US 20250265394A1

(19) **United States**

(12) **Patent Application Publication** (10) **Pub. No.: US 2025/0265394 A1**

SUBRAHMANYAM et al. (43) **Pub. Date: Aug. 21, 2025**

(54) **TECHNIQUES FOR GENERATING THREE-DIMENSIONAL DESIGN OBJECTS USING MACHINE LEARNING MODELS**

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(21) Appl. No.: **19/056,615**

(22) Filed: **Feb. 18, 2025**

Related U.S. Application Data

(60) Provisional application No. 63/556,176, filed on Feb. 21, 2024.

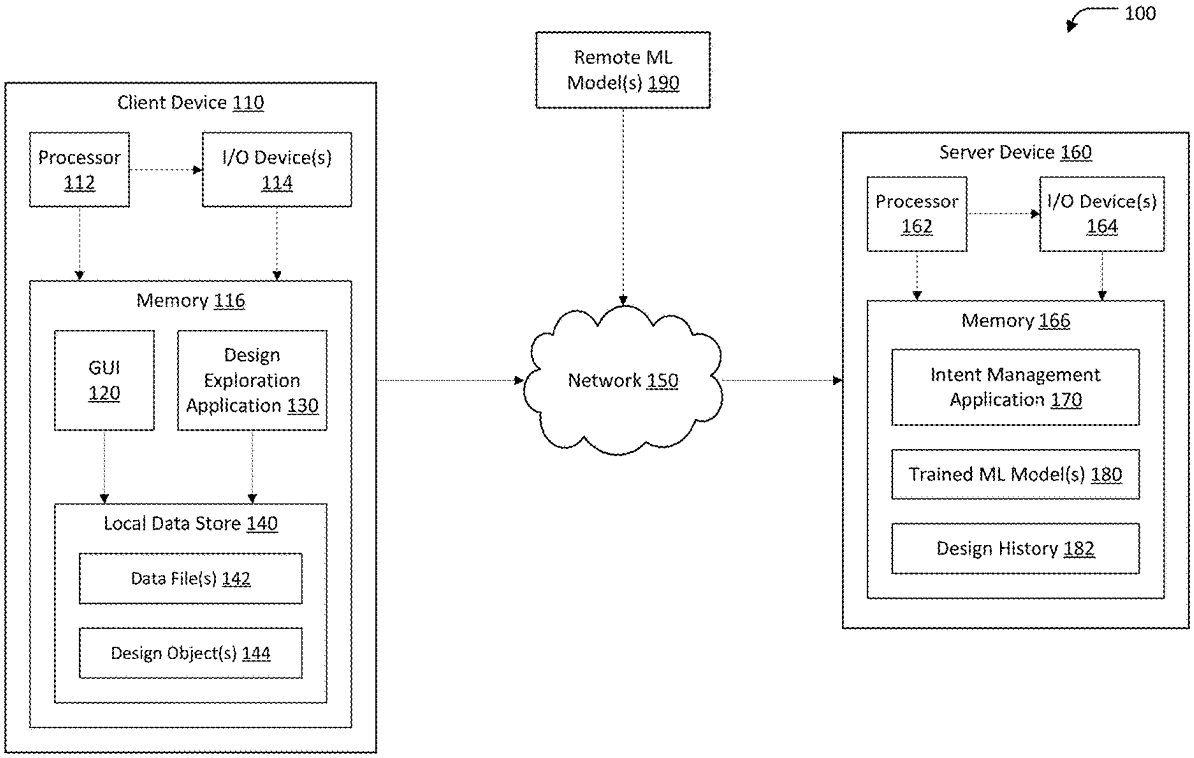
Publication Classification

(51) **Int. Cl.**
G06F 30/27 (2020.01)

(52) **U.S. Cl.**
CPC *G06F 30/27* (2020.01)

(57) **ABSTRACT**

In various embodiments, a computer-implemented method for generating a design object via a design exploration application comprises receiving an intent input, where the intent input includes at least a textual input, generating, based on the intent input, a design prompt, generating, via a trained machine learning (ML) model, a three-dimensional object based on the design prompt, converting the three-dimensional object to the design object, where the design object includes one or more editable features, and adding the design object to a design space.



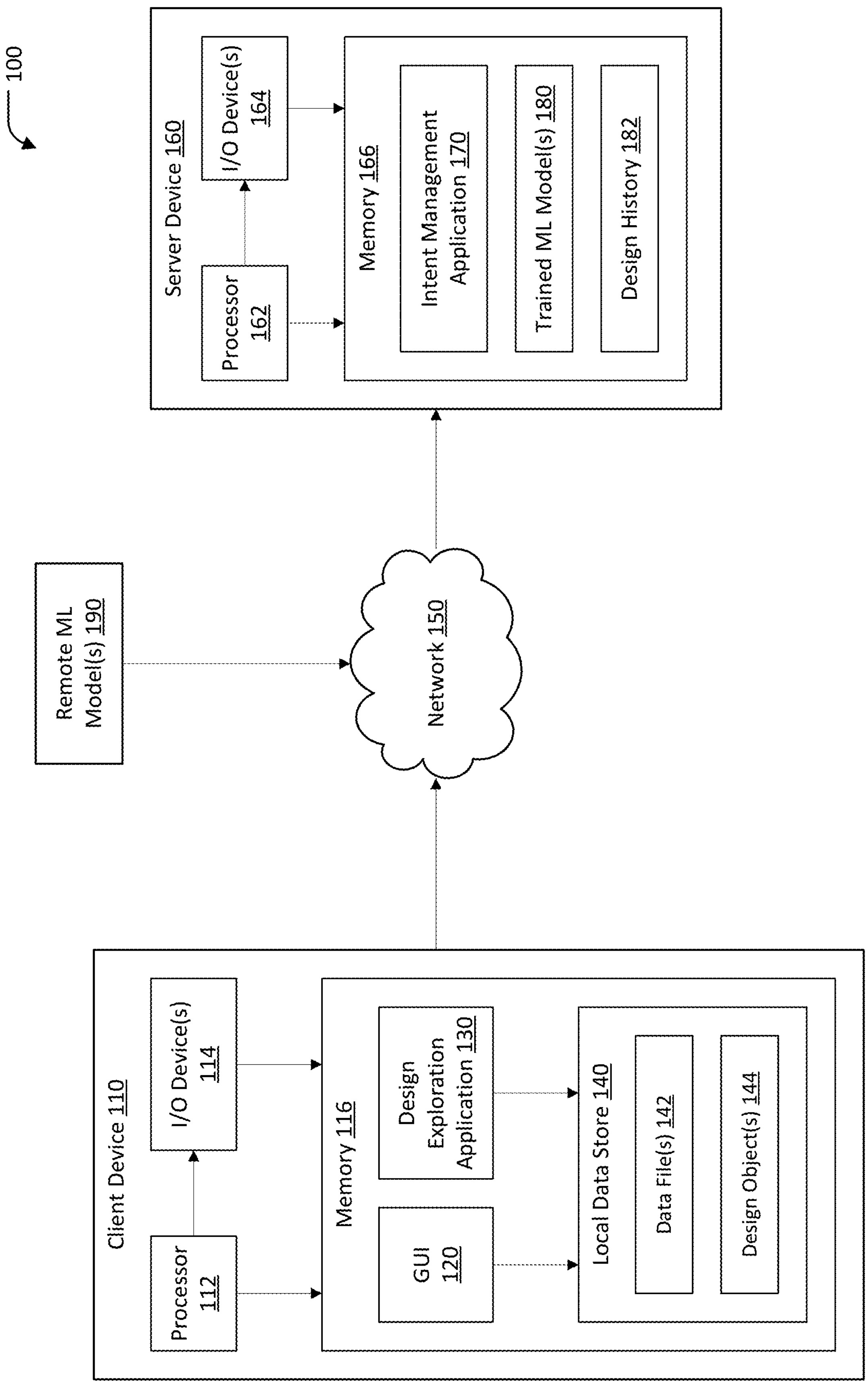

100
Client Device 110
Processor 112
I/O Device(s) 114
Memory 116
GUI 120
Design Exploration Application 130
Local Data Store 140
Data File(s) 142
Design Object(s) 144
Network 150
Remote ML Model(s) 190
Server Device 160
Processor 162
I/O Device(s) 164
Memory 166
Intent Management Application 170
Trained ML Model(s) 180
Design History 182

FIG. 1

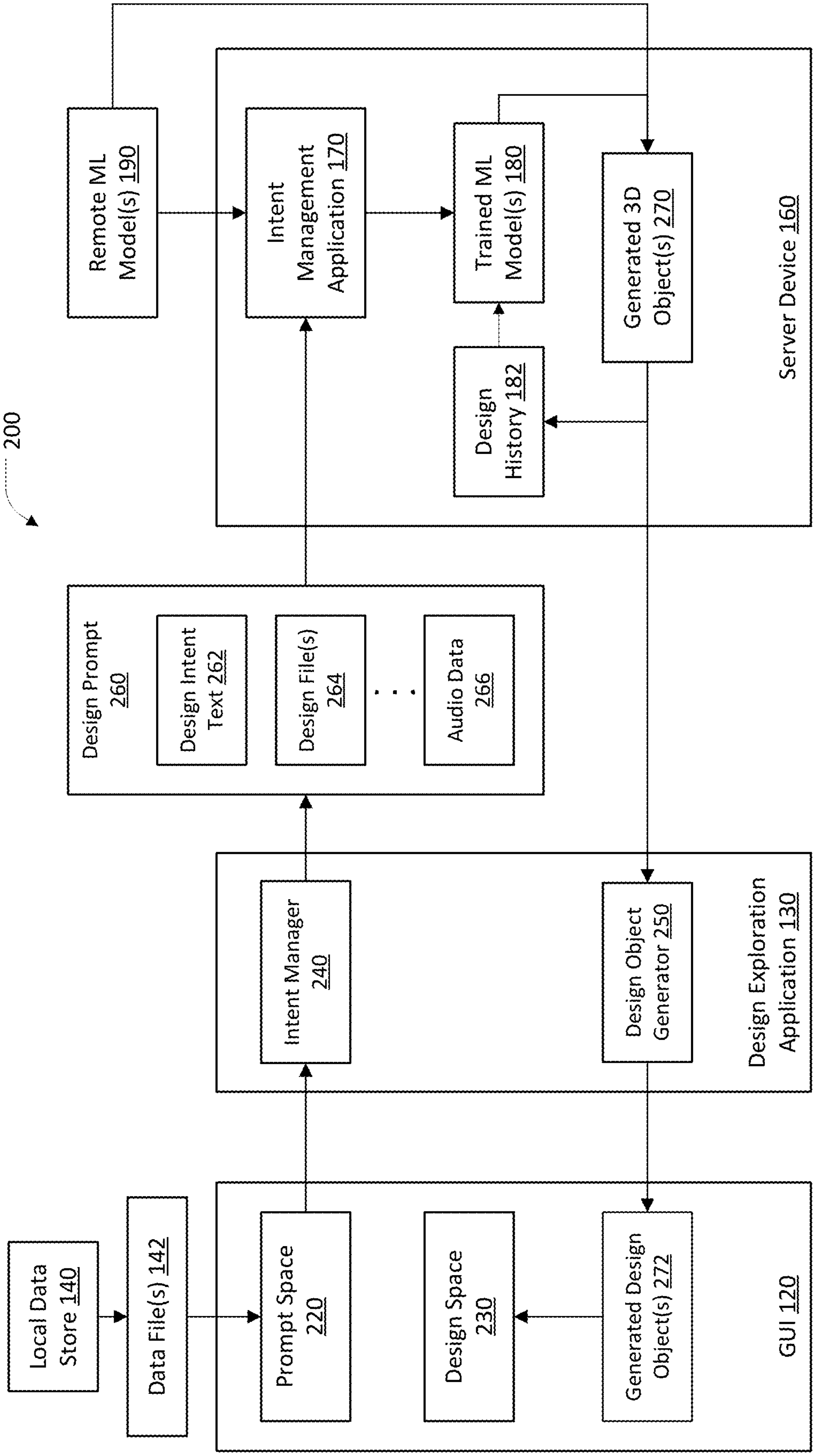

200
Local Data Store 140
Data File(s) 142
Prompt Space 220
Design Space 230
Generated Design Object(s) 272
GUI 120
Intent Manager 240
Design Object Generator 250
Design Exploration Application 130
Design Prompt 260
Design Intent Text 262
Design File(s) 264
. . .
Audio Data 266
Remote ML Model(s) 190
Intent Management Application 170
Trained ML Model(s) 180
Generated 3D Object(s) 270
Design History 182
Server Device 160

