

Module Interface Specification for AutoVox

Team #10, Five of a Kind
Omar Abdelhamid
Daniel Maurer
Andrew Bovbel
Olivia Reich
Khalid Farag

November 13, 2025

1 Revision History

Date	Version	Notes
November 13, 2025	1.0	Initial draft by All

2 Symbols, Abbreviations and Acronyms

See [SRS](#) Documentation.

Contents

1 Revision History	i
2 Symbols, Abbreviations and Acronyms	ii
3 Introduction	1
4 Notation	1
5 Module Decomposition	2
6 MIS of Input Interpreter	4
6.1 Module	4
6.2 Uses	4
6.3 Syntax	4
6.3.1 Exported Constants	4
6.3.2 Exported Access Programs	4
6.4 Semantics	5
6.4.1 State Variables	5
6.4.2 Environment Variables	5
6.4.3 Assumptions	5
7 MIS of Voxel Slicing	5
7.1 Module	5
7.2 Uses	5
7.3 Syntax	5
7.3.1 Exported Constants	5
7.3.2 Exported Access Programs	6
7.4 Semantics	6
7.4.1 State Variables	6
7.4.2 Environment Variables	6
7.4.3 Assumptions	6
8 MIS of Display Partitioning	6
8.1 Module	6
8.2 Uses	7
8.3 Syntax	7
8.4 Semantics	7
8.4.1 State Variables	7
8.4.2 Environment Variables	7
8.4.3 Assumptions	8

9 MIS of Project Manager	9
9.1 Module	9
9.2 Uses	9
9.3 Syntax	9
9.3.1 Exported Constants	9
9.3.2 Exported Access Programs	9
9.4 Semantics	9
9.4.1 State Variables	9
9.4.2 Environment Variables	10
9.4.3 Assumptions	10
9.4.4 Local Functions	10
10 MIS of Serialization Manager	11
10.1 Module	11
10.2 Uses	11
10.3 Syntax	11
10.3.1 Exported Constants	11
10.3.2 Exported Access Programs	11
10.4 Semantics	11
10.4.1 State Variables	11
10.4.2 Environment Variables	12
10.4.3 Assumptions	12
11 MIS of Backend Communication Manager	12
11.1 Module	12
11.2 Uses	12
11.3 Syntax	12
11.4 Semantics	13
11.4.1 State Variables	13
11.4.2 Environment Variables	13
11.4.3 Assumptions	13
12 MIS of Interaction Controller	14
12.1 Module	14
12.2 Uses	14
12.3 Syntax	14
12.4 Semantics	14
12.4.1 State Variables	14
12.4.2 Environment Variables	15
12.4.3 Assumptions	15

13 MIS of Visualization State Manager	16
13.1 Module	16
13.2 Uses	16
13.3 Syntax	16
13.3.1 Exported Constants	16
13.3.2 Exported Access Programs	16
13.4 Semantics	17
13.4.1 State Variables	17
13.4.2 Environment Variables	17
13.4.3 Assumptions	17
14 MIS of Model Manager	17
14.1 Module	17
14.2 Uses	17
14.3 Syntax	18
14.3.1 Exported Constants	18
14.3.2 Exported Access Programs	18
14.4 Semantics	18
14.4.1 State Variables	18
14.4.2 Environment Variables	18
14.4.3 Assumptions	18
15 MIS of History Manager	19
15.1 Module	19
15.2 Uses	19
15.3 Syntax	19
15.3.1 Exported Constants	19
15.3.2 Exported Access Programs	19
15.4 Semantics	19
15.4.1 State Variables	19
15.4.2 Environment Variables	19
15.4.3 Assumptions	20
16 MIS of Autosave Manager	20
16.1 Module	20
16.2 Uses	20
16.3 Syntax	20
16.4 Semantics	21
16.4.1 State Variables	21
16.4.2 Environment Variables	21
16.4.3 Assumptions	21

17 MIS of Voxel Tracking	22
17.1 Module	22
17.2 Uses	22
17.3 Syntax	22
17.3.1 Exported Constants	22
17.3.2 Exported Access Programs	22
17.4 Semantics	23
17.4.1 State Variables	23
17.4.2 Environment Variables	23
17.4.3 Assumptions	23
18 MIS of Highlight Manager	24
18.1 Module	24
18.2 Uses	24
18.3 Syntax	24
18.4 Semantics	24
18.4.1 State Variables	24
18.4.2 Environment Variables	24
18.4.3 Assumptions	25
19 MIS of Export Validation	26
19.1 Module	26
19.2 Uses	26
19.3 Syntax	26
19.3.1 Exported Constants	26
19.3.2 Exported Access Programs	26
19.4 Semantics	26
19.4.1 State Variables	26
19.4.2 Environment Variables	26
19.4.3 Assumptions	27
19.4.4 Local Functions	27
20 MIS of Export Manager	28
20.1 Module	28
20.2 Uses	28
20.3 Syntax	28
20.3.1 Exported Constants	28
20.3.2 Exported Access Programs	28
20.4 Semantics	29
20.4.1 State Variables	29
20.4.2 Environment Variables	29
20.4.3 Assumptions	29
20.4.4 Local Functions	29

