeling process in Rhino software is user friendly. Depending upon the shape, one wish to make a complete set of the toolbox has been provided. Rhino has a typical modeling interface. It is composed of four viewpoints and a tool palette on the left. At the bottom, the ortho and object snap controls are provided. At the top, the pan and zoom controls and the tool command prompt are
provided. It contains primitive tools, surface creation tools, surface editing tools, and solid editing tools in the panel. Thus, using these, along with different plug-ins, complex models can be easily made. Figure 2 shows a Voronoi-based simple bracelet using grasshopper plug-in.

Figure 3 presents a flower pattern-based pendant which has been generated using mathematical functions. Figure 4 shows an algorithm in grasshopper for creating flower pattern. The algorithm depicts how mathematical operations, essential functions like an interpolation of curve and graph mapper components can generate artistic patterns.

**Fig. 2** Voronoi-based simple bracelet using grasshopper plug-in

**Fig. 3** Flower pattern-based pendant
Here Bezier curve is used to generate the curve as this model is based on the graph method. The function construct points are plugged to generate the points. The multiplier $A \times B$ helps generate values faster, and $A + B$ is used to create offset from the origin. The second graph network is used to create rotation. The $\pi/2*xy$ expression is used to control the shape of the petal. IntCrv is used to interpolate the generated points that the Neg creates the negative instances of the number. It is basically to create the same curve on the other side. Loft function is used to create a space below the petals. The range is to define the range of values given as input. We can change these values and change the shape of petals as desired. Casting is one of the most popular methods by which jewelry is manufactured. Today additive manufacturing can play an important role in creating designing and producing final products. First one is, the selected design is passed to the CAD/CAM specialists. Designers use 3D CAD software that allows them to transform their design into a computer file. Moreover, it is directly printed using different 3D printing technologies [35, 36].

6 Future Research Implications and Research Limitations

In this paper, the study and modeling of jewelry are carried out. So in the future, its 3D printing and investigation of the prototype properties by using different AM techniques and materials can be carried out. The area of medical alert devices has been covered in brief. There are many challenges faced by them in the commercial world on which research is being carried out. So study can be conducted on how to make changes in the features and design to garner public attention.
7 Conclusion

The presented work aims at exploring the use of computer-aided design tools to develop innovative ways of designing jewelry. CAD allows simplifying iterative design, and inculcating changes in the designs becomes very easy as fewer modifications have to be made in the design. Also, by using parametric modeling, many problems can be solved. Jewelry designers can directly create molds by using CAD and additive manufacturing and shorten production time. Their application in the medical field opens a broad scope for the designers also. Mass customization is also another benefit provided by their collaboration. Here the designs created are for visualization purpose. Moreover, ensuring their manufacturability and reliability is part of future work. In future, we may aim at designing and manufacturing smart medical devices and several other ornamental items.

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