FIG. 2

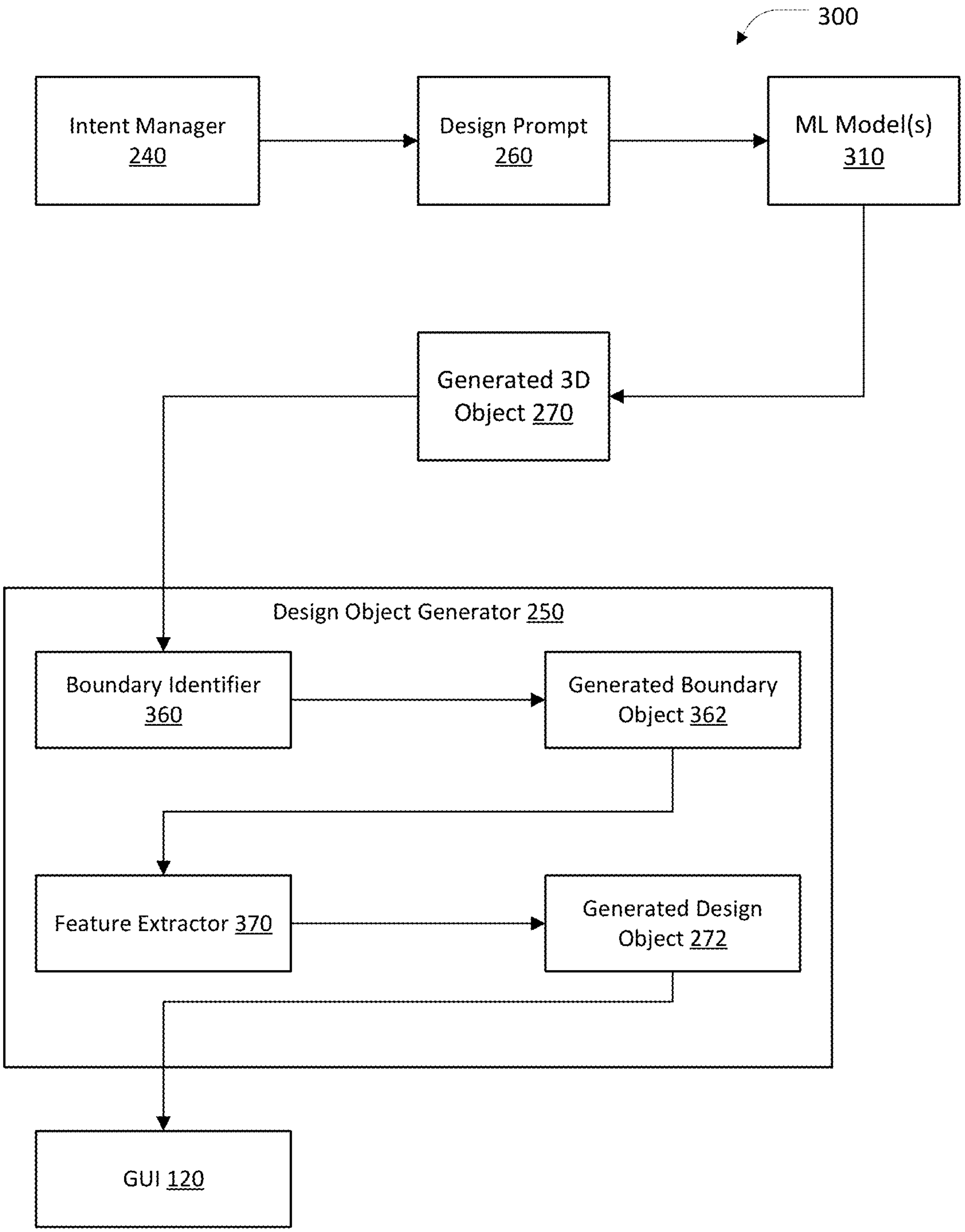
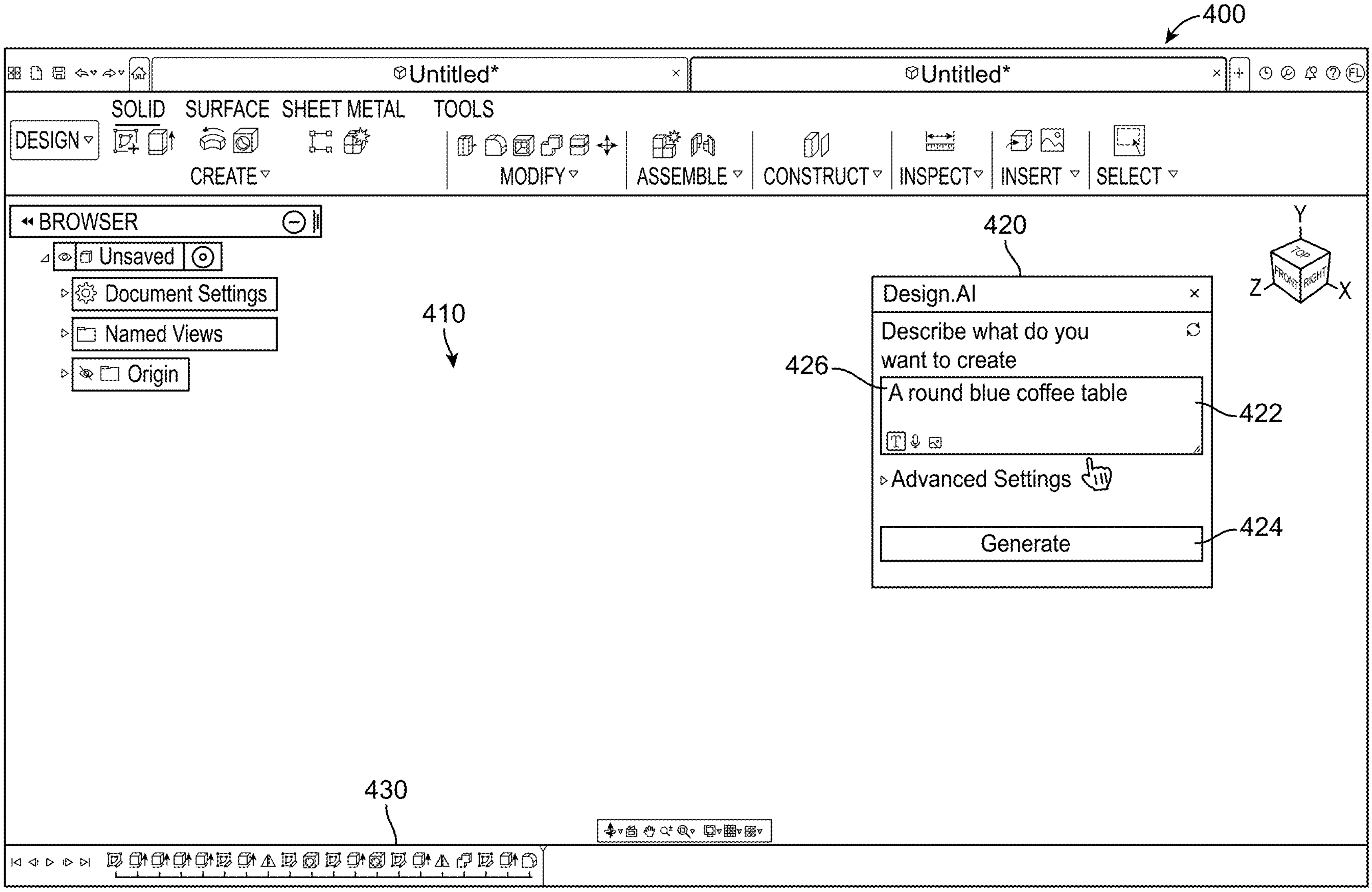

300
Intent Manager 240
Design Prompt 260
ML Model(s) 310
Generated 3D Object 270
Design Object Generator 250
Boundary Identifier 360
Generated Boundary Object 362
Feature Extractor 370
Generated Design Object 272
GUI 120