21 MIS of Error Diagnostic Handler	30
21.1 Module	30
21.2 Uses	30
21.3 Syntax	30
21.3.1 Exported Constants	30
21.3.2 Exported Access Programs	30
21.4 Semantics	31
21.4.1 State Variables	31
21.4.2 Environment Variables	31
21.4.3 Assumptions	31
21.4.4 Local Functions	31
22 MIS of Model Structure	32
22.1 Module	32
22.2 Uses	32
22.3 Syntax	32
22.3.1 Exported Constants	32
22.3.2 Exported Access Programs	32
22.4 Semantics	33
22.4.1 State Variables	33
22.4.2 Environment Variables	34
22.4.3 Assumptions	34
22.4.4 Local Functions	34
23 MIS of Graphics Adapter	35
23.1 Module	35
23.2 Uses	35
23.3 Syntax	35
23.3.1 Exported Constants	35
23.3.2 Exported Access Programs	35
23.4 Semantics	35
23.4.1 State Variables	35
23.4.2 Environment Variables	35
23.4.3 Assumptions	36
24 MIS of Database Handler	37
24.1 Module	37
24.2 Uses	37
24.3 Syntax	37
24.3.1 Exported Constants	37
24.3.2 Exported Access Programs	37
24.4 Semantics	37
24.4.1 State Variables	37

24.4.2 Environment Variables	38
24.4.3 Assumptions	38
25 MIS of Export Structure	39
25.1 Module	39
25.2 Uses	39
25.3 Syntax	39
25.3.1 Exported Constants	39
25.3.2 Exported Access Programs	39
25.4 Semantics	39
25.4.1 State Variables	39
25.4.2 Environment Variables	40
25.4.3 Assumptions	40
25.4.4 Local Functions	40

3 Introduction

The following document details the Module Interface Specifications for AutoVox. AutoVox is a desktop-based CAD enhancement tool that enables researchers and engineers to assign magnetic and material properties to individual voxels within a 3D model. The system allows users to import CAD files (STL format), automatically convert them into voxel grids, and interactively select and modify voxels layer by layer to assign magnetization directions and material assignments. This tool streamlines the magnetization planning process for multi-material 3D printing workflows in research laboratory environments.

Complementary documents include the System Requirement Specifications and Module Guide. The full documentation and implementation can be found at <https://github.com/OmarHassanAdelhamid/Five-of-a-Kind-capstone-project->

4 Notation

The structure of the MIS for modules comes from [Hoffman and Strooper \(1995\)](#), with the addition that template modules have been adapted from [Ghezzi et al. \(2003\)](#). The mathematical notation comes from Chapter 3 of [Hoffman and Strooper \(1995\)](#). For instance, the symbol $\mathbf{:=}$ is used for a multiple assignment statement and conditional rules follow the form $(c_1 \Rightarrow r_1 | c_2 \Rightarrow r_2 | \dots | c_n \Rightarrow r_n)$.

The following table summarizes the primitive data types used by AutoVox.

Data Type	Notation	Description
character	char	a single symbol or digit
String	str	a sequence of characters
integer	\mathbb{Z}	a number without a fractional component in $(-\infty, \infty)$
natural number	\mathbb{N}	a number without a fractional component in $[1, \infty)$
real	\mathbb{R}	any number in $(-\infty, \infty)$
boolean	bool	True or False
any type	Any	any data type is acceptable
list	list[T]	an ordered collection of objects of type T
set	set[T]	an unordered collection of unique objects of type T
dictionary	dict[key] = value	data structure containing multiple key-value pairs
tuple	tuple[T ₁ , T ₂ , ...] or tuple[T]	an ordered collection of values, potentially of different types
void	void	indicates no return value
current instance	self	a reference to the current instance of a module

The specification of AutoVox uses some derived data types: sequences, strings, and tuples. Sequences are lists filled with elements of the same data type. Strings are sequences of characters. Tuples contain a list of values, potentially of different types. In addition, AutoVox uses functions, which are defined by the data types of their inputs and outputs. Local functions are described by giving their type signature followed by their specification.

5 Module Decomposition

The following table is taken directly from the Module Guide document for this project.

Level 1	Level 2
Hardware-Hiding Module	None
Behaviour-Hiding Module	Input Interpreter Module Voxel Slicing Module Display Partitioning Module Project Manager Module Serialization Manager Module Backend Communication Manager Module Interaction Controller Module Visualization State Manager Module Model Manager Module History Manager Module Autosave Manager Module Voxel Tracking Module Highlight Manager Module Export Validation Module Export Manager Module Error Diagnostic Handler Module
Software Decision Module	Model Structure Module Graphics Adapter Module Database Handler Module Export Structure Module

Table 1: Module Hierarchy

6 MIS of Input Interpreter

InputInterpreter

6.1 Module

The InputInterpreter module is responsible for importing and parsing model or project files (e.g., STL, CSV) and normalizing them into a consistent internal format that downstream modules can process.

6.2 Uses

- `SerializationManager` for the input file deserialization.
- `ErrorDiagnosticHandler` for error handling and diagnostics.
- `VoxelSlicing` for voxel grid generation and layer generation.
- `DisplayPartitioning` for display partitioning the model.

6.3 Syntax

6.3.1 Exported Constants

- `SUPPORTED_FORMATS`: list[string] — supported file types (STL, CSV, binary).
- `DEFAULT_SCALE`: float — default scaling applied to geometry.

6.3.2 Exported Access Programs

Name	In	Out	Exceptions
<code>loadFile</code>	<code>filePath</code> : string	<code>IntermediateModel</code>	<code>FileNotFoundException</code> , <code>UnsupportedFileTypeError</code>
<code>detectFormat</code>	<code>filePath</code> : string	string	<code>None</code>
<code>parseSTL</code>	<code>fileData</code> : string	<code>MeshModel</code>	<code>ParseError</code>
<code>deserializeProject</code>	<code>fileData</code> : string	<code>ProjectModel</code>	<code>SchemaMismatchError</code>

6.4 Semantics

6.4.1 State Variables

- `currentModel`: `IntermediateModel` — latest parsed internal representation.
- `detectedFormat`: `string` — identifies file type.