FIG. 3

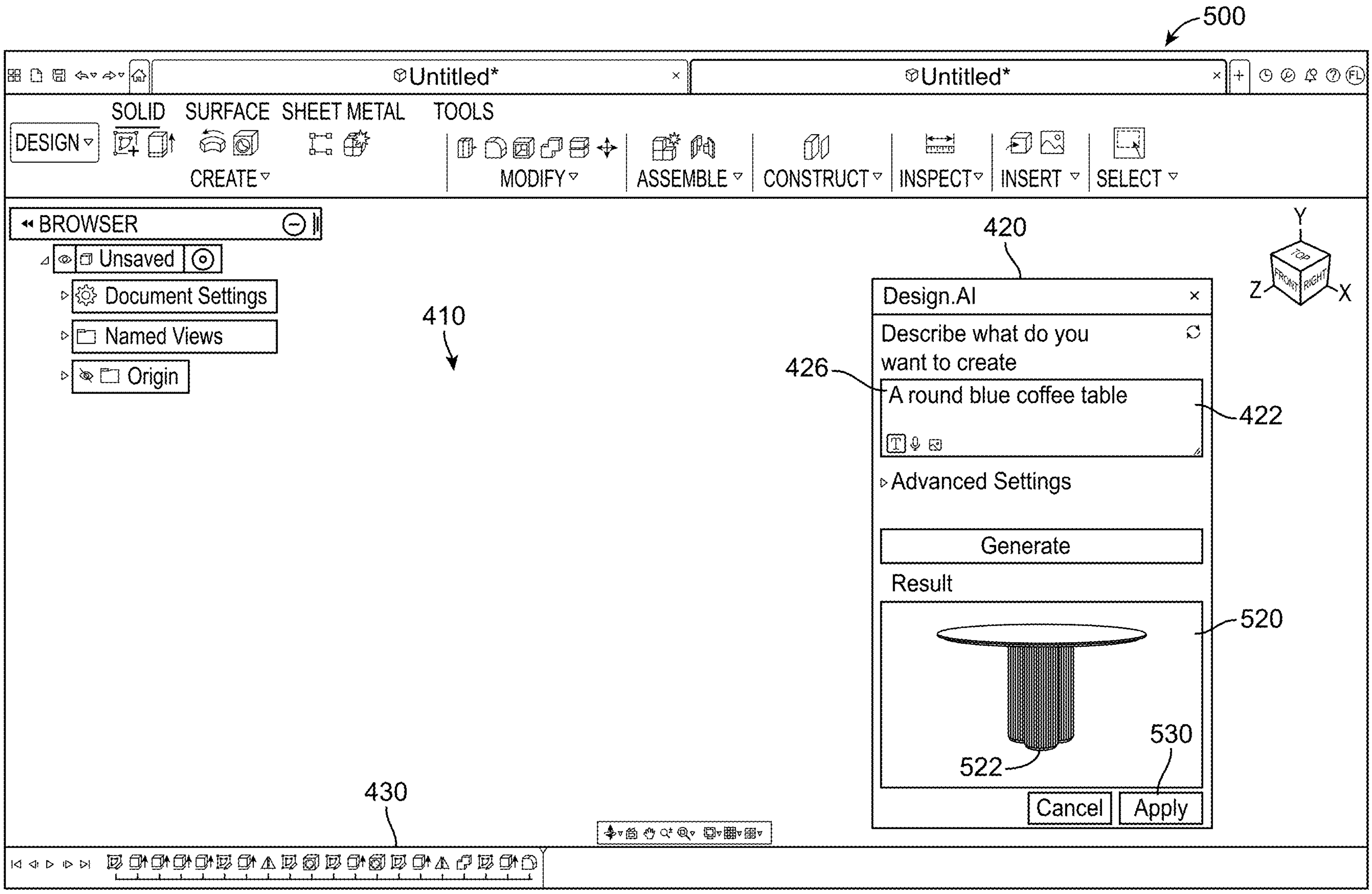


Design.AI

Describe what do you want to create

A round blue coffee table

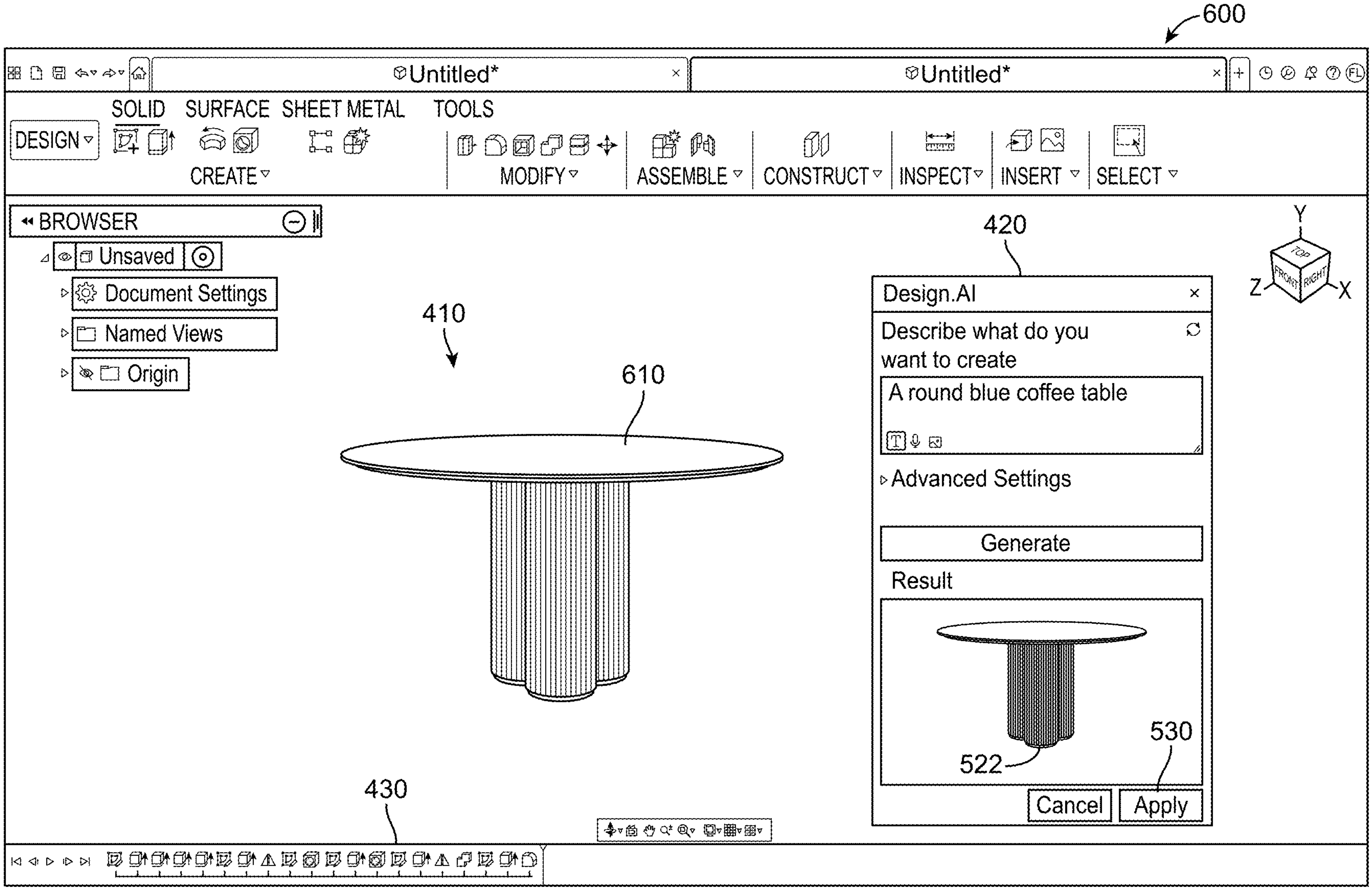
FIG. 4



Describe what do you want to create

A round blue coffee table

FIG. 5



Describe what do you want to create

A round blue coffee table

FIG. 6

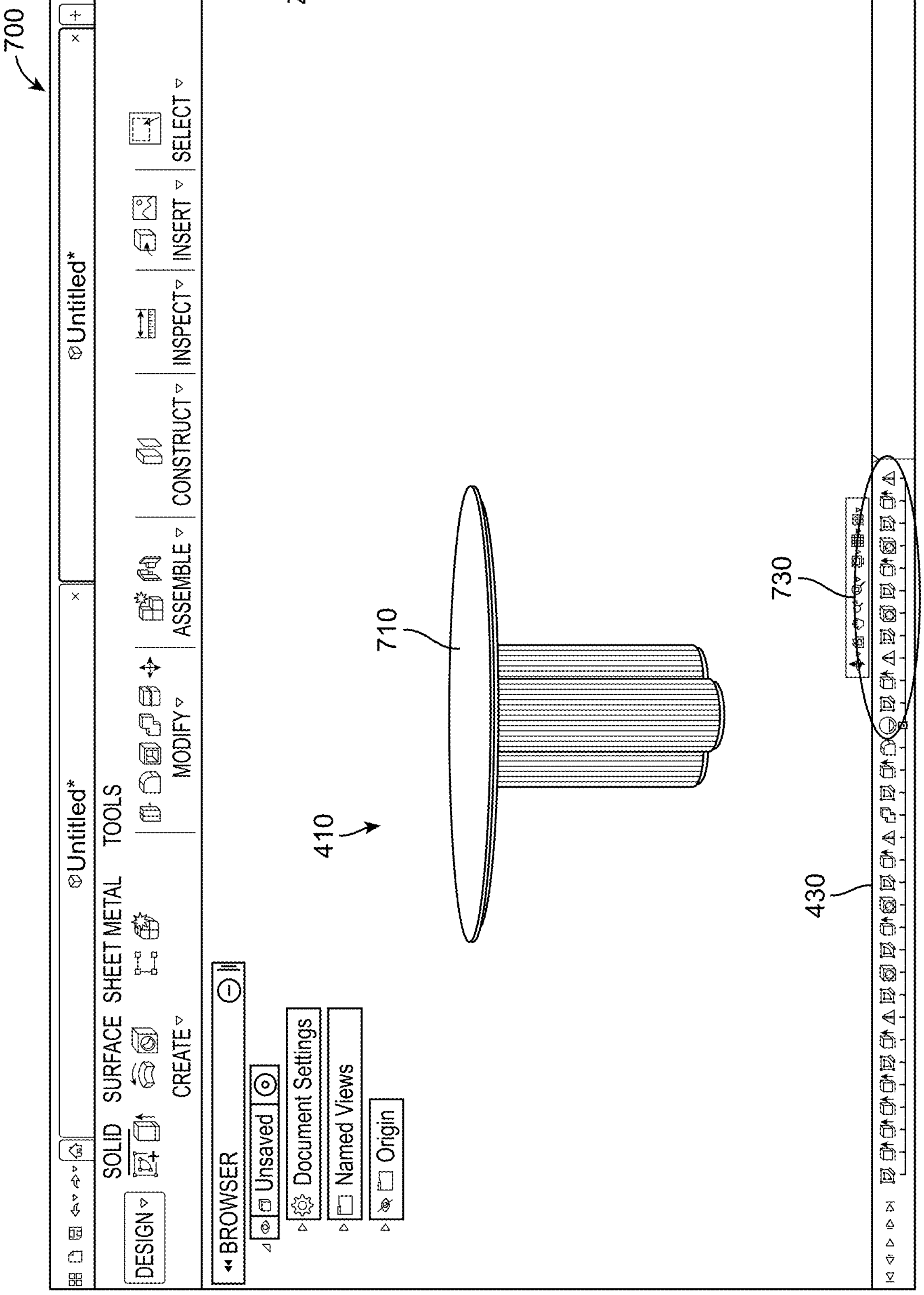
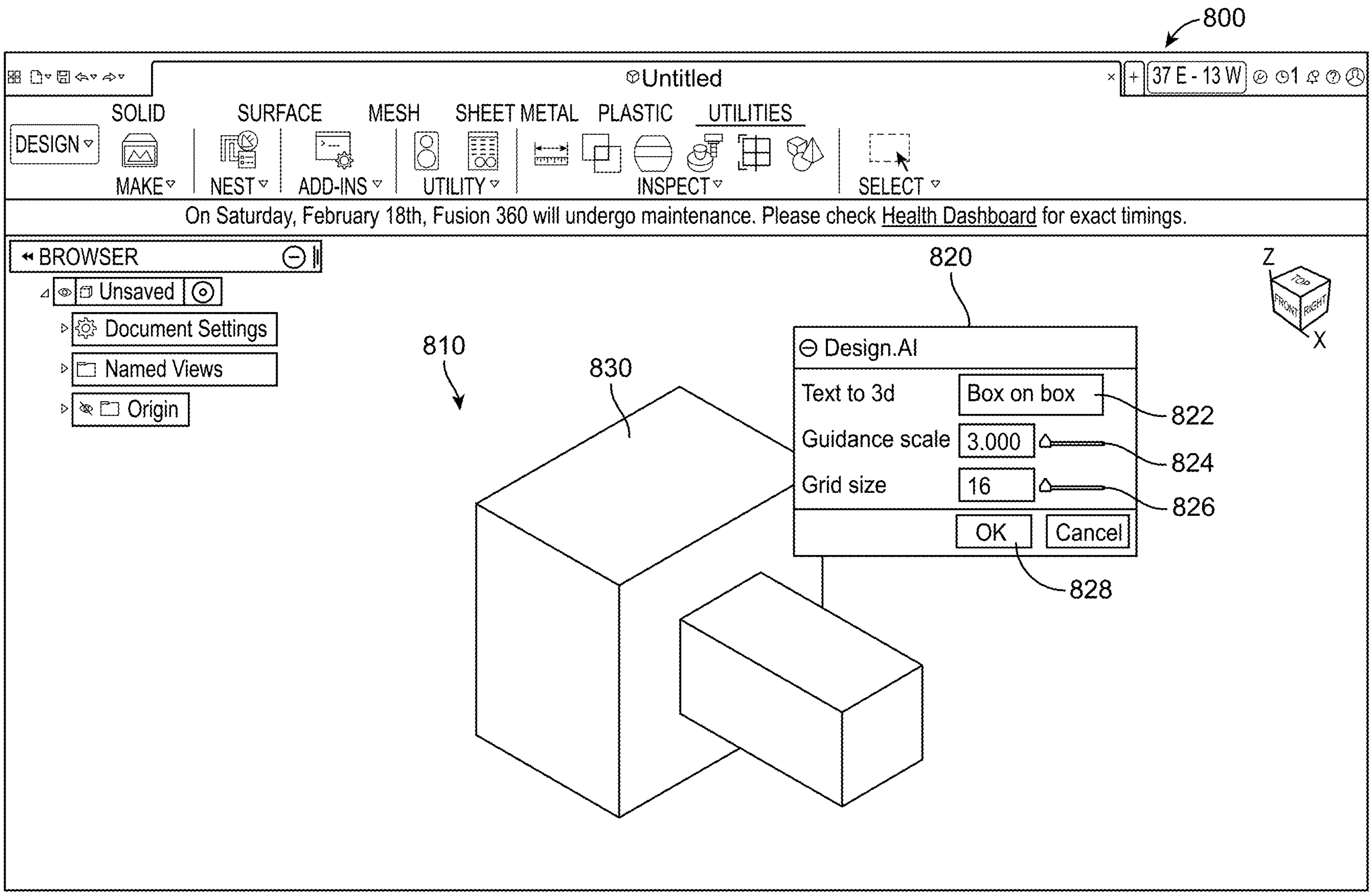

700
Untitled*
Untitled*
DESIGN ▷
SOLID
SURFACE
SHEET METAL
TOOLS
CREATE ▷
MODIFY ▷
ASSEMBLE ▷
CONSTRUCT ▷
INSPECT ▷
INSERT ▷
SELECT ▷
BROWSER
Unsaved
Document Settings
Named Views
Origin
TOP
FRONT
RIGHT
X
Y
Z
410
710
730
430

FIG. 7



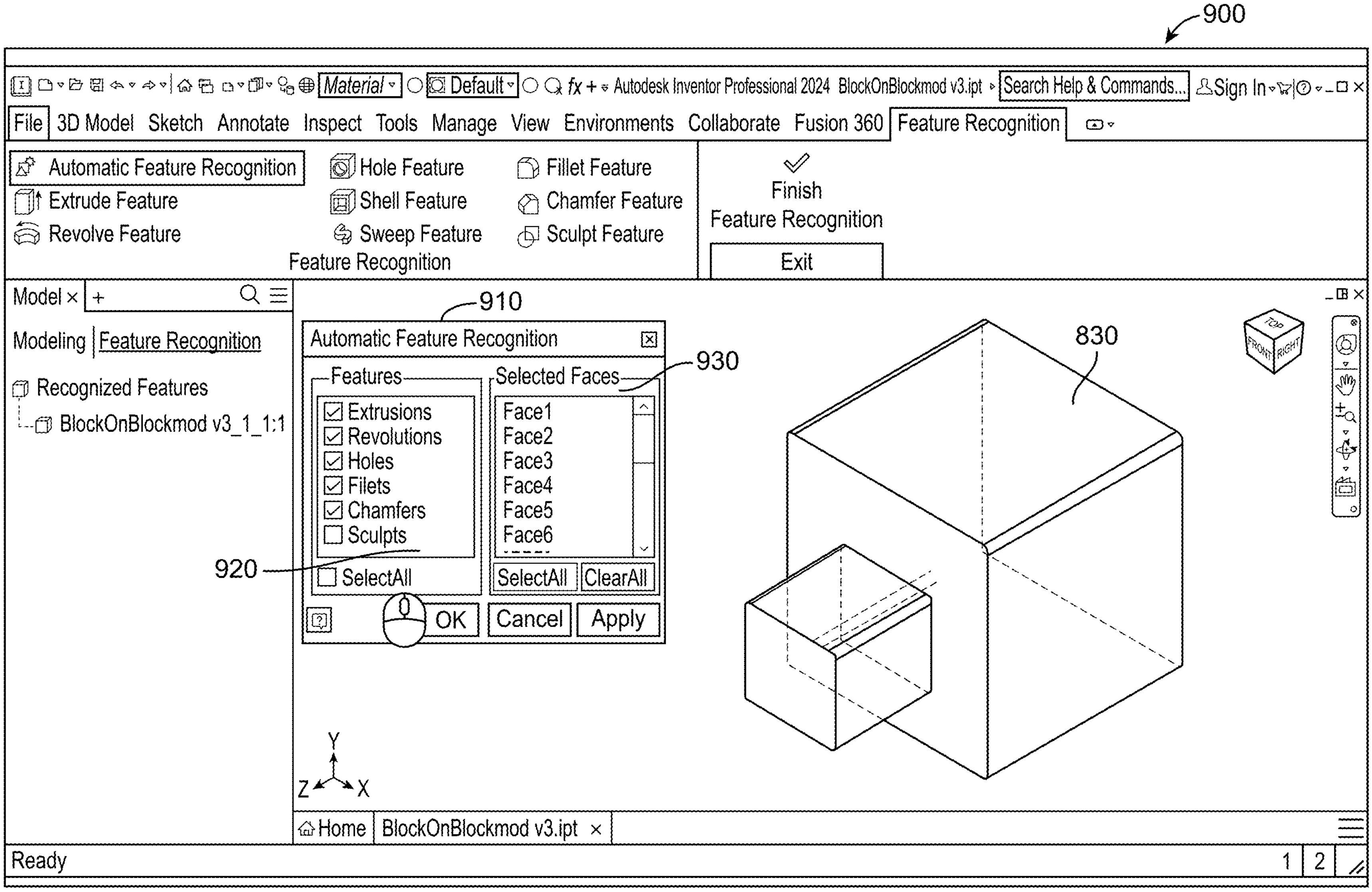
On Saturday, February 18th, Fusion 360 will undergo maintenance. Please check Health Dashboard for exact timings.

Text to 3d: Box on box

Guidance scale: 3.000

Grid size: 16

FIG. 8



Automatic Feature Recognition

Features

☑ Extrusions
☑ Revolutions
☑ Holes
☑ Filets
☑ Chamfers
☐ Sculpts

☐ SelectAll

Selected Faces

Face1
Face2
Face3
Face4
Face5
Face6

FIG. 9

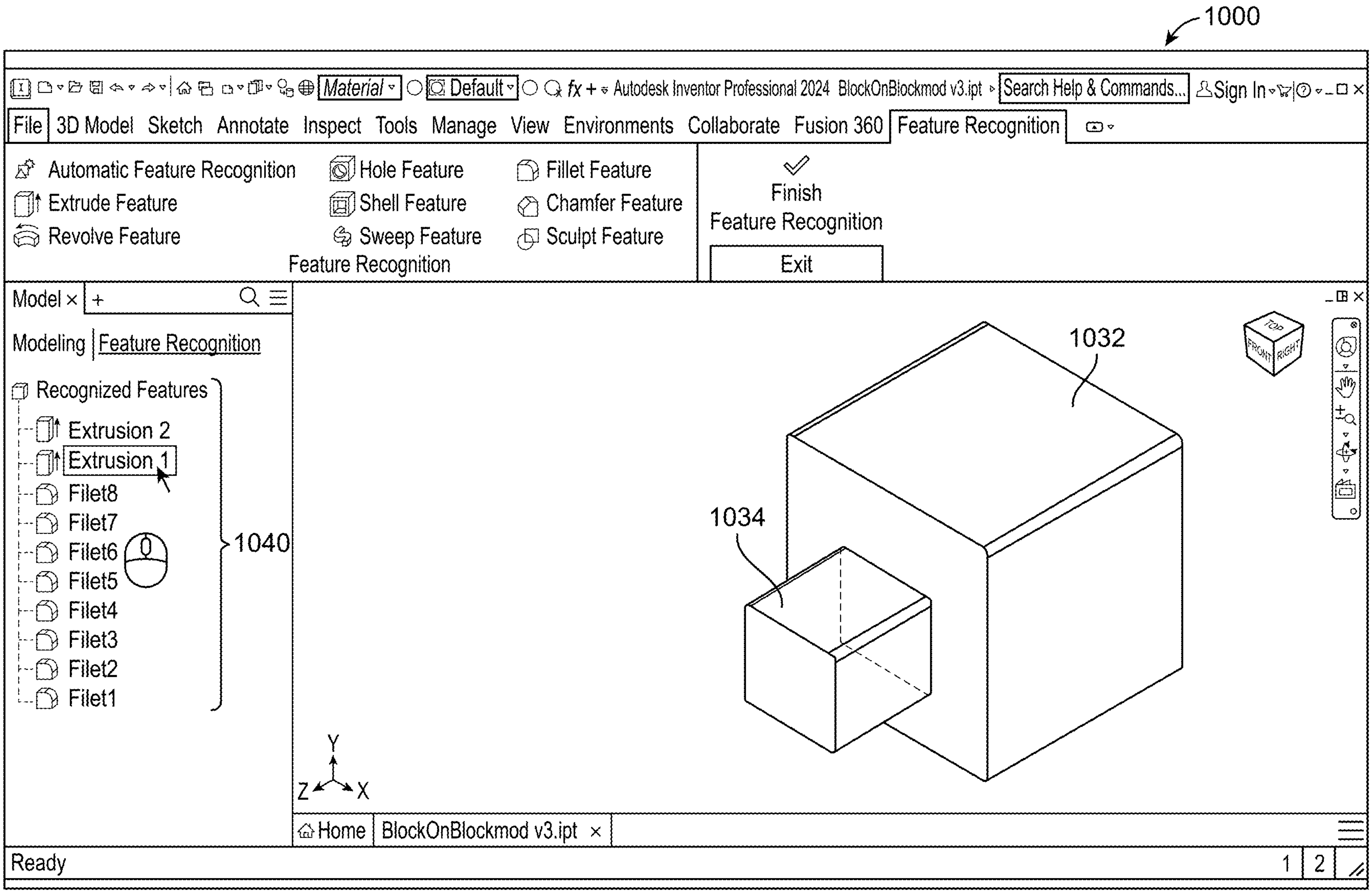

1000
Material
Default
fx
Autodesk Inventor Professional 2024 BlockOnBlockmod v3.ipt
Search Help & Commands...
Sign In
File
3D Model
Sketch
Annotate
Inspect
Tools
Manage
View
Environments
Collaborate
Fusion 360
Feature Recognition
Automatic Feature Recognition
Extrude Feature
Revolve Feature
Hole Feature
Shell Feature
Sweep Feature
Fillet Feature
Chamfer Feature
Sculpt Feature
Feature Recognition
Finish
Feature Recognition
Exit
Model ×
+
Modeling
Feature Recognition
Recognized Features
Extrusion 2
Extrusion 1
Filet8
Filet7
Filet6
Filet5
Filet4
Filet3
Filet2
Filet1
1040
1032
1034
TOP
FRONT
RIGHT
Y
Z
X
Home
BlockOnBlockmod v3.ipt ×
Ready
1
2