6.4.2 Environment Variables

- `FILE_PATH`: `string` — path to the input file on the filesystem.

6.4.3 Assumptions

- The file path exists and is readable.
- Data structure conforms to supported file format.
- Deserialized data follows expected schema.

7 MIS of Voxel Slicing

VoxelSlicing

7.1 Module

The VoxelSlicing module is responsible for converting the geometric model into a structured voxel grid. It divides the 3D model along the Z-axis into discrete slices based on a specified resolution, mapping geometry into voxelized layers for simulation and visualization.

7.2 Uses

- `ProjectManager` to get the model structure and data representation, and store the resulting voxel grid and layer list.
- `ErrorDiagnosticHandler` for error handling and diagnostics.

7.3 Syntax

7.3.1 Exported Constants

- `DEFAULT_RESOLUTION`: `tuple(float, float, float)` — default voxel size in x, y, and z directions.
- `MAX_LAYERS`: `int` — maximum number of layers allowed per model.

7.3.2 Exported Access Programs

Name	In	Out	Exceptions
voxelizeModel	model: Intermediate-Model, resolution: tuple	VoxelGrid	ResolutionError, GeometryError
generateLayers	voxelGrid: VoxelGrid	list[Layer]	None
setResolution	resolution: tuple	void	InvalidResolutionError

7.4 Semantics

7.4.1 State Variables

- `voxelGrid`: VoxelGrid — stores the resulting voxelized representation.
- `layerList`: list[Layer] — ordered collection of Z-level layers.
- `resolution`: tuple(float, float, float) — current voxel grid spacing.

7.4.2 Environment Variables

None

7.4.3 Assumptions

- Input model geometry is well-defined and watertight.
- Resolution values are positive real numbers.
- The number of layers does not exceed system memory capacity.

8 MIS of Display Partitioning

DisplayPartitioning

8.1 Module

The DisplayPartitioning module provides core functionality for partitioning the model into distinct display segments.

8.2 Uses

- `ProjectManager` to get the model structure and data representation, and store the resulting voxel grid and layer list.
- `ErrorDiagnosticHandler` for error handling and diagnostics.

8.3 Syntax

Exported Constants

- `MAX_PARTITION`: *int* — maximum number of partitions that can be created.
- `MAX_VOXEL_PARTITION`: *int* — maximum number of voxels per partition.
- `AVAILABLE_PARTITIONS`: *List[string]* — configuration of valid partition IDs used by the display layout.

Exported Access Programs:

Name	In	Out	Exceptions
<code>getPartitions</code>	None	<i>dict[string]</i>	None
<code>setCurrentPartition</code>	<code>id: string</code> <code>partition: PartitionItem</code>	<code>void</code>	None
<code>resizePartitions</code>	<code>id: string</code> <code>width: int</code> <code>height: int</code> <code>depth: int</code>	<code>void</code>	None

8.4 Semantics

8.4.1 State Variables

- `PartitionItem`: *record* — configuration for data that describes a partition.
- `PartitionDict`: *dict[string] = PartitionItem* — tracks all partitions.

8.4.2 Environment Variables

None

8.4.3 Assumptions

- A valid and complete `ModelStructure` exists.
- Display partitions adhere only to positive dimensions.
- `AVAILABLE_PARTITIONS` provides the display layout with a preset mapping to UI grid positions.

9 MIS of Project Manager

ProjectManager

9.1 Module

The ProjectManager module manages the creation, initialization, and persistence of project workspaces, handles project metadata storage, and ensures project resources are properly allocated.

9.2 Uses

- `ModelManager` to obtain and create the model structure and data representation.
- `ErrorDiagnosticHandler` for error handling and diagnostics.

9.3 Syntax

9.3.1 Exported Constants

None

9.3.2 Exported Access Programs

Name	In	Out	Exceptions
ProjectManager	-	self	IOError
create_project	project_path: str, config: dict	None	• IOError • ValueError
load_project	project_path: str	None	• IOError • FileNotFoundError
save_project	project_path: str	None	IOError
get_project_metadata	-	dict	-
initialize_workspace	workspace_path: str	None	IOError

9.4 Semantics

9.4.1 State Variables

- `project_path: str` - Path to the current project directory

- `workspace_root`: str - Root directory of the workspace
- `project_metadata`: dict - Dictionary containing project configuration and metadata
- `model`: ModelStructure - Reference to the model structure instance
- `is_initialized`: bool - Flag indicating if the project has been initialized

9.4.2 Environment Variables

- `FILE_SYSTEM`: The file system where project files are stored
- `WORKSPACE_ROOT`: Root directory environment variable for workspace location

9.4.3 Assumptions

- The file system has sufficient space for project creation
- The provided project path is a valid directory path
- Write permissions are available for the project directory
- The workspace root directory exists or can be created

9.4.4 Local Functions

- `validate_config(config: dict) -> bool`: Validates that the configuration dictionary contains required fields
- `create_project_structure(path: str) -> None`: Creates the directory structure for a new project
- `read_metadata_file(path: str) -> dict`: Reads and parses project metadata from file
- `write_metadata_file(path: str, metadata: dict) -> None`: Writes project metadata to file

10 MIS of Serialization Manager

SerializationManager

10.1 Module

The `SerializationManager` module handles the conversion of all internal model data between in-memory and persistent storage forms (JSON or binary). It ensures data integrity, schema consistency, and supports both saving and restoring complete project states.

10.2 Uses

- `ModuleManager` to get the current module state.
- `AutosaveManager` to get the current autosave state.
- `ErrorDiagnosticHandler` for error handling and diagnostics.