FIG. 10

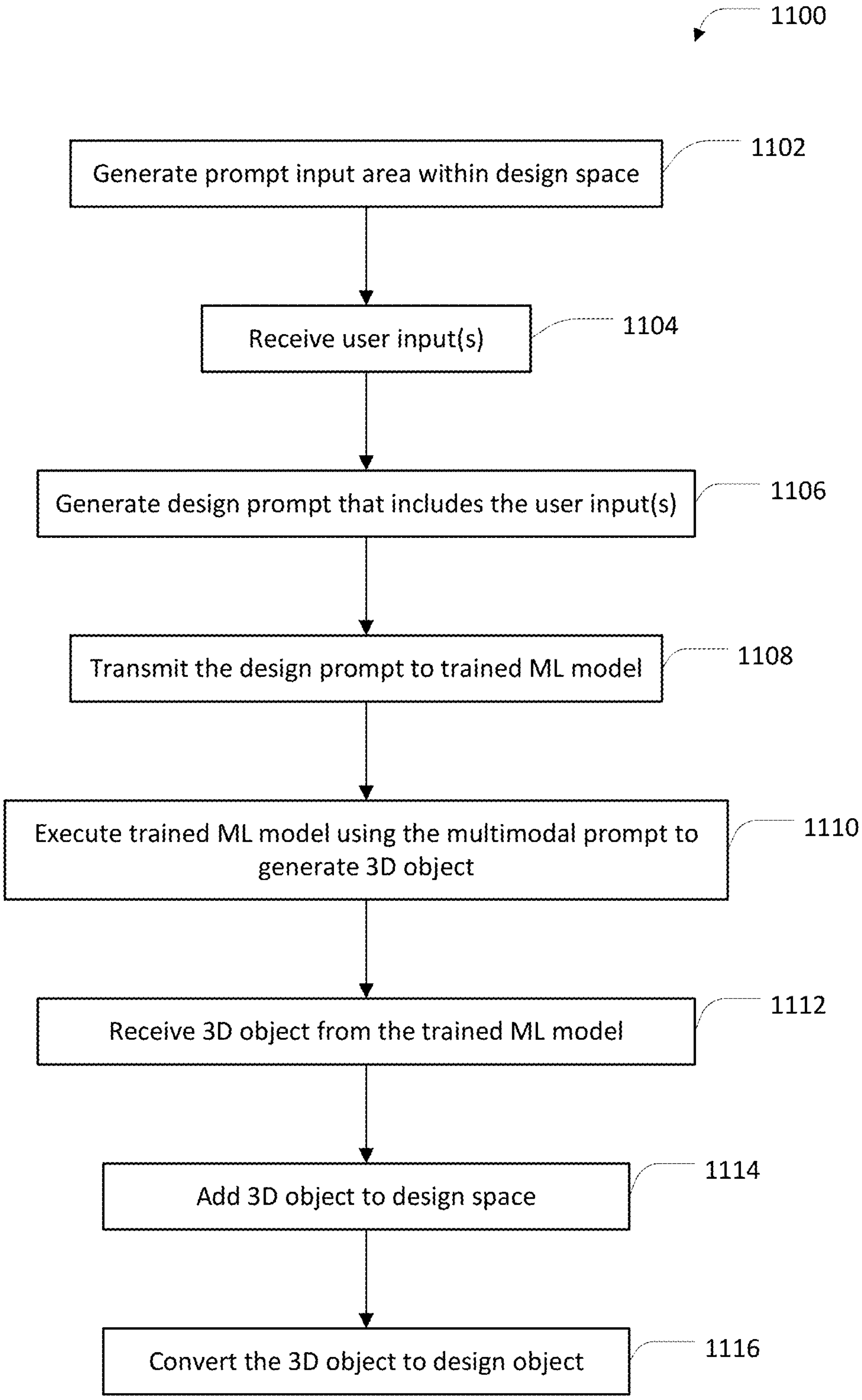

1100
Generate prompt input area within design space
1102
Receive user input(s)
1104
Generate design prompt that includes the user input(s)
1106
Transmit the design prompt to trained ML model
1108
Execute trained ML model using the multimodal prompt to generate 3D object
1110
Receive 3D object from the trained ML model
1112
Add 3D object to design space
1114
Convert the 3D object to design object
1116

FIG. 11

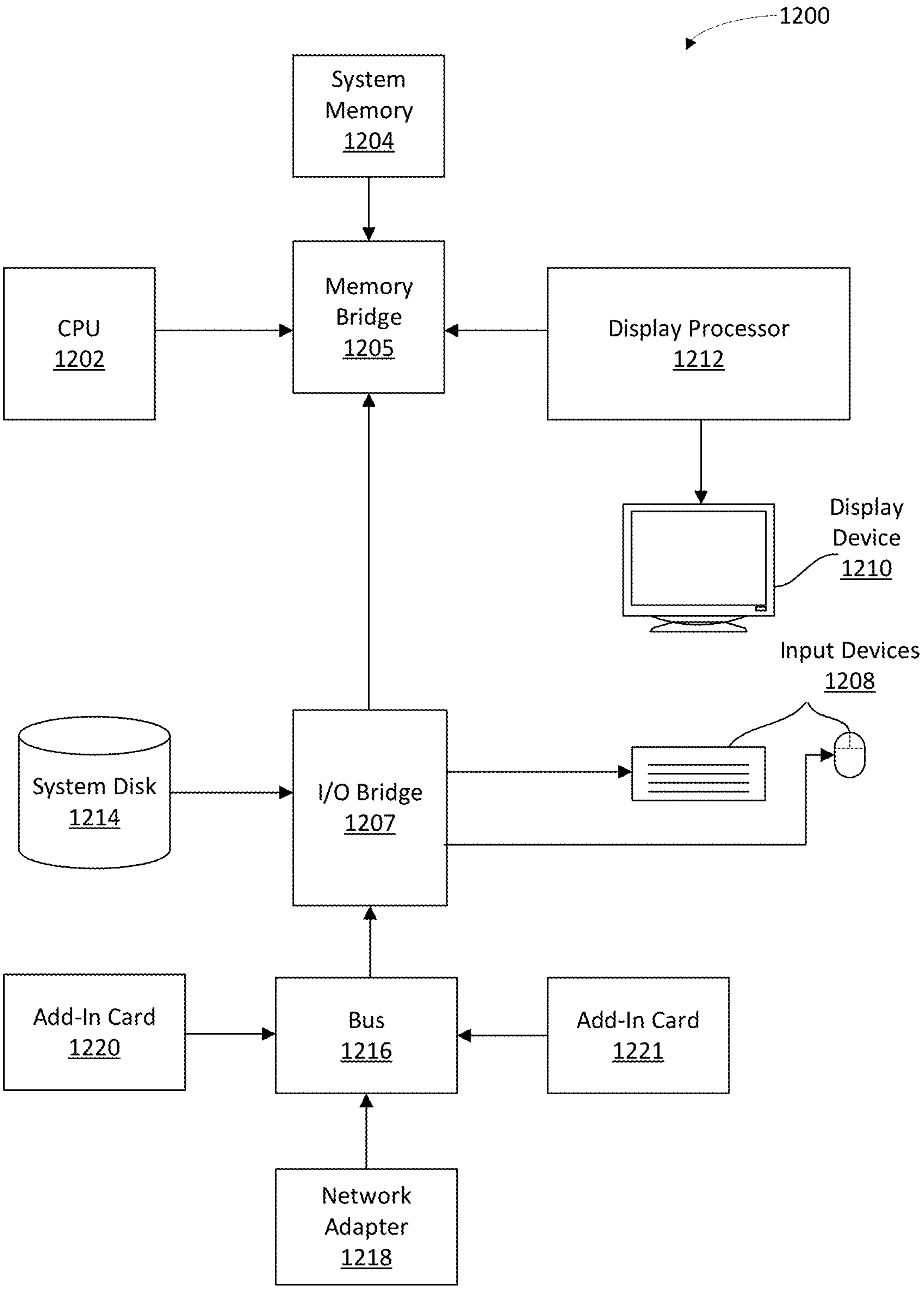

1200
System Memory 1204
CPU 1202
Memory Bridge 1205
Display Processor 1212
Display Device 1210
Input Devices 1208
System Disk 1214
I/O Bridge 1207
Add-In Card 1220
Bus 1216
Add-In Card 1221
Network Adapter 1218

FIG. 12

TECHNIQUES FOR GENERATING THREE-DIMENSIONAL DESIGN OBJECTS USING MACHINE LEARNING MODELS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority benefit of United States Provisional Patent Application titled, "TECHNIQUES FOR GENERATING THREE-DIMENSIONAL DESIGNS FROM TEXT PROMPTS," filed on Feb. **21**, **2024**, and having Ser. No. 63/556,176. The subject matter of this related application is hereby incorporated herein by reference.

BACKGROUND

Field of the Various Embodiments

[0002] The various embodiments relate generally to computer-aided design and artificial intelligence, and, more specifically, to techniques for generating three-dimensional design objects using machine learning models.

Description of the Related Art

[0003] Design exploration for three-dimensional (3D) objects generally refers to a phase of a design process during which a designer generates and evaluates various designs alternatives for one or more 3D objects within a larger 3D design project. As is well-understood in practice, manually generating multiple designs for even a relatively simple 3D object can be very labor-intensive and time-consuming. Because the time allocated for generating a design (a 3D design object) for a specific 3D object is usually limited, users typically produce only a small number of 3D design objects, which can reduce the overall quality of the final design due to the lack of options. Accordingly, various conventional computer-aided design (CAD) applications have been developed that attempt to automate the generation and evaluation of 3D design objects.

[0004] One approach to automating how CAD applications generate and evaluate 3D design objects involves implementing an artificial intelligence (AI) model, such as a generative machine learning model, to automatically synthesize content items, such as text or images in response to a prompt provided by the user. The prompt provided to the AI model is usually in the form of a design problem statement that specifies one or more design characteristics to which the generated content item should adhere. The prompt can include any number of quantitative goals, physical objects, physical and functional constraints, and/or mechanical and geometric quantities that guide how the AI model should generate a content item. The AI model responds to the prompt by executing various optimization algorithms to generate content items that satisfy the applicable design characteristics specified in the prompt. In some cases, the AI model generates content items that the user selects for use in the larger 3D design project. In other cases, the AI model generates multiple content items. A design exploration application generates multiple design alternatives based on the content items and presents those design alternatives to a user within a design space. The user subsequently explores the design space, where different design alternatives can be viewed and evaluated to select the best design alternative to incorporate into the larger 3D design project.

[0005] One drawback of the above approach is that conventional CAD applications do not incorporate the content produced by the AI models when generating an overall 3D design. Oftentimes, when a user generates a new 3D design object, a user needs to nominate distinct preserve geometries, obstacle geometries, and starting shape geometries, as well as specify objectives and manufacturing parameters. In this regard, the use of the AI models to generate usable components for an overall 3D design is limited to highly skilled users. Such users can specify technical prompts to generate applicable content items and can manually modify the content items produced by the AI models to be incorporated into the overall 3D design. Consequently, less experienced users avoid using AI models when generating designs due to the complex and time consuming nature of interacting with the AI models and incorporating generated content items into an overall 3D design. Further, the need to manually convert content items generated by the AI models into 3D design objects that are usable within the design exploration application substantially reduces overall design quality, as such manual modifications may conflict with one or more design parameters specified in the original design problem statement.

[0006] As the foregoing illustrates, what is needed in the art are more effective techniques for automatically generating designs using artificial intelligence models.

SUMMARY

[0007] In various embodiments, a computer-implemented method for generating a design object via a design exploration application comprises receiving an intent input, where the intent input includes at least a textual input, generating, based on the intent input, a design prompt, generating, via a trained machine learning (ML) model, a three-dimensional object based on the design prompt, converting the three-dimensional object to the design object, where the design object includes one or more editable features, and adding the design object to a design space.

[0008] At least one technical advantage of the disclosed techniques relative to the prior art is that the disclosed techniques enable design systems to incorporate generative artificial intelligence systems that determine the design intent of a user more accurately. Further, design systems that use the disclosed techniques can automatically convert content items produced by such generative artificial intelligence systems to parametric-based design objects that include a set of editable features. In that regard, the disclosed techniques provide an automated process for generating prompts from inputs provided by the user, such as combinations of text, speech, sketches, images, and/or stored designs. Generating prompts using varying types of data enables the user to provide additional context to portions of a prompt that a trained generative artificial intelligence model can understand, which enables the generative artificial intelligence model to infer the design intents and ideas of the user with greater accuracy. Further, by automatically converting content items into parametric-based 3D design objects that can be easily added to the design space, the design system can quickly incorporate outputs of the generative artificial intelligence system into overall 3D designs to generate large numbers of alternative designs. Accordingly, with the disclosed techniques, 3D design objects that align better with the actual design-oriented intentions and ideas of users can be more readily generated and manufactured. These technical advantages provide one or more technological advancements over prior art approaches.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] So that the manner in which the above recited features of the various embodiments can be understood in detail, a more particular description of the inventive concepts, briefly summarized above, may be had by reference to various embodiments, some of which are illustrated in the appended drawings. It is to be noted, however, that the appended drawings illustrate only typical embodiments of the inventive concepts and are therefore not to be considered limiting of scope in any way, and that there are other equally effective embodiments.

[0010] FIG. **1** is a conceptual illustration of a system configured to implement one or more aspects of the various embodiments;

[0011] FIG. **2** is a more detailed illustration of the design exploration application of FIG. **1**, according to various embodiments;

[0012] FIG. **3** is an exemplar technique of the design exploration application of FIG. **1** producing a generated design object based on a design prompt, according to various embodiments;

[0013] FIG. **4** is an exemplar illustration of design exploration application of FIG. **2** causing the GUI to display the prompt area, according to various embodiments;

[0014] FIG. **5** is an exemplar illustration of an update to the prompt input area of FIG. **4**, according to various embodiments;

[0015] FIG. **6** is an exemplar illustration of the generated 3D object of FIG. **5** being added to the design space **410**, according to various embodiments.

[0016] FIG. **7** is an exemplar illustration of the 3D object of FIG. **6** converted to a design object including a set of features, according to various embodiments;

[0017] FIG. **8** is another exemplar illustration of an update to the design space of FIG. **2**, according to various embodiments;

[0018] FIG. **9** is an exemplar illustration of a menu for the feature extractor of FIG. **3** within the design space, according to various embodiments;

[0019] FIG. **10** is an exemplar illustration of the feature extractor of FIG. **3** generating a plurality of design object and a list of editable features, according to various embodiments;

[0020] FIG. **11** sets forth a flow diagram of method steps for generating 3D objects, according to various embodiments; and

[0021] FIG. **12** depicts one architecture of a system within which embodiments of the present disclosure may be implemented.

DETAILED DESCRIPTION

[0022] In the following description, numerous specific details are set forth to provide a more thorough understanding of the various embodiments. However, it will be apparent to one skilled in the art that the inventive concepts may be practiced without one or more of these specific details.

System Overview

[0023] FIG. **1** is a conceptual illustration of a system **100** configured to implement one or more aspects of the various embodiments. As shown, in some embodiments, the system **100** includes, without limitation, a client device **110**, a server device **160**, and one or more remote machine learning (ML) models **190**. The client device **110** includes, without limitation, a processor **112**, one or more input/output (I/O) devices **114**, and a memory **116**. The memory **116** includes, without limitation, a graphical user interface (GUI) **120**, a design exploration application **130**, and a local data store **140**. The local data store **140** includes, without limitation, one or more data files **142** and one or more design objects **144**. The server device **160** includes, without limitation, a processor **162**, one or more I/O devices **164**, and a memory **166**. The memory **166** includes, without limitation, an intent management application **170**, one or more trained ML models **180**, and design history **182**. In some other embodiments, the system **100** can include any number and/or types of other client devices, server devices, remote ML models, or any combination thereof.

[0024] Any number of the components of the system **100** can be distributed across multiple geographic locations or implemented in one or more cloud computing environments (e.g., encapsulated shared resources, software, data) in any combination. In some embodiments, the client device **110** and/or zero or more other client devices (not shown) can be implemented as one or more compute instances in a cloud computing environment, implemented as part of any other distributed computing environment, or implemented in a stand-alone fashion. In various embodiments, the client device **110** can be integrated with any number and/or types of other devices (e.g., one or more other compute instances and/or a display device) into a user device. Some examples of user devices include, without limitation, desktop computers, laptops, smartphones, and tablets.

[0025] In general, the client device **110** is configured to implement one or more software applications. For explanatory purposes only, each software application is described as residing in the memory **116** of the client device **110** and executing on the processor **112** of the client device **110**. In some embodiments, any number of instances of any number of software applications can reside in the memory **116** and any number of other memories associated with any number of other compute instances and execute on the processor **112** of the client device **110** and any number of other processors associated with any number of other compute instances in any combination. In the same or other embodiments, the functionality of any number of software applications can be distributed across any number of other software applications that reside in the memory **116** and any number of other memories associated with any number of other compute instances and execute on the processor **112** and any number of other processors associated with any number of other compute instances in any combination. Further, subsets of the functionality of multiple software applications can be consolidated into a single software application.

[0026] In particular, the client device **110** is configured to implement a design exploration application **130** to generate 3D designs. In operation, the design exploration application **130** causes one or more ML models **180**, **190** to synthesize 3D designs based on any number of goals and constraints. The design exploration application **130** then presents the designs as one or more design objects **144** to a user in the context of a design space. In some embodiments, the user can explore and modify the one or more design objects via the GUI **120**. Additionally, or alternatively the user can also include at least one of the design objects **144** for use in additional design and/or manufacturing activities.

[0027] In various embodiments, the processor **112** can be any instruction execution system, apparatus, or device capable of executing instructions. For example, the processor **112** could comprise a central processing unit (CPU), a digital signal processing unit (DSP), a microprocessor, an application-specific integrated circuit (ASIC), a neural processing unit (NPU), a graphics processing unit (GPU), a field-programmable gate array (FPGA), a controller, a microcontroller, a state machine, or any combination thereof. In some embodiments, the processor **112** is a programmable processor that executes program instructions to manipulate input data. In some embodiments, the processor **112** can include any number of processing cores, memories, and other modules for facilitating program execution.

[0028] The input/output (I/O) devices **114** include devices configured to receive input, including, for example, a keyboard, a mouse, and so forth. In some embodiments, the I/O devices **114** also includes devices configured to provide output, including, for example, a display device, a speaker, and so forth. Additionally, or alternatively the I/O devices **114** may further include devices configured to both receive and provide input and output, respectively, including, for example, a touchscreen, a universal serial bus (USB) port, and so forth.

[0029] The memory **116** includes a memory module, or collection of memory modules. In some embodiments, the memory **116** can include a variety of computer-readable media selected for their size, relative performance, or other capabilities: volatile and/or non-volatile media, removable and/or non-removable media, etc. The memory **116** can include cache, random access memory (RAM), storage, etc. The memory **116** can include one or more discrete memory modules, such as dynamic RAM (DRAM) dual inline memory modules (DIMMs). Of course, various memory chips, bandwidths, and form factors may alternately be selected. The memory **116** stores content, such as software applications and data, for use by the processor **112**. In some embodiments, a storage (not shown) supplements or replaces the memory **116**. The storage can include any number and type of external memories that are accessible to the processor **112** of the client device **110**. For example, and without limitation, the storage can include a Secure Digital (SD) Card, an external Flash memory, a portable compact disc read-only memory, an optical storage device, a magnetic storage device, or any suitable combination of the foregoing.

[0030] Non-volatile memory included in the memory **116** generally stores one or more application programs including the design exploration application **130**, and data (e.g., the data files **142** and/or the design objects stored in the local data store **140**) for processing by the processor **112**. In various embodiments, the memory **116** can include non-volatile memory, such as optical drives, magnetic drives, flash drives, or other storage. In some embodiments, separate data stores, such as one or more external data stores connected via the network **150** ("cloud storage") can supplement the memory **116**. In various embodiments, the design exploration application **130** within the memory **116** can be executed by the processor **112** to implement the overall functionality of the client device **110** to coordinate the operation of the system **100** as a whole.

[0031] In various embodiments, the memory **116** can include one or more modules for performing various functions or techniques described herein. In some embodiments, one or more of the modules and/or applications included in the memory **116** may be implemented locally on the client device **110**, and/or may be implemented via a cloud-based architecture. For example, any of the modules and/or applications included in the memory **116** could be executed on a remote device (e.g., smartphone, a server system, a cloud computing platform, etc.) that communicates with the client device **110** via a network interface or an I/O devices interface.

[0032] The design exploration application **130** resides in the memory **116** and executes on the processor **112** of the client device **110**. The design exploration application **130** interacts with a user via the GUI **120**. In some embodiments, the design exploration application **130** and one or more separate applications (not shown) interact with the same user via the GUI **120**. In various embodiments, the design exploration application **130** operates as a 3D design application to generate and modify an overall 3D design that includes one or more design objects **144**. The design exploration application **130** interacts with a user via the GUI **120** in order to generate the one or more design objects **144** via direct user input (e.g., one or more tools to generate design objects, wireframe geometries, meshes, etc.) or using separate devices (e.g., the trained ML models **180**, the remote ML models **190**, separate 3D design applications, etc.). When generating the one or more design objects **144** using separate devices, the design exploration application **130** generates a prompt that effectively describes design-related intentions using one or more modalities (e.g., text, speech, images, etc.). The design exploration application **130** then causes the one or more of the ML models **180**, **190** to operate on the generated prompt to generate a relevant content item. The design exploration application **130** receives the content item from the one or more ML models **180**, **190** and displays the content item within the GUI **120**. The user can select via the GUI **120** the for use in generating a design object **144**, such as converting an image into a parametric-based design object **144** that includes a set of editable features. In such instances, the user can modify one or more features of the design object **144** and can incorporate the design object **144** into a larger 3D design.

[0033] The GUI **120** can be any type of user interface that allows users to interact with one or more software applications via any number and/or types of GUI elements. The GUI **120** can be displayed in any technically feasible fashion on any number and/or types of stand-alone display device, any number and/or types of display screens that are integrated into any number and/or types of user devices, or any combination thereof. The design exploration application **130** can perform any number and/or types of operations to directly and/or indirectly display and monitor any number and/or types of interactive GUI elements and/or any number and/or types of non-interactive GUI elements within the GUI **120**. In some embodiments, each interactive GUI element enables one or more types of user interactions that automatically trigger corresponding user events. Some examples of types of interactive GUI elements include, without limitation, scroll bars, buttons, text entry boxes, drop-down lists, and sliders. In some embodiments, the design exploration application **130** organizes GUI elements into one or more container GUI elements (e.g., panels and/or panes).

[0034] The local data store **140** is a part of storage in the client device **110** that stores one or more design objects **144** included in an overall 3D design and/or one or more data files **142** associated with 3D design. For example, an overall 3D design for a building can include multiple stored design objects **144**, including design objects **144** separately representing doors, windows, fixtures, walls, appliances, and so forth. The local data store **140** can also include data files **142** relating to a generated overall 3D design (e.g., component files, metadata, etc.). Additionally, or alternatively the local data store **140** includes data files **142** related to generating prompts for transmission to the one or more ML models **180**, **190**. For example, the local data store **140** can store one or more data files **142** for sketches, geometries (e.g., wireframes, meshes, etc.), images, videos, application states (e.g., camera angles used within a design space, tools selected by a user, etc.), audio recordings, and so forth.

[0035] The design objects **144** include geometries (e.g., vertices, edges, and/or faces), textures, images, and/or other components that the design exploration application **130** uses to generate portions of an overall 3D design. In various embodiments, the geometry of a given design object **144** refers to any multi-dimensional model of a physical structure, including CAD models, meshes, and point clouds, as well as circuit layouts, piping diagrams, free-body diagrams, and so forth. In various embodiments, the design object **144** includes a set of features that can be separately editable and/or modified. In such instances, the design exploration application **130** can apply alternative designs based on varying parametric values for each of the respective features. For example, the design exploration application **130** can identify a plurality of parametric values for a given feature (e.g., varying type values for an identified hole). The design exploration application **130** can then generate a plurality of alternative designs for an overall 3D design by selecting one of the parametric values for the given feature.

[0036] In some embodiments, the design exploration application **130** stores multiple design objects **144** for a given 3D design and stores multiple iterations of a given target object that the ML models **180**, **190**. For example, the user can form an initial prompt using the design exploration application **130** and receive a first generated design object **144**(1) from the trained ML model **180**(1), then refine the prompt and receive a second generated design object **144**(2) from the trained ML model **180**(1).

[0037] The network **150** can be any technically feasible set of interconnected communication links, including a local area network (LAN), wide area network (WAN), the World Wide Web, or the Internet, among others. The network **150** enables communications between the client device **110** and other devices in network **150** via wired and/or wireless communications protocols, including Bluetooth, Bluetooth low energy (BLE), wireless local area network (WiFi), cellular protocols, satellite networks, and/or near-field communications (NFC).

[0038] The server device **160** is configured to communicate with the design exploration application **130** to generate one or more design objects **144**. In operation, the server device **160** executes the intent management application **170** to process a prompt generated by the design exploration application **130**, select one or more ML models **180**, **190** trained to generate content items in response to the contents of the prompt, and input the prompt into the selected ML models **180**, **190**. Once the selected ML models **180**, **190** generate the content items that are responsive to the prompt, the server device **160** transmits the generated content items to the client device **110**, where the generated content items are usable by the design exploration application **130** to generate design objects **144** for the overall 3D design.

[0039] In various embodiments, the processor **162** can be any instruction execution system, apparatus, or device capable of executing instructions. For example, the processor **162** could comprise a central processing unit (CPU), a digital signal processing unit (DSP), a microprocessor, an application-specific integrated circuit (ASIC), a neural processing unit (NPU), a graphics processing unit (GPU), a field-programmable gate array (FPGA), a controller, a microcontroller, a state machine, or any combination thereof. In some embodiments, the processor **162** is a programmable processor that executes program instructions to manipulate input data. In some embodiments, the processor **162** can include any number of processing cores, memories, and other modules for facilitating program execution.

[0040] The input/output (I/O) devices **164** include devices configured to receive input, including, for example, a keyboard, a mouse, and so forth. In some embodiments, the I/O devices **164** also includes devices configured to provide output, including, for example, a display device, a speaker, and so forth. Additionally, or alternatively the I/O devices **164** may further include devices configured to both receive and provide input and output, respectively, including, for example, a touchscreen, a universal serial bus (USB) port, and so forth.

[0041] The memory **166** includes a memory module, or collection of memory modules. In some embodiments, the memory **166** can include a variety of computer-readable media selected for their size, relative performance, or other capabilities: volatile and/or non-volatile media, removable and/or non-removable media, etc. The memory **166** can include cache, random access memory (RAM), storage, etc. The memory **166** can include one or more discrete memory modules, such as dynamic RAM (DRAM) dual inline memory modules (DIMMs). Of course, various memory chips, bandwidths, and form factors may alternately be selected. The memory **166** stores content, such as software applications and data, for use by the processor **162**. In some embodiments, a storage (not shown) supplements or replaces the memory **166**. The storage can include any number and type of external memories that are accessible to the processor **162** of the server device **160**. For example, and without limitation, the storage can include a Secure Digital (SD) Card, an external Flash memory, a portable compact disc read-only memory, an optical storage device, a magnetic storage device, or any suitable combination of the foregoing.

[0042] Non-volatile memory included in the memory **166** generally stores one or more application programs including the intent management application **170** and one or more trained ML models **180**, and data (e.g., design history **182**) for processing by the processor **112**. In various embodiments, the memory **166** can include non-volatile memory, such as optical drives, magnetic drives, flash drives, or other storage. In some embodiments, separate data stores, such as one or more external data stores connected via the network **150** can supplement the memory **166**. In various embodiments, the intent management application **170** and/or the one or more ML models **180** within the memory **166** can be executed by the processor **162** to implement the overall functionality of the server device **160** to coordinate the operation of the system **100** as a whole.

[0043] In various embodiments, the memory **166** can include one or more modules for performing various functions or techniques described herein. In some embodiments, one or more of the modules and/or applications included in the memory **166** may be implemented locally on the client device **110**, server device **160**, and/or may be implemented via a cloud-based architecture. For example, any of the modules and/or applications included in the memory **166** could be executed on a remote device (e.g., smartphone, a server system, a cloud computing platform, etc.) that communicates with the server device **160** via a network interface or an I/O devices interface. Additionally, or alternatively the intent management application **170** could be executed on the client device **110** and can communicate with the trained ML models **180** operating at the server device **160**.

[0044] In various embodiments, the intent management application **170** receives a prompt from the design exploration application **130** and inputs the prompt into an applicable ML model **180**, **190**. In some embodiments, one or more of the ML models **180**, **190** are trained to respond to specific types of inputs, such as a ML model that is trained to generate content items (e.g., text, images, 3D volumes, etc.) from a specific combination of modalities (e.g., text, images, audio data, etc.). In such instances, the intent management application **170** processes a prompt to determine the modalities of the data that are included in the prompt and identifies one or more ML models **180**, **190** that have been trained to respond to such a combination of modalities. Upon identifying the one or more ML models, the intent management application **170** selects an ML model (e.g., the trained ML model **180**(1)) and inputs the prompt into the selected ML model **180**(1).

[0045] The trained ML models **180** include one or more generative ML models that have been trained on a relatively large amount of existing data and optionally any number of results (e.g., design objects **144** and evaluations provided by the user) to perform any number and/or types of prediction tasks based on patterns detected in the existing data. In various embodiments, the remote ML models **190** are trained ML models that communicate with the server device **160** to receive prompts via the intent management application **170**. In some embodiments, the trained ML model **180** is trained using various combinations of data from multiple modalities, such as textual data, image data, sound data, and so forth. The trained ML model **180** and/or the remote ML model **190** trained using at least two modalities of data are also referred to herein as a multimodal ML model. For example, in some embodiments, the one or more trained ML models **180** can include a third-generation Generative Pre-Trained Transformer (GPT-3) model, a specialized version of a GPT-3 model referred to as a "DALL-E2" model, a fourth-generation Generative Pre-Trained Transformer (GPT-4) model, and so forth. In various embodiments, the trained ML models **180** can be trained to generate content items from various combinations of modalities. Such combinations include text, a CAD object, a geometry, an image, a sketch, a video, an application state, an audio recording, etc.).

[0046] The design history **182** includes data and metadata associated with the one or more trained ML models **180** and/or the one or more remote ML models **190** generating design objects **144** in response to prompts provided by the design exploration application **130**. In some embodiments, the design history **182** includes successive iterations of design objects **144** that a single ML model **180** generates in response to a series of prompts. Additionally, or alternatively the design history **182** includes multiple design objects **144** that were generated by different ML models **180**, **190** in response to the same prompt. In some embodiments, the design history **182** includes feedback provided by the user for a given design object **144**. In such instances, the server device **160** can use the design history **182** as training data to further train the one or more ML models **180**. Additionally, or alternatively the design exploration application **130** can retrieve contents of the design history **182** and display the retrieved contents to the user via the GUI **120**.

[0047] FIG. **2** is a more detailed illustration of the design exploration application **130** of FIG. **1**, according to various embodiments. As shown, in some embodiments, the system **200** includes, without limitation, the GUI **120**, the design exploration application **130**, the local data store **140**, the one or more data files **142**, the server device **160**, the one or more remote ML models **190**, the and a design prompt **260**. The GUI **120** includes, without limitation, a prompt space **220**, a design space **230**, and one or more generated design objects **272**. The design exploration application **130** includes, without limitation, an intent manager **240** and a design object generator **250**. The server device **160** includes, without limitation, the intent management application **170**, the one or more trained ML models **180**, the design history **182**, and one or more generated 3D objects **270**. The design prompt **260** includes, without limitation, design intent text **262**, one or more design files **264**, and audio data **266**.

[0048] For explanatory purposes only, the functionality of the design exploration application **130** is described herein in the context of exemplar interactive and linear workflows used to generate the generated design object **272** in accordance with user-based design-related intentions expressed during the workflow. The generated design object **272** includes, without limitation, one or more parametric-based content items, such as images, wireframe models, geometries, and/or meshes for use a three-dimensional design, as well and any amount (including none) and/or types of associated metadata.

[0049] As persons skilled in the art will recognize, the techniques described herein are illustrative rather than restrictive and can be altered and applied in other contexts without departing from the broader spirit and scope of the inventive concepts described herein. For example, the techniques described herein can be modified and applied to generate any number of generated design objects **272** associated with any target 3D object in a linear fashion, a nonlinear fashion, an iterative fashion, a non-iterative fashion, a recursive fashion, a non-recursive fashion, or any combination thereof during an overall process for generating and evaluating designs for that target 3D object. A target 3D object can include any number (including one) and/or types of target 3D objects and/or target 3D object components.