10.3 Syntax

10.3.1 Exported Constants

- `SUPPORTED_FORMATS`: list[string] — allowed serialization formats {JSON, BIN}.
- `CURRENT_SCHEMA_VERSION`: string — defines latest project data schema.

10.3.2 Exported Access Programs

Name	In	Out	Exceptions
<code>encodeModel</code>	<code>model: ModelState</code>	<code>string</code>	<code>SerializationError</code>
<code>decodeModel</code>	<code>data: string</code>	<code>ModelState</code>	<code>DeserializationError, SchemaMismatchError</code>
<code>verifySchema</code>	<code>data: string</code>	<code>bool</code>	<code>SchemaMismatchError</code>

10.4 Semantics

10.4.1 State Variables

- `serializedData`: string — current encoded representation.
- `schemaVersion`: string — identifies schema used during last encode/decode.

10.4.2 Environment Variables

- `SAVE_PATH`: string — default file path for serialized model data.

10.4.3 Assumptions

- Input model follows internal data structure specification.
- Decoded data matches the expected schema version.
- File system paths used for storage are valid and writable.

11 MIS of Backend Communication Manager

BackendCommunicator

11.1 Module

The `BackendCommunicator` module manages the transfer and synchronization of data between the backend server and frontend UI.

11.2 Uses

- `SerializationManager` for necessary JSON, binary, and CSV transforms.
- `InteractionController` for processing interaction data from the frontend.
- `ErrorDiagnosticHandler` for error handling and diagnostics.

11.3 Syntax

Exported Constants

- None

Exported Access Programs

Name	In	Out	Exceptions
<code>checkServerStatus</code>	None	<code>Promise<void></code>	Network Error
<code>initDataLogs</code>	None	<code>Promise<boolean></code>	Network Error
<code>getDataLogs</code>	None	string	None
<code>getInteraction</code>	None	UIdata: string	None

11.4 Semantics

11.4.1 State Variables

- `serverStatus`: *ServerStatusType* — tracks the current connection status of the backend server.
- `data_log`: *string* — all data gathered from the frontend that requires interpretation on the backend.

11.4.2 Environment Variables

- `SERVER_URL`: *string* — backend server URL from environment configuration.

11.4.3 Assumptions

- Backend service is reachable and operational.
- Connection is available for data synchronization.
- Valid configurations exist for necessary data transfer operations.

12 MIS of Interaction Controller

InteractionController

12.1 Module

The InteractionController module manages the process of raw events from interaction with the UI to associated actions within internal code.

12.2 Uses

- `ModelManager` to handle user intent related to model modification.
- `ExportManager` to handle user intent related to export.
- `ErrorDiagnosticHandler` for error handling and diagnostics.

12.3 Syntax

Exported Constants

- `UI_EVENTS`: *list[string]* — identifies all supported UI events that can be detected from user interaction.
- `UI_ACTIONS`: *list[string]* — identifies all supported interactions that can be derived from UI events.

Exported Access Programs

Name	In	Out	Exceptions
<code>interpretEvent</code>	<code>UIdata: string</code>	<code>UIEvent</code>	None

12.4 Semantics

12.4.1 State Variables

- `currentEvent`: *UIEvent* — configuration for a UI event.
- `currentView`: *string* — identifies what view is currently displayed during interaction.
- `pointerPosition`: *[int, int]* — pointer coordinates captured from the most recent relevant event.
- `allEvents`: *list[string]* — identifies all supported UI events that can be detected from user interaction.

12.4.2 Environment Variables

None

12.4.3 Assumptions

- User intent does not exceed the scope of supported actions that can be derived.
- There can only be one current active view at a given moment.
- `pointerPosition` is contained within the screen resolution.

13 MIS of Visualization State Manager

VisualizationManager

13.1 Module

The VisualizationManager module oversees the creation of UI views while managing subsequent updates to the display state of the specified current UI views on a backend level.

13.2 Uses

- `GraphicsAdapter` for rendering updates visible to user.
- `VoxelTracking` for specifying the set of voxels affected by a given update.
- `HighlightManager` for managing change in voxels being highlighted.
- `InteractionController` for handling user interaction data from the frontend.
- `ErrorDiagnosticHandler` for error handling and diagnostics.

13.3 Syntax

13.3.1 Exported Constants

- `DEFAULT_VIEWS`: *list[string]* — list of identifiers corresponding to the default views generated upon project initialization.

13.3.2 Exported Access Programs

Name	In	Out	Exceptions
<code>getCurrentView</code>	None	<code>ViewState</code>	None
<code>setView</code>	<code>state: ViewState</code>	<code>void</code>	None
<code>getHighlightState</code>	None	<code>HighlightState</code>	None
<code>updateModel</code>	<code>voxelCoords: List[VoxelCoord]</code>		
<code>updateType: Mod-</code> <code>elUpdateType</code>	<code>void</code>	<code>None</code>	
<code>updateHighlight</code>	<code>semanticKey: string</code>	<code>void</code>	None

13.4 Semantics

13.4.1 State Variables

- `currentView`: *string* — identifies which UI view is currently shown to the user.
- `viewStatus`: *dict[string] = ViewItem* — stores all data encapsulated within a UI view.
- `updateBundle`: *dict[string] = UpdateItem* — stores all data needed to update a UI view upon a render request.
- `pendingUpdates`: *list[UpdateKey]* — updates waiting to be processed in rendering.
- `renderStatus`: *boolean* — records the success status of the rendering process.
- `supportedViews`: *list[string]* — identifiers corresponding to all available project views.