[0050] For example, in some embodiments, a generated 3D object **272** can be generated and displayed within the GUI **120** during a first iteration, any portion (including all) of the generated 3D object **270** can be selected via the GUI

120, and a first design prompt **260** can be set equal to the selected portion of the generated 3D object **272** to recursively generate a second generated 3D object **270** via the one or more ML models **180**, **190** and the design object generator **250** during a second iteration. In the same or other embodiments, the design exploration application **130** can display and/or re-display any number of GUI elements (e.g., the generated 3D objects **270**), generate and/or regenerate any amount of data, or any combination thereof any number of times and/in any order while producing each new generated design object **272**.

[0051] In operation, the design exploration application **130** causes the GUI **120** to display the design space **230**. A user triggers the GUI **120** to display the prompt space **220** and provides the contents for the design prompt **260** via the prompt space **220**. The design exploration application **130** processes the content to generate the design prompt **260** and transmits the design prompt **260** to the server device **160**. The intent management application **170** identifies the contents included in the design prompt **260**. The intent management application **170** identifies one or more trained ML models **180** and/or remote ML models **190** that have been trained to process the combination of modalities corresponding to the identified contents. The intent management application **170** inputs the design prompt **260** into one or more of the identified ML models **180**, **190**. The identified ML models **180**, **190** respond to the design prompt **260** by generating one or more generated 3D objects **270**. The design object generator **250** receives the one or more generated 3D objects **270** and converts the generated 3D objects **270** to one or more generated design objects **272**. The design exploration application **130** displays the one or more generated design objects **272** in the prompt space **220** and/or the design space **230**.

[0052] In various embodiments, the design space **230** is a virtual workspace that includes one or more renderings of design objects (e.g., geometries of the design objects **144** and/or the generated design objects **272**) that form an overall 3D design. In some embodiments, the design space **230** includes multiple design alternatives for the overall 3D design. For example, the design space **230** may graphically organize multiple 3D designs that include differing combinations of design objects **144**, **272**. In such instances, the user interacts with the GUI to navigate between design alternatives to quickly analyze tradeoffs between different design options, observe trends in design options, constrain the design space, select specific design options, and so forth.

[0053] The prompt space **220** is panel, window, and/or portion of the GUI **120** in which a user can generate prompts, such as the design prompt **260**. In some embodiments, the prompt space **220** is a panel, such as a window separate from the design space. Alternatively, in some embodiments, the prompt space **220** is a window, panel, or other graphic element overlays at least a portion of the design space **230**. In such instances, a user can invoke the prompt space **220** as a prompt input area at various locations within the design space **230**. The user can then input data that is to be included in a design prompt **260**.

[0054] In various embodiments, the intent manager **240** determines the intent of inputs provided by the user. For example, the intent manager **240** can comprise a natural language (NL) processor that parses text provided by the user. Additionally, or alternatively the intent manager **240** can include processes audio data to identify words included in audio data and parse the identified words. In various embodiments, the intent manager **240** identifies one or more keywords in textual data. In some embodiments, the intent manager **240** includes one or more keyword datasets (not shown) that the intent manager **240** references when identifying the one or more keywords included in textual data. For example, the keyword datasets can include, without limitation, a 3D keyword dataset that includes any number and/or types of 3D keywords, a customized keyword dataset that includes any number and/or types of customized keywords, and/or a user keyword dataset that includes any number and/or types of user keywords (e.g., words and/or phrases specified by a user). The keywords can comprise particular words or phrases (e.g., demonstrative pronouns, technical terms, referential terms, etc.) that are relevant to designing 3D objects. For example, a user can input a regular sentence ("I want a fastener to connect these faces") within the prompt space **220**. The intent manager identifies "fastener," "connect," and "faces" as words relevant to the ML model **180**, **190** when generating content items for producing the generated design object **272**. In such instances, the intent manager **240** can include, supplement, and/or replace the identified keywords as part of the design intent text **262**.

[0055] In various embodiments, the design exploration application **130** updates the prompt space **220** and/or the design space **230** based on inputs by the user and/or data received from the server device **160**. For example, the design exploration application **130** can initially respond to the user invoking a prompt via a hotkey or a marking menu by displaying the prompt space **220** to receive data to include in the design prompt **260**. When the user initially inputs one or more types of data within the prompt space **220**, the design exploration application can generate and transmits the design prompt **260** to the server device **160**. Upon receipt of the generated 3D object **270**, the design exploration application **130** can then update the prompt space **220** to further include the generated 3D object **270**.

[0056] In various embodiments, the design exploration application **130** receives textual and/or non-textual data to include in the design prompt **260** via the input areas included in the prompt space **220**. When providing non-textual data, the user can retrieve stored data, such as one or more stored data files **142** (e.g., stored geometries, stored CAD files, audio recordings, stored sketches, etc.) from the local data store **140**. Additionally, or alternatively the user can retrieve contents from the design history **182** and can add the contents into the input area. In such instances, the contents from the design history **182** can be stored in one or more data files **142** that the user retrieves from the local data store **140** and/or the server device **160**.

[0057] The design prompt **260** is a prompt that includes one or more modalities of data (e.g., textual data, image data, audio data, etc.) that specifies the design intent of the user. In various embodiments, the design exploration application **130** receives one or more types of data and builds the design prompt **260** to include the data received. For example, a user can initially write design intent text **262** that is a natural language phrase, as well as an uploaded sketch. Upon receiving the sketch, the design exploration application **130** can then generate the design prompt **260** to include both the design intent text **262** and the sketch (e.g., the design file **264**(1)). In some embodiments, the design prompt **260** can include multiple data inputs of the same modality. For example, the design prompt **260** can include multiple design intent texts **262** (e.g., **262**(1), **262**(2), etc.) and/or multiple design files **264** (e.g., **264**(1), **264**(2), etc.).

[0058] The design intent text **262** includes textual data that describes the intent of the user. For example, the design intent text can include descriptions for characteristics of a target 3D design object (e.g., "a chrome hubcap"). In some embodiments, the design exploration application **130** generates design intent text **262** from a different type of data input. For example, the prompt space **220** can include a set of sliders for specific parameter values, such as grid size and guidance scale. In such instances, the design exploration application **130** can include respective the numerical values for the respective sliders as additional design intent texts **262** (e.g., **262**(2) and **262**(3)) to supplement the entered phrase. In another example, the intent manager **240** can perform NL processing to identify words included in an audio recording. In such instances, the design exploration application **130** generates design intent text **262** that includes the identified words.

[0059] The design files **264** include one or more files (e.g., CAD files, stored text, audio recordings, stored geometries, etc.) that the user adds to be included in the design prompt **260**. In some embodiments, the design files **264** can include textual data (e.g., textual descriptions, physical dimensions, etc.). In various embodiments, a user can add multiple design files **264** to include in the design prompt **260**. In some embodiments, the design exploration application **130** converts various types of data into the design files **264**. For example, the user can enter a sketch via the input area of the prompt space **220**. In such instances, the design exploration application **130** can store sketch as a design file **264**. The design files **264** can include one or more modalities (e.g., textual data, video data, audio data, image data, etc.). In some embodiments, some types of data can be separate. For example, the design prompt **260** can include audio data **266** (e.g., spoken descriptions directly into the input area and/or stored audio files) as separate from the design files **264**.

[0060] In various embodiments, the intent management application **170** receives and processes the design prompt **260** to identify the modalities of the contents of the design prompt **260**. For example, the intent management application **170** can identify the modalities of the design intent text **262**, the one or more design files **264**, and/or the audio data **266** included in the design prompt **260**. The intent management application **170** then identifies at least one ML model **180**, **190** that was trained with that combination of modalities identified in the contents of the design prompt **260** and selects one of the identified ML models **180**, **190**. The intent management application **170** executes the selected ML model by inputting the design prompt **260** into the selected ML model. The selected ML model produces the generated 3D object **270** in response to the design prompt **260**. In some embodiments, the server device **160** includes the generated 3D object **270** in the design history **182**. In such instances, the generated 3D object **270** is a portion of the design history **182** used as training data to train one or more trained ML models **180** (e.g., further training the selected ML model, training other ML models, etc.). Once the selected ML model **180**, **190** produces the generated 3D object **270**, the server device **160** transmits the generated 3D object **270** to the design exploration application **130**.

[0061] The design object generator **250** processes the generated 3D object **270**. In various embodiments, the generated 3D object **270** can be a mesh or a point cloud that does not have separately editable components. For example, the generated 3D object can be a mesh of a table where the individual legs of the table are not separate and cannot be separately editable. In such instances, the design object generator **250** can automatically convert the generated 3D object **270** into the generated design object **272**, where the generated design object **272** is parametric-based and has a corresponding set of features. As will be discussed further with respect to FIG. **3**, in some embodiments, the design object generator **250** can produce intermediate objects and components (e.g., boundary objects, textures, etc.) when producing the generated design object **272**. In some embodiments, the design exploration application **130** can cause the GUI **120** to display the generated 3D object **270**. For example, the design exploration application **130** can update a preview area that is included in the prompt space **220** to display the generated 3D object **270**. The user can then perform actions (e.g., drag-and-drop, select button, etc.) to select the generated 3D object **270** for use in the design space **230**. In such instances, the design object generator **250** can respond to the selection of the generated 3D object **270** by producing the generated design object **272**. The user can then modify one or more of the set of features that correspond to the generated design object **272**.

Generating Design Objects Using Machine Learning Models

[0062] FIG. **3** is an exemplar technique of the design exploration application **130** of FIG. **1** producing a generated design object **272** based on a design prompt **260**, according to various embodiments. As shown, the configuration **300** includes, without limitation, the intent manager **240**, the design prompt **260**, one or more ML models **310**, the generated 3D object **270**, the design object generator **250**, and the GUI **120**. The design object generator **250** includes, without limitation, a boundary identifier **360**, a generated boundary object **362**, a feature extractor **370**, and the generated design object **272**.

[0063] In operation, the intent manager **240** included in the design exploration application **130** generates and transmits the design prompt **260**. The design prompt **260** is transmitted to one or more ML models **310** (e.g., the trained ML models **180** and/or the remote ML models **190**). The one or more ML models **310** generate the 3D object **270** and the generated 3D object **270** is transmitted to the design object generator **250** included in the design exploration application **130**. The design object generator **250** converts the generated 3D object **272** to a design object **272**, where the generated design object **272** is parametric-based and has a corresponding set of features that the user can edit via the GUI **120**.

[0064] As discussed in FIG. **2**, the intent manager **240** can process one or more inputs by the user to generate the design prompt **260**. The intent management application **170** (not shown) identifies the applicable ML models **310** and transmits the design prompt to the ML models **310**. In various embodiments, the ML models **310** can generate one or more content items, including the generated 3D object **270**. For example, a first ML model **310**(1) can generate a 2D image based on the design prompt **260** and a second ML model **310**(2) can generate the 3D object **270**. In various embodiments, the generated 3D object **270** can be a mesh, a point cloud, or a boundary object that is not a parametric-based object. For example, the generated 3D object **270** can be a mesh wireframe of a door, where individual components of the door (e.g., window slots, handle, hinges, etc.) are considered the same mass and are not separate and do not have corresponding parameters. The generated 3D object **270** can then be transmitted to the design object generator **250** and the design object generator **250** can respond by automatically generating the design object **272**.

[0065] In various embodiments, the design object generator **250** automatically converts the generated 3D object **270** into the generated design object **272**. where the generated design object **272** is parametric-based and has a corresponding set of features. In some embodiments, the generated 3D object **270** is a mesh, wireframe, or point claim. In such instances, the boundary identifier **360** included in the design object generator **250** automatically converts the generated 3D object **270** to the generated boundary object **362**. For example, the boundary identifier **360** can add faces to the point cloud or the mesh to generate a boundary representation (BREP) of the point cloud or mesh. In such instances, the generated boundary object **362** includes sets of vertices, edges, and faces representing the exterior boundaries of the point cloud or mesh.

[0066] In various embodiments, the feature extractor **370** converts the generated boundary object **362** to the generated design object **272**. In some embodiments, boundary identifier **360** transmits the generated boundary object **362** to the feature extractor **370**, whereupon the feature extractor **370** extracts a set of features that correspond to one or more design objects **272**. In some embodiments, the feature extractor **370** recognizes combinations of geometry, such as lines and arcs and maps the geometry to physical features, such as a hole or a chamfer. In various embodiments, the feature extractor **370** can extract one or more feature types, such as chamfer, coil, round, decal, emboss, fillet, flange, hole, rib, shell, and/or thread. In such instances, the resultant design object **272** includes a set of editable features that respond to edits to a given portion of the design object **272**. For example, design object **272**(1) including a through hole will maintain the through hole when a user changes the thickness of the surface (rather than becoming a blind hole). In some embodiments, the design object generator **250** displays an interface for the feature extractor **370**. In such instances, the user can select one or more feature types to automatically extract from the generated boundary object **362**. In some embodiments, the feature extractor **370** produces a plurality of generated design objects **272** (e.g., a double-hung window that includes two sashes **272**(1), **272** (2) and a frame **272**(3)). In such instances, each of the respective design objects **272**(1)-**272**(3) can include a distinct set of features.

[0067] FIG. **4** is an exemplar illustration of design exploration application **130** of FIG. **2** causing the GUI **120** to display the prompt space **220**, according to various embodiments. As shown, the visualization **400** includes a design space **410**, a prompt input area **420**, and design history **430**. The prompt input area **420** includes an intent input area **422** and a trigger button **424**. The intent input area **422** includes the textual phrase **426**. In operation, the user invokes the prompt input area **420** to provide one or more inputs to generate a design prompt **260**. The prompt input area **420** includes an intent input area **422** that enables the user to enter text, an audio recording, and/or upload one or more files. For example, the user can enter the textual phrase **426** (e.g., "a round blue coffee table"). The design history **430** illustrates a set of previous steps that the user made within the design space **410** when producing an overall 3D design.

[0068] FIG. **5** is an exemplar illustration of an update to the prompt input area **420** of FIG. **4**, according to various embodiments. As shown, the visualization **500** includes the design space **410**, the prompt input area **420**, and the design history **430**. The prompt input area **420** includes the intent input area **422**, a preview area **520**, and a selection button **530**. The intent input area **422** includes the textual phrase **426**. The preview area **520** includes the generated 3D object **522**. In operation, upon the user trigger button **424**, the design exploration responds by generating a design prompt **260** that includes the textual phrase **426** in its contents. The design exploration application **130** transmits the design prompt **260** for the one or more ML models **310** to process. The one or more ML models **310** process the content of the design prompt **260** and generate and transmit the 3D object **522** to the design exploration application **130**. In such instances, the design exploration application **130** updates the preview area **520** of the prompt input area **420** to display the generated 3D object **522**. In such instances, the user can click on the select button **530** to trigger the design exploration application **130** to import the generated 3D object **522**.

[0069] FIG. **6** is an exemplar illustration of the generated 3D object **522** of FIG. **5** being added to the design space **410**, according to various embodiments. As shown, the visualization **600** includes the design space **410**, the prompt input area **420**, the design history **430**, and a 3D object **610**. The prompt input area **420** includes the intent input area **422**, a preview area **520**, and a selection button **530**. In operation, upon the user clicking on the selection button **530**, the design exploration application **130** responds by adding the generated 3D object **522** to the design space **410** as the 3D object **610**. In some embodiments, the generated 3D object **522** is a mesh, point cloud, or wireframe. In such instances, the design object generator **250** uses the boundary identifier **360** to convert the generated 3D object **522** to the 3D object **610**. The 3D object **610** produced by the boundary identifier **360** is a boundary representation of the generated 3D object **522** and includes one or more faces, vertices, and edges.