13.4.2 Environment Variables

None

13.4.3 Assumptions

- Partitions are initialized.
- `ViewItem` is properly formatted in accordance with `ViewItem` specification.
- `UpdateItem` is properly formatted in accordance with `UpdateItem` specification.
- `currentView`, `ViewState`, and `DEFAULT_VIEWS` are elements of `supportedViews`.

14 MIS of Model Manager

ModelManager

14.1 Module

The ModelManager module oversees the management and manipulation of the voxel-based 3D model. It provides APIs to add, remove, or modify voxels, update magnetization/material properties, and synchronize changes with autosave and history tracking modules.

14.2 Uses

- `ModelStructure` to get the model structure and data representation.
- `VisualizationManager` to get the current view state.
- `ErrorDiagnosticHandler` for error handling and diagnostics.

14.3 Syntax

14.3.1 Exported Constants

- `MAX_VOXEL_COUNT`: int — maximum allowed voxel entries per project.
- `AUTOSAVE_INTERVAL_S`: float — time threshold (in seconds) before triggering autosave.

14.3.2 Exported Access Programs

Name	In	Out	Exceptions
<code>addVoxel</code>	<code>coord: VoxelCoord,</code> <code>material: MaterialType,</code> <code>mag: Vector3</code>	<code>void</code>	<code>InvalidInputError</code>
<code>removeVoxel</code>	<code>coord: VoxelCoord</code>	<code>void</code>	<code>NotFoundError</code>
<code>modifyVoxel</code>	<code>coord: VoxelCoord,</code> <code>new-</code> <code>Data: VoxelData</code>	<code>void</code>	<code>NotFoundError</code>
<code>saveModel</code>	<code>None</code>	<code>bool</code>	<code>IOerror</code>
<code>loadModel</code>	<code>filePath: string</code>	<code>bool</code>	<code>DeserializationError</code>

14.4 Semantics

14.4.1 State Variables

- `voxelGrid`: `VoxelGrid` — stores all voxel elements and layer mapping.
- `metadata`: `dict` — contains file name, author, timestamp, etc.
- `autosaveTimer`: `float` — time since last autosave.
- `unsavedChanges`: `bool` — true if edits have occurred since last save.

14.4.2 Environment Variables

- `SAVE_PATH`: `string` — default save location for serialized project data.

14.4.3 Assumptions

- Voxel coordinates fall within the defined model boundaries.
- Data supplied for voxel modifications are valid according to schema.
- Autosave operations will not interrupt ongoing edits.

15 MIS of History Manager

HistoryManager

15.1 Module

The HistoryManager module maintains the complete change history of the 3D voxel model. It allows undoing and redoing edits by recording incremental changes (deltas) after every modification.

15.2 Uses

- ErrorDiagnosticHandler for error handling and diagnostics.

15.3 Syntax

15.3.1 Exported Constants

- MAX_HISTORY_SIZE: int — maximum number of undo states stored.

15.3.2 Exported Access Programs

Name	In	Out	Exceptions
recordChange	delta: ModelDelta	void	None
undo	None	bool	EmptyHistoryError
redo	None	bool	EmptyHistoryError
clearHistory	None	void	None

15.4 Semantics

15.4.1 State Variables

- historyStack: list[ModelState] — sequence of previous model states.
- redoStack: list[ModelState] — sequence of undone model states available for redo.
- currentIndex: int — current pointer in the history sequence.

15.4.2 Environment Variables

None

15.4.3 Assumptions

- Changes are discrete and atomic.
- No new change is made while undo or redo is in progress.
- The number of stored states does not exceed `MAX_HISTORY_SIZE`.

16 MIS of Autosave Manager

AutosaveManager

16.1 Module

The `AutosaveManager` module prepares data to be saved, monitors when updates require saving, and invokes periodic scheduled transfers to file-based storage.

16.2 Uses

- `HistoryManager` to get the latest history state during periodic saves.
- `DatabaseHandler` to store serialized data persistently.
- `ErrorDiagnosticHandler` for error handling and diagnostics.

16.3 Syntax

Exported Constants

- `AUTOSAVE_INTERVAL_MS`: *int* — minimum amount of time (in milliseconds) between autosave operations.
- `FILE_ID`: *string* — file to which autosave operations are written.

Exported Access Programs

Name	In	Out	Exceptions
<code>forceSave</code>	None	None	IO Error
<code>enableAutosave</code>	None	None	None
<code>disableAutosave</code>	None	None	None
<code>lastAutosaveTime</code>	None	DateTime	None

16.4 Semantics

16.4.1 State Variables

- `autosavePermission`: *bool* — indicates whether autosave is enabled or disabled.
- `lastAutosave`: *DateTime* — timestamp of last transfer to file-based storage.
- `autosaveHistory`: *dict[DateTime] = Update* — complete log of transfers to file-based storage.

16.4.2 Environment Variables

- `SYSTEM_TIME`: *DateTime* — global time supplied by the current system.

16.4.3 Assumptions

- `SYSTEM_TIME` always increases monotonically.
- Data preparation method is compatible with file-based storage.
- Connection is available to file-based storage.
- Valid configuration exists for operations to file-based storage.

17 MIS of Voxel Tracking

VoxelTracking

17.1 Module

The VoxelTracking module interprets the voxel data structure to locate and track voxels that satisfy particular property criteria, such as selection state, material type, or user-defined rules. It efficiently identifies and accesses relevant voxels to determine which voxels are currently subject to operations like highlighting, selection, or further processing.

17.2 Uses

- `ModelStructure` to get the model structure and data representation.
- `ErrorDiagnosticHandler` for error handling and diagnostics.