[0070] FIG. **7** is an exemplar illustration of the 3D object **610** of FIG. **6** converted to a design object including a set of features, according to various embodiments. As shown, the visualization **700** includes the design space **410**, the design history **430**, and a design object **710** and feature extraction history **730**. In operation, the design object generator **250** uses the feature extractor **370** to convert the 3D object **610** to a design object **710**. For example, upon the design exploration application **130** adding the 3D object **610** to the design space **410**, the design object generator **250** can respond by performing a series of steps to extract one or more features from the 3D object **610** to generate the design object **710**. As shown by the feature extraction history **730** portion of the design history **430**, the feature extractor **370** can perform a series of steps (e.g., fillet, extrude, etc.) to extract a set of editable features for the design object **710**. In various embodiments, the design exploration application **130** can update the GUI to display the set of features and/or display a set of parameter values corresponding to the extracted features (e.g., sliders for chamfer size, etc.).

[0071] FIG. **8** is a more detailed illustration of the design exploration application of FIG. **1** producing a design prompt and converting a 3D object to a design object, according to various embodiments. As shown, the visualization **800** includes a design space **810**, a prompt input area **820**, and a boundary object **830**. The prompt input area **820** includes an intent input area **822**, a guidance scale value **824**, a grid size value **826**, and a trigger button **828**. In operation, the design exploration application **130** can cause the GUI **120** to display a prompt input area **820** that can include various input types, including the intent input area for a user to type, as well also text input and slider combinations for users to specify values for the guidance scale and grid size. The guidance scale value **824** specifies how closely the generated 3D object is to adhere to the prompt, where higher values indicate that the generated 3D object is to adhere more closely to the contents of the prompt. The grid size value **826** indicates the size of the generated 3D object, as the grid size value **826** specifies the spacing between horizontal lines and/or vertical lines on a grid. In this manner, the user can specify a size for the generated 3D object and then incorporate the 3D object into a larger 3D design within a defined grid.

[0072] As shown, upon the user clicking on the trigger button **828**, the design exploration application **130** generates a design prompt **260** that includes the text entered in the intent input area **822**, as well as the guidance scale value **824** and the grid size value **826**. The one or more ML models **310** respond to the design prompt **260** and generate 3D object **270**. Upon the design exploration application **130** receiving the generated 3D object **270**, the design object generator **250** automatically converts the generated 3D object **270** to the boundary object **830**. The boundary object is a boundary representation of the generated 3D object **270** and includes a set of faces that correspond to the surface of the generated 3D object **270**.

[0073] FIG. **9** is an exemplar illustration of a menu **910** for the feature extractor **370** of FIG. **3** within the design space **810**, according to various embodiments. As shown, the visualization **900** includes the boundary object **830** and a feature extraction menu **910**. The feature extraction menu **910** includes a list of feature types **920** and a set of faces **930**. In operation, the design exploration application **130** can update the GUI **120** to display a feature recognition environment. In such instances, the design exploration application **130** can provide the feature extraction menu **910** to select specific faces of the boundary object **830** for feature extraction and one or more feature types that are to be extracted from the set of faces. For example, the user can select extrusions, revolutions, holes, fillets, chamfers, and sculpts as features to be extracted from the faces of the boundary object **830**.

[0074] FIG. **10** is an exemplar illustration of the feature extractor **370** of FIG. **3** generating a plurality of design object **1032**, **1034** and a list of editable features **1040**, according to various embodiments. As shown, the visualization **1000** includes a set of design objects **1032**, **1034**, and a list of features **1040**. In operation, the feature extractor **370** converts the boundary object **830** into a set of design objects **1032**, **1034**. Each of the respective design objects **1032**, **1034** includes a distinct set of features. The

[0075] FIG. **11** sets forth a flow diagram of method steps for generating 3D objects, according to various embodiments. Although the method steps are described with reference to the systems of FIGS. **1-10** and **12**, persons skilled in the art will understand that any system configured to implement the method steps, in any order, falls within the scope of the embodiments.

[0076] As shown, a method **1100** begins at step **1102**, where the design exploration application **130** generates a prompt input area within a design space. In various embodiments, the design exploration application **130** overlays the prompt input area **420** as an overlay over a portion of the design space **230** in response to a user input. In such instances, the user can invoke the prompt input area **420** at various locations within the design space **230**. The prompt input area **420** includes an intent input area **422** for the user to enter data. The GUI **120** displays the respective sets of features for the design objects **1032**, **1034** as a single list of features **1040**. In such instances, the design exploration application **130** can add the design objects **1032**, **1034** to the design space **810** for incorporation into a larger 3D design. Additionally, or alternatively the design exploration application **130** can add the extracted features to the GUI **120** to enable the user to modify components of the respective design objects **1032**, **1034**.

[0077] At step **1104**, the design exploration application **130** receives one or more user inputs. In various embodiments, the design exploration application **130** receives one or more user inputs that collectively indicate an intent for a 3D design. In various embodiments, the one or more user inputs can include textual data and/or non-textual data. For example, the user can add a textual phrase **426** within the intent input area **422** and/or select one or more design parameters, such as a guidance scale value **824** or a grid size value **826**. Additionally, or alternatively in some embodiments, user can add non-textual data. For example, the user can add one or more design files **264** (e.g., a stored sketch uploaded to the intent input area **422**) via the intent input area **422**. As another example, the user can record a speech utterance via the intent input area **422**.

[0078] At step **1106**, the design exploration application **130** generates a design prompt **260** that includes the user inputs. In various embodiments, the design exploration application **130** generates a design prompt **260** that includes one or more of the user inputs added to the intent input area **422**. In various embodiments, the design prompt **260** can include a single input. For example, the design prompt **260** can include design intent text **262** that the user typed via the intent input area **422**. Alternatively, in some embodiments, the design prompt **260** includes two or more user inputs. For example the design prompt **260** can include multiple design intent texts, such as a typed phrase, a guidance scale value **824**, and a grid size value **826**. Additionally, or alternatively in some embodiments, the design prompt **260** includes two or more modalities of user input. For example, the design prompt **260** can include design intent text **262** and one or more design files **264** (e.g., a stored sketch uploaded to the intent input area **422**).

[0079] At step **1108**, the design exploration application **130** transmits the design prompt **260**. In various embodiments, the design exploration application **130** generates the design prompt **260** and transmits the design prompt **260** to the server device **160** for input into one or more ML models **180**, **190**. In some embodiments, the server device **160** transmits the design prompt **260** to a single ML model (e.g., the trained ML model **180**) from a plurality of ML models **310**. In such instances, the intent management application **170** operating on the server device **160** can identify the contents of the design prompt **260** to identify an applicable ML model. For example, the intent management application **170** can identify the combination of modalities included in the design prompt **260** and can select an applicable ML model **180** that was trained using the identified combination of modalities.

[0080] At step **1110**, the design exploration application **130** executes a trained ML model **180** using the design prompt **260** to generate a 3D object **270**. In various embodiments, the design exploration application **130** causes the server device **160** to execute the at least one trained ML model **180** on the design prompt **260** to generate the 3D object **270**. In various embodiments, one or more trained ML models **180** local to the server device **160** and/or one or more remote ML devices **180** are trained using multimodal prompts. The intent management application **170** inputs the design prompt **260** into the selected ML model **180**.

[0081] At step **1112**, the design exploration application **130** receives the generated 3D object **270** from the trained ML model **180**. In various embodiments, the server device **160** receives the generated 3D object **270** from the selected ML model **180** and transmits the generated 3D object **270** to the client device **110**. In such instances, the design exploration application **130** receives the generated 3D object **270** and causes the client device **110** to store the generated 3D object **270** in the local data store **140**.

[0082] At step **1114**, the design exploration application **130** adds the generated 3D object **270** to the design space **230**. In various embodiments, the design exploration application **130**, upon receiving the generated 3D object **270**, adds the generated 3D object **270** to a location in the design space **230** for viewing via the GUI **120**. In some embodiments, the design exploration application **130** displays the generated 3D object **270** within a preview area **520** included in the prompt space **220**. In such instances, the user can review the generated 3D object **270** within the preview area **520** before providing an input to add the generated 3D object **270** to the design space **230**. Alternatively, in some embodiments, the design exploration application **130** displays the generated 3D object **270** directly within the design space **230**. In such instances, the design exploration application **130** can automatically convert the generated 3D object **270** to a different format. For example, the boundary identifier **360** included in the design exploration application **130** can convert the generated 3D object **270** to a generated boundary object **362**.

[0083] At step **1116**, the design exploration application **130** converts the 3D object to a design object. In various embodiments, the design object generator **250** included in the design exploration application **130** converts the generated 3D object **270** into the generated design object **272**. In some embodiments, the boundary identifier **360** included in the design object generator **250** automatically converts the generated 3D object **270** to first a generated boundary object **362**. In such instances, the feature extractor **370** included in the design object generator **250** can convert the generated boundary object **362** to the generated design object **272**. The design exploration application **130** can then transmit the generated design object **272** to the GUI **120** for display within the preview area **520** included in the prompt space **220**. Alternatively, in some embodiments, the design object generator **250** can automatically convert the generated 3D object **270** to a different format and can update the interface. For example, the boundary identifier **360** included in the design object generator **250** can convert the generated 3D object **270** to a generated boundary object **362**. The design object generator **250** can then display an interface for the feature extractor **370** to extract one or more feature types (e.g., chamfer, hole, rib, thread, etc.) from the generated boundary object **362**. In some embodiments, the feature extractor **370** produces a plurality of generated design objects **272** (e.g., the design objects **1032** and **1034**). In such instances, each of the respective design objects **1032**, **1034** can include a distinct set of features (e.g., the feature set **1040** for the design object **1034**).

System Implementation

[0084] FIG. **12** depicts one architecture of a system **1200** within which embodiments of the present disclosure may be implemented. This figure in no way limits or is intended to limit the scope of the present disclosure. In various implementations, system **1200** may be an augmented reality, virtual reality, or mixed reality system or device, a personal computer, video game console, personal digital assistant, mobile phone, mobile device, or any other device suitable for practicing one or more embodiments of the present disclosure. Further, in various embodiments, any combination of two or more systems **1200** may be coupled together to practice one or more aspects of the present disclosure.

[0085] As shown, system **1200** includes a central processing unit (CPU) **1202** and a system memory **1204** communicating via a bus path that may include a memory bridge **1205**. CPU **1202** includes one or more processing cores, and, in operation, CPU **1202** is the master processor of system **1200**, controlling and coordinating operations of other system components. System memory **1204** stores software applications and data for use by CPU **1202**. CPU **1202** runs software applications and optionally an operating system. Memory bridge **1205**, which may be, e.g., a Northbridge chip, is connected via a bus or other communication path (e.g., a HyperTransport link) to an I/O (input/output) bridge **1207**. I/O bridge **1207**, which may be, e.g., a Southbridge chip, receives user input from one or more user input devices **1208** (e.g., keyboard, mouse, joystick, digitizer tablets, touch pads, touch screens, still or video cameras, motion sensors, and/or microphones) and forwards the input to CPU **1202** via memory bridge **1205**.

[0086] A display processor **1212** is coupled to memory bridge **1205** via a bus or other communication path (e.g., a PCI Express, Accelerated Graphics Port, or HyperTransport link); in one embodiment display processor **1212** is a graphics subsystem that includes at least one graphics processing unit (GPU) and graphics memory. Graphics memory includes a display memory (e.g., a frame buffer) used for storing pixel data for each pixel of an output image. Graphics memory can be integrated in the same device as the GPU, connected as a separate device with the GPU, and/or implemented within system memory **1204**.

[0087] Display processor **1212** periodically delivers pixels to a display device **1210** (e.g., a screen or conventional CRT, plasma, OLED, SED or LCD based monitor or television). Additionally, display processor **1212** may output pixels to film recorders adapted to reproduce computer generated images on photographic film. Display processor **1212** can provide display device **1210** with an analog or digital signal. In various embodiments, one or more of the various graphical user interfaces set forth in Appendices A-J, attached hereto, are displayed to one or more users via display device

1210, and the one or more users can input data into and receive visual output from those various graphical user interfaces.

[0088] A system disk **1214** is also connected to I/O bridge **1207** and may be configured to store content and applications and data for use by CPU **1202** and display processor **1212**. System disk **1214** provides non-volatile storage for applications and data and may include fixed or removable hard disk drives, flash memory devices, and CD-ROM, DVD-ROM, Blu-ray, HD-DVD, or other magnetic, optical, or solid state storage devices.

[0089] A switch **1216** provides connections between I/O bridge **1207** and other components such as a network adapter **1218** and various add-in cards **1220** and **1221**. Network adapter **1218** allows system **1200** to communicate with other systems via an electronic communications network, and may include wired or wireless communication over local area networks and wide area networks such as the Internet.

[0090] Other components (not shown), including USB or other port connections, film recording devices, and the like, may also be connected to I/O bridge **1207**. For example, an audio processor may be used to generate analog or digital audio output from instructions and/or data provided by CPU **1202**, system memory **1204**, or system disk **1214**. Communication paths interconnecting the various components in FIG. **1** may be implemented using any suitable protocols, such as PCI (Peripheral Component Interconnect), PCI Express (PCI-E), AGP (Accelerated Graphics Port), HyperTransport, or any other bus or point-to-point communication protocol(s), and connections between different devices may use different protocols, as is known in the art.

[0091] In one embodiment, display processor **1212** incorporates circuitry optimized for graphics and video processing, including, for example, video output circuitry, and constitutes a graphics processing unit (GPU). In another embodiment, display processor **1212** incorporates circuitry optimized for general purpose processing. In yet another embodiment, display processor **1212** may be integrated with one or more other system elements, such as the memory bridge **1205**, CPU **1202**, and I/O bridge **1207** to form a system on chip (SoC). In still further embodiments, display processor **1212** is omitted and software executed by CPU **1202** performs the functions of display processor **1212**.

[0092] Pixel data can be provided to display processor **1212** directly from CPU **1202**. In some embodiments of the present disclosure, instructions and/or data representing a scene are provided to a render farm or a set of server computers, each similar to system **1200**, via network adapter **1218** or system disk **1214**. The render farm generates one or more rendered images of the scene using the provided instructions and/or data. These rendered images may be stored on computer-readable media in a digital format and optionally returned to system **1200** for display. Similarly, stereo image pairs processed by display processor **1212** may be output to other systems for display, stored in system disk **1214**, or stored on computer-readable media in a digital format.

[0093] Alternatively, CPU **1202** provides display processor **1212** with data and/or instructions defining the desired output images, from which display processor **1212** generates the pixel data of one or more output images, including characterizing and/or adjusting the offset between stereo image pairs. The data and/or instructions defining the desired output images can be stored in system memory **1204** or graphics memory within display processor **1212**. In an embodiment, display processor **1212** includes 3D rendering capabilities for generating pixel data for output images from instructions and data defining the geometry, lighting shading, texturing, motion, and/or camera parameters for a scene. Display processor **1212** can further include one or more programmable execution units capable of executing shader programs, tone mapping programs, and the like.

[0094] Further, in other embodiments, CPU **1202** or display processor **1212** may be replaced with or supplemented by any technically feasible form of processing device configured process data and execute program code. Such a processing device could be, for example, a central processing unit (CPU), a graphics processing unit (GPU), an application-specific integrated circuit (ASIC), a field-programmable gate array (FPGA), and so forth. In various embodiments any of the operations and/or functions described herein can be performed by CPU **1202**, display processor **1212**, or one or more other processing devices or any combination of these different processors.

[0095] CPU **1202**, render farm, and/or display processor **1212** can employ any surface or volume rendering technique known in the art to create one or more rendered images from the provided data and instructions, including rasterization, scanline rendering REYES or micropolygon rendering, ray casting, ray tracing, image-based rendering techniques, and/or combinations of these and any other rendering or image processing techniques known in the art.

[0096] In other contemplated embodiments, system **1200** may be a robot or robotic device and may include CPU **1202** and/or other processing units or devices and system memory **1204**. In such embodiments, system **1200** may or may not include other elements shown in FIG. **1**. System memory **1204** and/or other memory units or devices in system **1200** may include instructions that, when executed, cause the robot or robotic device represented by system **1200** to perform one or more operations, steps, tasks, or the like.