17.3 Syntax

17.3.1 Exported Constants

- `MAX_QUERY_RESULTS`: int — maximum number of voxels returned in a single query result.
- `SUPPORTED_PROPERTIES`: list[string] — list of property names that can be queried (e.g., "material", "magnetization", "selected", "layer").

17.3.2 Exported Access Programs

Name	In	Out	Exceptions
<code>queryByMaterial</code>	<code>materialType: MaterialType</code>	<code>list[VoxelCoord]</code>	<code>InvalidMaterialError</code>
<code>queryBySelection</code>	<code>isSelected: bool</code>	<code>list[VoxelCoord]</code>	<code>None</code>
<code>queryByRegion</code>	<code>bounds: BoundingBox</code>	<code>list[VoxelCoord]</code>	<code>InvalidBoundsError</code>
<code>queryByLayer</code>	<code>layerZ: int</code>	<code>list[VoxelCoord]</code>	<code>IndexError</code>
<code>queryByProperty</code>	<code>propertyName: string, value: Any</code>	<code>list[VoxelCoord]</code>	<code>InvalidPropertyError</code>
<code>getVoxelProperties</code>	<code>coord: VoxelCoord</code>	<code>VoxelProperties</code>	<code>NotFoundError</code>

17.4 Semantics

17.4.1 State Variables

- `queryCache`: `dict[string, list[VoxelCoord]]` — cached results of recent queries for performance optimization.
- `activeSelections`: `set[VoxelCoord]` — set of currently selected voxel coordinates.

17.4.2 Environment Variables

None

17.4.3 Assumptions

- Voxel coordinates provided in queries are within valid grid boundaries.
- Property names used in queries match those defined in `SUPPORTED_PROPERTIES`.
- The voxel grid structure remains consistent during query operations.

18 MIS of Highlight Manager

HighlightManager

18.1 Module

The HighlightManager module manages the voxel highlights in accordance with visual semantic meaning.

18.2 Uses

- `ErrorDiagnosticHandler` for error handling and diagnostics.

18.3 Syntax

Exported Constants

- `DEFAULT_HIGHLIGHT_MAP`: `dict[string, string]` — mapping from semantic keys to their default highlight colours.

Exported Access Programs

Name	In	Out	Exceptions
<code>getHighlight</code>	<code>semanticKey: string</code>	<code>ColourValue</code>	<code>None</code>
<code>editPalette</code>	<code>semanticKey: string</code> <code>newColour: ColourValue</code>	<code>void</code>	<code>None</code>
<code>setHighlight</code>	<code>semanticKey: string</code>	<code>void</code>	<code>None</code>
<code>resetPalette</code>	<code>None</code>	<code>void</code>	<code>None</code>

18.4 Semantics

18.4.1 State Variables

- `highlightColourMap`: `dict[string, string]` — current mapping from semantic keys to active highlight colours.

18.4.2 Environment Variables

`None`

18.4.3 Assumptions

- Semantic keys must correspond to valid entries maintained by the TrackingManager.
- Colour values are valid colour representations.

19 MIS of Export Validation

ExportValidation

19.1 Module

The ExportValidation module validates export readiness by checking export file format requirements, verifying completeness of voxel properties (material and magnetization), and ensuring all export constraints are met.

19.2 Uses

- `VoxelTracking` to get all the voxels in the model, ensure all voxels have material and magnetization properties.
- `ErrorDiagnosticHandler` for error handling and diagnostics.

19.3 Syntax

19.3.1 Exported Constants

- `MAX_VOXELS`: $\mathbb{Z} = 13996800000$ - Maximum number of voxels allowed
- `MAX_LAYERS`: $\mathbb{Z} = 518400$ - Maximum number of layers allowed

19.3.2 Exported Access Programs

Name	In	Out	Exceptions
<code>validate_export_readiness</code>	<code>model: ModelStructure</code>	<code>ValidationResult</code>	-
<code>check_printer_compatibility</code>	<code>model: ModelStructure</code>	<code>bool</code>	-
<code>check_property_completeness</code>	<code>model: ModelStructure</code>	<code>list[str]</code>	-
<code>validate_file_format</code>	<code>file_path: str</code>	<code>bool</code>	<code>IOError</code>

19.4 Semantics

19.4.1 State Variables

None

19.4.2 Environment Variables

None

19.4.3 Assumptions

- The model structure provided is valid and properly initialized
- All voxels in the model have consistent property structures
- File paths provided are accessible and readable

19.4.4 Local Functions

- `count_voxels(model: ModelStructure) -> Z`: Counts the total number of voxels in the model
- `count_layers(model: ModelStructure) -> Z`: Counts the total number of layers in the model
- `check_printer_specs(model: ModelStructure) -> bool`: Validates model against printer-specific constraints

20 MIS of Export Manager

ExportManager

20.1 Module

The ExportManager module coordinates the export process, transforms internal model data into export-compatible formats, and serializes project data including voxel grids, metadata, material properties, and magnetization information according to export specifications.

20.2 Uses

- `ModelStructure` to obtain the model structure and data representation.
- `ExportValidation` to validate export validity.
- `ExportStructure` to define the export data structure format.
- `ErrorDiagnosticHandler` for error handling and diagnostics.