[0097] It will be appreciated that the system shown herein is illustrative and that variations and modifications are possible. The connection topology, including the number and arrangement of bridges, may be modified as desired. For instance, in some embodiments, system memory **1204** is connected to CPU **1202** directly rather than through a bridge, and other devices communicate with system memory **1204** via memory bridge **1205** and CPU **1202**. In other alternative topologies display processor **1212** is connected to I/O bridge **1207** or directly to CPU **1202**, rather than to memory bridge **1205**. In still other embodiments, I/O bridge **1207** and memory bridge **1205** might be integrated into a single chip. The particular components shown herein are optional; for instance, any number of add-in cards or peripheral devices might be supported. In some embodiments, switch **1216** is eliminated, and network adapter **1218** and add-in cards **1220**, **1221** connect directly to I/O bridge **1207**.

[0098] In sum, the disclosed techniques can be used to generate designs for one or more 3D objects based on design intentions expressed by users using one or more modalities provided via a GUI. In various embodiments, a design exploration application displays a prompt input area for a user to generate a design prompt. The prompt input enables the user to specify the design intent via a textual input and/or one or more non-textual inputs, which can include sketches, stored files (e.g., stored images, previous designs, stored sketches, and so forth), and/or audio inputs. The design exploration application then generates a design that includes the intent inputs. The design exploration application transmits the design prompt to an intent management application operating at a server device. Upon receipt, the intent management application identifies one or more generative ML models that are trained to process the content included in the design prompt. The intent management application inputs the design prompt to the identified generative ML model. The generative ML model can be local or remote to the server device. The generative ML model, which was trained using design histories of design prompts, generated content items, and evaluations of the generated content items, generates a content item, such as a 3D design, that is responsive to the design prompt. The design exploration application receives the one or more generated design objects from the server device and displays the 3D design via the GUI. In response to the user selecting the 3D design for use, the design exploration application adds the 3D design to the design space. In some embodiments, the design exploration application automatically converts the 3D design into a design object that includes a set of editable features. Alternatively, the design exploration application responds to one or more user inputs by extracting one or more types of features from the 3D design to generate the design object.

[0099] At least one technical advantage of the disclosed techniques relative to the prior art is that the disclosed techniques enable design systems to incorporate generative artificial intelligence systems that determine the design intent of a user more accurately. Further, design systems using the disclosed techniques can automatically convert content items produced by such generative artificial intelligence system to parametric-based design objects that include a set of editable features. In that regard, the disclosed techniques provide an automated process for generating prompts from inputs provided by the user, including combinations of text, speech, sketches, images, and/or stored designs. Generating prompts using varying types of data enables a user to provide additional context to portions of a prompt that a trained generative artificial intelligence model can understand, which enables the generative artificial intelligence model to better infer the design intents and ideas of the user. Further, by automatically converting content items into parametric-based 3D design objects that can be easily added to the design space, the design system can quickly incorporate outputs of the generative artificial intelligence system into overall 3D designs to generate large numbers of alternative designs. Accordingly, with the disclosed techniques, 3D design objects that align better with the actual design-oriented intentions and ideas of users can be more readily generated and manufactured. These technical advantages provide one or more technological advancements over prior art approaches.

[0100] 1. In various embodiments, a computer-implemented method for generating a design object via a design exploration application comprises receiving an intent input, where the intent input includes at least a textual input, generating, based on the intent input, a design prompt, generating, via a trained machine learning (ML) model, a three-dimensional object based on the design prompt, converting the three-dimensional object to the design object, where the design object includes one or more editable features, and adding the design object to a design space.

[0101] 2. The computer-implemented method of clause 1, further comprising receiving at least one of a text string, a grid size, or a guidance scale as input via a graphical user interface, where the textual input includes the text string, the grid size, or the guidance scale.

[0102] 3. The computer-implemented method of clause 1 or 2, further comprising transmitting the design prompt to a remote device for processing by the ML model to generate the three-dimensional object.

[0103] 4. The computer-implemented method of any of clauses 1-3, where the three-dimensional object comprises at least one of a mesh representation or a point cloud.

[0104] 5. The computer-implemented method of any of clauses 1-4, further comprising converting the three-dimensional object to a boundary object, where the design object is based on the boundary object.

[0105] 6. The computer-implemented method of any of clauses 1-4, further comprising extracting one or more features from the boundary object to generate the design object, where the design object includes the one or more editable features.

[0106] 7. The computer-implemented method of any of clauses 1-6, further comprising extracting one or more features from the boundary object to generate a plurality of design objects, where the plurality of design objects includes at least the design object and a second design object.

[0107] 8. The computer-implemented method of any of clauses 1-7, where the intent input further includes a non-textual input comprising at least one of a CAD file, an image, a sketch, or an audio recording.

[0108] 9. The computer-implemented method of any of clauses 1-8, further comprising generating a prompt input area within the design space, where the prompt input area includes an intent input area through which the intent input is received.

[0109] 10. The computer-implemented method of any of clauses 1-9, where the prompt input area further includes a preview area that displays the three-dimensional object.

[0110] 11. In various embodiments, one or more non-transitory computer-readable media includes instructions that, when executed by one or more processors, cause the one or more processors to generate a design object via a design exploration application by performing the steps of receiving an intent input, where the intent input includes at least a textual input, generating, based on the intent input, a design prompt, generating, via a trained machine learning (ML) model, a three-dimensional object based on the design prompt, converting the three-dimensional object to the design object, where the design object includes one or more editable features, and adding the design object to a design space.

[0111] 12. The one or more non-transitory computer-readable media of clause 11, where the one or more editable features comprises at least one of a chamfer, a coil, a round, a decal, an emboss, a fillet, a flange, a hole, a rib, a shell, or a thread.

[0112] 13. The one or more non-transitory computer-readable media of clause 11 or 12, further comprising instructions that, when executed by the one or more processors, cause the one or more processors to perform the steps of adding the three-dimensional object to the design space, and detecting a user input associated with the three-dimensional object in the design space, where three-dimensional object is converted to the design object in response to the user input.

[0113] 14. The one or more non-transitory computer-readable media of any of clauses 11-13, further comprising instructions that, when executed by the one or more processors, cause the one or more processors to perform the steps of generating a set of parameters based on the one or more editable features, and displaying the set of parameters via a graphical user interface.

[0114] 15. The one or more non-transitory computer-readable media of any of clauses 11-14, where the three-dimensional object comprises at least one of a mesh representation or a point cloud.

[0115] 16. The one or more non-transitory computer-readable media of any of clauses 11-15, further comprising instructions that, when executed by the one or more processors, cause the one or more processors to perform the step of converting the three-dimensional object to a boundary object, where the design object is based on the boundary object.

[0116] 17. The one or more non-transitory computer-readable media of any of clauses 11-16, further comprising instructions that, when executed by the one or more processors, cause the one or more processors to perform the step of extracting one or more features from the boundary object to generate the design object, where the design object includes the one or more editable features.

[0117] 18. The one or more non-transitory computer-readable media of any of clauses 11-17, further comprising instructions that, when executed by the one or more processors, cause the one or more processors to perform the step of extracting one or more features from the boundary object to generate a plurality of design objects, where the plurality of design objects includes at least the design object and a second design object.

[0118] 19. The one or more non-transitory computer-readable media of any of clauses 11-18, where the intent input further includes a non-textual input comprising at least one of a CAD file, an image, a sketch, or an audio recording.

[0119] **20**. In various embodiments, a system comprises one or more memories storing instructions, and one or more processors coupled to the one or more memories that, when executing the instructions, generate a design object via a design exploration application by performing the steps of receiving, by a design exploration application, an intent input, where the intent input includes at least a textual input, generating, based on the intent input, a design prompt, executing a trained machine learning (ML) model on the design prompt to generate a three-dimensional object, converting, by the design exploration application, the three-dimensional object to a design object, where the design object includes one or more editable features, and adding the design object to a design space.

[0120] Any and all combinations of any of the claim elements recited in any of the claims and/or any elements described in this application, in any fashion, fall within the contemplated scope of the present invention and protection.

[0121] The descriptions of the various embodiments have been presented for purposes of illustration, but are not intended to be exhaustive or limited to the embodiments disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art without departing from the scope and spirit of the described embodiments.

[0122] Aspects of the present embodiments may be embodied as a system, method or computer program product. Accordingly, aspects of the present disclosure may take the form of an entirely hardware embodiment, an entirely software embodiment (including firmware, resident software, micro-code, etc.) or an embodiment combining software and hardware aspects that may all generally be referred to herein as a “module,” a “system,” or a “computer.” In addition, any hardware and/or software technique, process, function, component, engine, module, or system described in the present disclosure may be implemented as a circuit or set of circuits. Furthermore, aspects of the present disclosure may take the form of a computer program product embodied in one or more computer readable medium(s) having computer readable program code embodied thereon.

[0123] Any combination of one or more computer readable medium(s) may be utilized. The computer readable medium may be a computer readable signal medium or a computer readable storage medium. A computer readable storage medium may be, for example, but not limited to, an electronic, magnetic, optical, electromagnetic, infrared, or semiconductor system, apparatus, or device, or any suitable combination of the foregoing. More specific examples (a non-exhaustive list) of the computer readable storage medium would include the following: an electrical connection having one or more wires, a portable computer diskette, a hard disk, a random access memory (RAM), a read-only memory (ROM), an erasable programmable read-only memory (EPROM or Flash memory), an optical fiber, a portable compact disc read-only memory (CD-ROM), an optical storage device, a magnetic storage device, or any suitable combination of the foregoing. In the context of this document, a computer readable storage medium may be any tangible medium that can contain, or store a program for use by or in connection with an instruction execution system, apparatus, or device.

[0124] Aspects of the present disclosure are described above with reference to flowchart illustrations and/or block diagrams of methods, apparatus (systems) and computer program products according to embodiments of the disclosure. It will be understood that each block of the flowchart illustrations and/or block diagrams, and combinations of blocks in the flowchart illustrations and/or block diagrams, can be implemented by computer program instructions. These computer program instructions may be provided to a processor of a general purpose computer, special purpose computer, or other programmable data processing apparatus to produce a machine. The instructions, when executed via the processor of the computer or other programmable data processing apparatus, enable the implementation of the functions/acts specified in the flowchart and/or block diagram block or blocks. Such processors may be, without limitation, general purpose processors, special-purpose processors, application-specific processors, or field-programmable gate arrays.

[0125] The flowchart and block diagrams in the figures illustrate the architecture, functionality, and operation of possible implementations of systems, methods and computer program products according to various embodiments of the present disclosure. In this regard, each block in the flowchart or block diagrams may represent a module, segment, or portion of code, which comprises one or more executable instructions for implementing the specified logical function (s). It should also be noted that, in some alternative implementations, the functions noted in the block may occur out of the order noted in the figures. For example, two blocks shown in succession may, in fact, be executed substantially concurrently, or the blocks may sometimes be executed in the reverse order, depending upon the functionality involved. It will also be noted that each block of the block diagrams and/or flowchart illustration, and combinations of blocks in the block diagrams and/or flowchart illustration, can be implemented by special purpose hardware-based systems that perform the specified functions or acts, or combinations of special purpose hardware and computer instructions.

[0126] While the preceding is directed to embodiments of the present disclosure, other and further embodiments of the disclosure may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.

What is claimed is:

1. A computer-implemented method for generating a design object via a design exploration application, the computer-implemented method comprising:

receiving an intent input, wherein the intent input includes at least a textual input;

generating, based on the intent input, a design prompt;

generating, via a trained machine learning (ML) model, a three-dimensional object based on the design prompt;

converting the three-dimensional object to the design object, wherein the design object includes one or more editable features; and

adding the design object to a design space.

2. The computer-implemented method of claim **1**, further comprising receiving at least one of a text string, a grid size, or a guidance scale as input via a graphical user interface, wherein the textual input includes the text string, the grid size, or the guidance scale.

3. The computer-implemented method of claim **2**, further comprising transmitting the design prompt to a remote device for processing by the ML model to generate the three-dimensional object.

4. The computer-implemented method of claim **1**, wherein the three-dimensional object comprises at least one of a mesh representation or a point cloud.

5. The computer-implemented method of claim **1**, further comprising converting the three-dimensional object to a boundary object, wherein the design object is based on the boundary object.

6. The computer-implemented method of claim **5**, further comprising extracting one or more features from the boundary object to generate the design object, wherein the design object includes the one or more editable features.

7. The computer-implemented method of claim **5**, further comprising extracting one or more features from the boundary object to generate a plurality of design objects, wherein the plurality of design objects includes at least the design object and a second design object.

8. The computer-implemented method of claim **1**, wherein the intent input further includes a non-textual input comprising at least one of a CAD file, an image, a sketch, or an audio recording.

9. The computer-implemented method of claim **1**, further comprising generating a prompt input area within the design space, wherein the prompt input area includes an intent input area through which the intent input is received.

10. The computer-implemented method of claim **9**, wherein the prompt input area further includes a preview area that displays the three-dimensional object.

11. One or more non-transitory computer-readable media including instructions that, when executed by one or more processors, cause the one or more processors to generate a design object via a design exploration application by performing the steps of:

receiving an intent input, wherein the intent input includes at least a textual input;

generating, based on the intent input, a design prompt;

generating, via a trained machine learning (ML) model, a three-dimensional object based on the design prompt;

converting the three-dimensional object to the design object, wherein the design object includes one or more editable features; and

adding the design object to a design space.

12. The one or more non-transitory computer-readable media of claim **11**, wherein the one or more editable features comprises at least one of a chamfer, a coil, a round, a decal, an emboss, a fillet, a flange, a hole, a rib, a shell, or a thread.

13. The one or more non-transitory computer-readable media of claim **11**, further comprising instructions that, when executed by the one or more processors, cause the one or more processors to perform the steps of:

adding the three-dimensional object to the design space; and

detecting a user input associated with the three-dimensional object in the design space, wherein three-dimensional object is converted to the design object in response to the user input.

14. The one or more non-transitory computer-readable media of claim **11**, further comprising instructions that, when executed by the one or more processors, cause the one or more processors to perform the steps of:

generating a set of parameters based on the one or more editable features; and

displaying the set of parameters via a graphical user interface.

15. The one or more non-transitory computer-readable media of claim **11**, wherein the three-dimensional object comprises at least one of a mesh representation or a point cloud.

16. The one or more non-transitory computer-readable media of claim **11**, further comprising instructions that, when executed by the one or more processors, cause the one or more processors to perform the step of converting the three-dimensional object to a boundary object, wherein the design object is based on the boundary object.

17. The one or more non-transitory computer-readable media of claim **16**, further comprising instructions that, when executed by the one or more processors, cause the one or more processors to perform the step of extracting one or more features from the boundary object to generate the design object, wherein the design object includes the one or more editable features.

18. The one or more non-transitory computer-readable media of claim **16**, further comprising instructions that, when executed by the one or more processors, cause the one or more processors to perform the step of extracting one or more features from the boundary object to generate a plurality of design objects, wherein the plurality of design objects includes at least the design object and a second design object.

19. The one or more non-transitory computer-readable media of claim **11**, wherein the intent input further includes a non-textual input comprising at least one of a CAD file, an image, a sketch, or an audio recording.

20. A system comprising:

one or more memories storing instructions; and

one or more processors coupled to the one or more memories that, when executing the instructions, generate a design object via a design exploration application by performing the steps of:

receiving, by a design exploration application, an intent input, wherein the intent input includes at least a textual input;

generating, based on the intent input, a design prompt;

executing a trained machine learning (ML) model on the design prompt to generate a three-dimensional object;

converting, by the design exploration application, the three-dimensional object to a design object, wherein the design object includes one or more editable features; and

adding the design object to a design space.

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