20.3 Syntax

20.3.1 Exported Constants

- `DEFAULT_EXPORT_FORMAT`: str = "CSV" - Default export file format

20.3.2 Exported Access Programs

Name	In	Out	Exceptions
ExportManager	-	self	-
export_project	model: ModelStructure, export_path: str, format: str	None	• IOError • ValueError
transform_to_export_format	model: ModelStructure, format: str	ExportData	-
serialize_data	data: ExportData, format: str	str	ValueError

20.4 Semantics

20.4.1 State Variables

- `export_format`: str - Current export format being used
- `export_config`: dict - Configuration settings for export operations

20.4.2 Environment Variables

- `FILE_SYSTEM`: The file system where export files are written

20.4.3 Assumptions

- The model structure provided has been validated for export readiness
- The export path directory exists or can be created
- Write permissions are available for the export directory
- The export format is supported

20.4.4 Local Functions

- `group_voxels_by_layer(model: ModelStructure) -> dict`: Groups voxels by their layer Z-coordinate
- `encode_csv(export_data: ExportData) -> str`: Encodes export data into CSV format string
- `validate_export_path(path: str) -> bool`: Validates that the export path is writable
- `create_export_directory(path: str) -> None`: Creates the export directory if it does not exist

21 MIS of Error Diagnostic Handler

ErrorDiagnosticHandler

21.1 Module

The ErrorDiagnosticHandler module detects, diagnoses, and handles errors that occur during model operations, graphics rendering, and file interactions. It provides error classification, logging, and recovery mechanisms to ensure system stability and user feedback.

21.2 Uses

None

21.3 Syntax

21.3.1 Exported Constants

- `ERROR_MODEL_UNRESPONSIVE`: str = "MODEL_UNRESPONSIVE" - Error code for unresponsive model
- `ERROR_GRAPHICS_UPDATE`: str = "GRAPHICS_UPDATE_FAILURE" - Error code for graphics update failure
- `ERROR_FILE_ISSUE`: str = "FILE_OPERATION_ERROR" - Error code for file operation errors

21.3.2 Exported Access Programs

Name	In	Out	Exceptions
<code>detect_error</code>	<code>error_context: dict</code>	<code>ErrorDiagnostic</code>	-
<code>classify_error</code>	<code>error_code: str,</code> <code>error_context: dict</code>	<code>ErrorType</code>	-
<code>log_error</code>	<code>error_diagnostic: ErrorDiagnostic</code>	<code>None</code>	<code>IOError</code>
<code>handle_error_recovery</code>	<code>error_diagnostic: ErrorDiagnostic</code>	<code>RecoveryAction</code>	-
<code>get_error_source</code>	<code>error_diagnostic: ErrorDiagnostic</code>	<code>str</code>	-

21.4 Semantics

21.4.1 State Variables

- `error_log`: list[`ErrorDiagnostic`] - History of detected errors
- `error_patterns`: dict - Patterns for error classification

21.4.2 Environment Variables

- `LOG_FILE`: File system location for error logging

21.4.3 Assumptions

- Error context dictionaries contain sufficient information for diagnosis
- Log file location is writable
- Error codes follow the defined constants

21.4.4 Local Functions

- `analyze_error_pattern(error_context: dict) -> str`: Analyzes error context to identify error patterns
- `determine_error_source(context: dict) -> str`: Determines the source component from error context
- `format_error_message(error_code: str, context: dict) -> str`: Formats a human-readable error message
- `suggest_recovery_steps(error_type: ErrorType) -> list[str]`: Generates recovery step suggestions based on error type

22 MIS of Model Structure

ModelStructure

22.1 Module

The ModelStructure module stores and organizes all voxel and layer data for the model, including per-voxel properties, metadata, and structural dimensions.

22.2 Uses

- `ErrorDiagnosticHandler` for error handling and diagnostics.

22.3 Syntax

22.3.1 Exported Constants

- `VOXEL_SIZE_XY`: $\mathbb{R} = 300.0$ - Voxel size in X and Y dimensions (micrometers)
- `VOXEL_SIZE_Z`: $\mathbb{R} = 110.0$ - Voxel size in Z dimension (micrometers)

22.3.2 Exported Access Programs

Name	In	Out	Exceptions
ModelStructure	dimensions: tuple[\mathbb{Z} , \mathbb{Z} , \mathbb{Z}]	self	ValueError
get voxel	position: tuple[\mathbb{Z} , \mathbb{Z} , \mathbb{Z}]	Voxel	IndexError
set voxel	position: tuple[\mathbb{Z} , \mathbb{Z} , \mathbb{Z}], voxel: Voxel	None	IndexError
get layer	z: \mathbb{Z}	Layer	IndexError
get property	position: tuple[\mathbb{Z} , \mathbb{Z} , \mathbb{Z}], property_name: str	Any	• IndexError • KeyError
set property	position: tuple[\mathbb{Z} , \mathbb{Z} , \mathbb{Z}], property_name: str, value: Any	None	• IndexError • ValueError
add layer	layer: Layer	None	ValueError
get metadata	-	dict	-
set metadata	key: str, value: Any	None	-
validate voxel	voxel: Voxel	bool	-
has material	voxel: Voxel	bool	-
has magnetization	voxel: Voxel	bool	-

22.4 Semantics

22.4.1 State Variables

- **voxel_grid**: 3D array[Voxel] - Three-dimensional grid storing voxel data
- **layers**: list[Layer] - Ordered list of layers, indexed by Z-coordinate
- **metadata**: dict - Dictionary containing model metadata (dimensions, material properties, etc.)
- **dimensions**: tuple[\mathbb{Z} , \mathbb{Z} , \mathbb{Z}] - Grid dimensions (X, Y, Z)

22.4.2 Environment Variables

None

22.4.3 Assumptions

- Voxel positions are within the grid boundaries defined by `dimensions`
- Layer ordering follows Z-axis ordering (bottom to top)
- Property names are consistent across voxels
- Material types and magnetization vectors conform to expected formats

22.4.4 Local Functions

- `validate_position(position: tuple[Z, Z, Z]) -> bool`: Checks if position is within grid boundaries
- `maintain_layer_ordering() -> None`: Ensures layers remain ordered by Z-coordinate
- `create_layer_from_z(z: Z) -> Layer`: Creates a new layer structure for a given Z-coordinate
- `validate_property_value(property_name: str, value: Any) -> bool`: Validates that a property value conforms to expected type and constraints

23 MIS of Graphics Adapter

GraphicsAdapter

23.1 Module

GraphicsAdapter handles all communication with the graphics API to enable visual rendering and generate a model on the UI.

23.2 Uses

- ErrorDiagnosticHandler for error handling and diagnostics.

23.3 Syntax

23.3.1 Exported Constants

- None

23.3.2 Exported Access Programs

Name	In	Out	Exceptions
requestRender	str: <i>UpdateKey</i>		
update: <i>UpdateBundle</i>	void		NetworkError
getUpdateStatus	str: <i>UpdateKey</i>	boolean	None
checkServerStatus	None	Promise<void>	NetworkError

23.4 Semantics

23.4.1 State Variables

- updateStatus: *boolean* — tracks status of rendering completion.

23.4.2 Environment Variables

- API_BASE_URL: *string* — external base URL for establishing environment configurations and enabling backend API requests.

23.4.3 Assumptions

- Backend service is reachable and operational.
- Connection is available for API.
- Valid configurations exist for necessary API operations.

24 MIS of Database Handler

DatabaseHandler

24.1 Module

The DatabaseHandler module manages persistent storage for project and model data. It provides standardized interfaces for reading, writing, and deleting serialized model files, ensuring version integrity and consistent access to saved projects.

24.2 Uses

- `ModelStructure` to access model structures to keep track of the project.
- `ErrorDiagnosticHandler` for error handling and diagnostics.

24.3 Syntax

24.3.1 Exported Constants

- `DEFAULT_SAVE_DIR`: string — default directory path for project files.
- `DB_FORMAT_VERSION`: string — current format version for data compatibility.

24.3.2 Exported Access Programs

Name	In	Out	Exceptions
<code>saveProject</code>	<code>id: string, data: SerializedModel</code>	<code>bool</code>	<code>IOError</code>
<code>loadProject</code>	<code>id: string</code>	<code>SerializedModel</code>	<code>FileNotFoundException</code>
<code>deleteProject</code>	<code>id: string</code>	<code>bool</code>	<code>IOError</code>
<code>listProjects</code>	<code>None</code>	<code>list[string]</code>	<code>None</code>

24.4 Semantics

24.4.1 State Variables

- `projectMap`: `dict[string, SerializedModel]` — mapping of project identifiers to serialized data.
- `storagePath`: `string` — root directory for persistent project files.

24.4.2 Environment Variables

- FILE_SYSTEM: OS-level file system used for reading/writing project data.

24.4.3 Assumptions

- Project IDs are unique.
- File I/O operations succeed given sufficient permissions.
- SerializationManager ensures schema compatibility before writing data.

25 MIS of Export Structure

ExportStructure

25.1 Module

The ExportStructure module defines and implements the internal data structure for representing exported files, including field ordering, data types, and encoding format. It ensures consistency between internal model representations and external file layouts used during export operations.

25.2 Uses

- `ErrorDiagnosticHandler` for error handling and diagnostics.

25.3 Syntax

25.3.1 Exported Constants

- `EXPORT_SCHEMA_VERSION`: string — current version of the export structure schema.
- `FIELD_ORDER`: list[string] — ordered list of field names in export format: `[“x”, “y”, “z”, “layer”, “material_id”, “magnetization_x”, “magnetization_y”, “magnetization_z”]`.
- `DEFAULT_ENCODING`: string — default character encoding for export files (e.g., `“UTF-8”`).

25.3.2 Exported Access Programs

Name	In	Out	Exceptions
<code>defineStructure</code>	<code>format: string</code>	<code>ExportSchema</code>	<code>UnsupportedFormatError</code>
<code>getFieldOrder</code>	<code>format: string</code>	<code>list[string]</code>	<code>UnsupportedFormatError</code>
<code>getFieldType</code>	<code>fieldName: string</code>	<code>DataType</code>	<code>InvalidFieldError</code>
<code>validateStructure</code>	<code>data: ExportData</code>	<code>bool</code>	<code>StructureMismatchError</code>
<code>createHeader</code>	<code>metadata: dict</code>	<code>ExportHeader</code>	<code>None</code>

25.4 Semantics

25.4.1 State Variables

- `exportSchema`: `ExportSchema` — current export structure schema definition.
- `fieldTypes`: `dict[string, DataType]` — mapping from field names to their data types.

25.4.2 Environment Variables

None

25.4.3 Assumptions

- Export format identifiers match supported formats ("CSV").
- Field names in export data match those defined in `FIELD_ORDER`.
- Data types conform to the schema defined by `fieldTypes`.
- Export structure remains consistent across export operations.

25.4.4 Local Functions

- `mapInternalToExport(internalData: VoxelData) -> ExportData`: Maps internal voxel representation to export format structure.
- `validateFieldValue(fieldName: string, value: Any) -> bool`: Validates that a field value matches its expected data type.
- `encodeFieldValue(fieldName: string, value: Any) -> string`: Encodes a field value according to the export format specification.

References

Carlo Ghezzi, Mehdi Jazayeri, and Dino Mandrioli. *Fundamentals of Software Engineering*. Prentice Hall, Upper Saddle River, NJ, USA, 2nd edition, 2003.

Daniel M. Hoffman and Paul A. Strooper. *Software Design, Automated Testing, and Maintenance: A Practical Approach*. International Thomson Computer Press, New York, NY, USA, 1995. URL <http://citeseer.ist.psu.edu/428727.html>.