

SE 3XA3: Module Interface Specification

Sudoku Solver

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1 Module Hierarchy

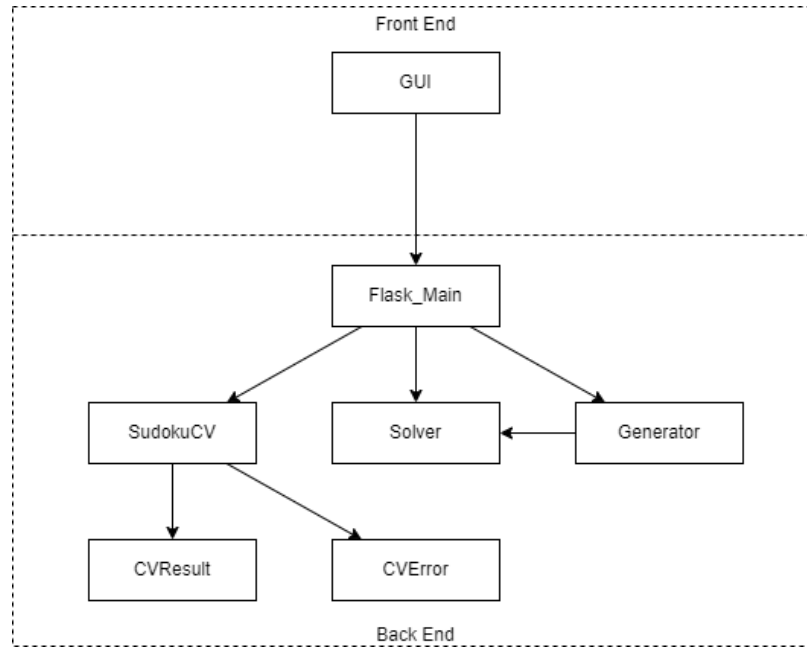


Figure 1: Use hierarchy among modules

2 SudokuCV Module

2.1 Syntax

2.1.1 Exported Routines

Name	Inputs	Outputs	Exceptions
<code>__init__</code>	string		NO_MODEL
<code>recognize</code>	image, boolean, boolean	CVResult	NO_GRID, GRID_SMALL, IMG_SMALL

2.2 Semantics

2.2.1 State Variables

`model`: The Keras machine learning model loaded for this instance of the SudokuCV.

2.2.2 Environmental Variables

`model_file`: file path to a trained Keras machine learning model used for digit recognition.

`dimensions = (900, 900)`: specifies resolution of intermediate images during processing

`min_dimensions = (200, 200)`: specifies minimum resolution required to process the input image

2.2.3 Assumptions

`__init__` is called before any other access routine

2.2.4 Semantics of Exported Routines

- **__init__(model_file)**

Input:

- * model_file: string; path to the trained machine learning

Transition:

- * model_file is loaded into model state variable using Keras

Exceptions:

- * NO_MODEL, if no valid model file is found at model_path

- **recognize(image, is_file, show_image)**

Input:

- * image: a source image file path or buffer string, depending on is_file

- * is_file: optional boolean (default=True), indicates whether source is file or buffer data

- * show_image: optional boolean (default=False), displays intermediary processed images for debugging

Output:

- * CVResult object containing recognition results processed from input image.

Exceptions:

- * NO_GRID, if no square grid is detected in the input image.

- * GRID_SMALL, if no square grid is detected in the input image.

- * NO_GRID, if no square grid is detected in the input image.

3 CVResult Module

3.1 Syntax

3.1.1 Exported Routines

Name	Inputs	Outputs	Exceptions
__init__	int[], float[], image, string		
getConfidence		2D float[]	CV_FAIL
getConfidentResults	float	2D int[]	CV_FAIL
saveImg	string		CV_FAIL, SAVE_FAIL
deleteImg	string		CV_FAIL, DEL_FAIL
getImage		image	CV_FAIL

3.2 Semantics

3.2.1 State Variables

uuid: unique identifier for this CVResult object

raw_results: integer array of recognized digits

confidence: float array of prediction confidence for each recognized digit

error: error message string, empty if recognition did not experience error

image: a processed image of the original input

3.2.2 Environmental Variables

N/A

3.2.3 Assumptions

`__init__` is called before any other access routine.

Error message string is passed into the constructor if recognition failed.

3.2.4 Semantics of Exported Routines

- **`__init__(raw_results, confidence, image, error)`**

Input:

- * `raw_results`: integer list of recognized digits with 0 representing empty
- * `confidence`: float list of confidence rate from 0 (no confidence) to 1 (certain) for each result
- * `image`: processed image of the original input
- * `error`: error string description of exception encountered during recognition

Transition:

- * `raw_results` and `confidence` lists are converted to numpy arrays and saved in respective state variables.
- * `image` and `error` are stored in state variables
- * a UUID (universally unique identifier) is generated and stored in the `uuid` variable

Exceptions: N/A

- **`getConfidence()`**

Input: N/A

Output:

- * 2D float list representing confidence rates (0 to 1) for each recognized cell content

Exceptions:

- * `CV_FAIL`, if error state variable is not empty

- **`getConfidentResults(threshold)`**

Input:

- * `threshold`: float value to cut off prediction acceptance at

Output:

- * 2D int list of recognized digits with confidence above threshold, 0 otherwise

Exceptions:

- * `CV_FAIL`, if error state variable is not empty

- **`saveImg(directory)`**

Input:

- * `directory`: string path of the directory to save the image in

Transition:

- * The image is saved in the specified directory using the UUID as file name

Exceptions:

- * `CV_FAIL`, if error state variable is not empty
- * `SAVE_FAIL`, if directory does not exist or permission is denied

- **`deleteImg()`**

Input:

- * `directory`: string path of the directory to delete the image from

Transition:

- * The image with the UUID as file name is deleted from the directory

Exceptions:

- * CV_FAIL, if error state variable is not empty
- * DEL_FAIL, if file does not exist or permission is denied

- **getImage()**

Input: N/A

Output:

- * processed image encoded as a base64 string

Exceptions:

- * CV_FAIL, if error state variable is not empty

4 CVErrors Module

4.1 Syntax

4.1.1 Exported Routines

Name	Inputs	Outputs	Exceptions
getErrorMessage	int	string	UNDEFINED
getErrors		dictionary	

4.2 Semantics

4.2.1 State Variables

N/A

4.2.2 Environmental Variables

ERR_MSGS: dictionary of error code matched with string descriptions

4.2.3 Assumptions

N/A

4.2.4 Semantics of Exported Routines

- **getErrorMessage(errorID)**

Input:

- * errorID: int error code

Output:

- * string description of the error

Exceptions:

- * UNDEFINED, if errorID is not in the ERR_MSGS dictionary

- **getErrorList()**

Input: N/A

Output:

- * returns all available error key-value pairs in the ERR_MSGS dictionary

Exceptions: N/A

5 Solver Module

5.1 Syntax

5.1.1 Exported Routines

Name	Inputs	Outputs	Exceptions
solve	2D int[]	boolean	INVALID_POSITION, INVALID_NUM
valid	2D int[], int[], int	boolean	
find_empty	2D int[]	int[]	
getSolvedCoordinates			
getUnfilledCoordinates	2D int[]	int[]	
solve_randomly	2D int[]	boolean	
validateBoard	2D int[]	boolean	

5.2 Semantics

5.2.1 State Variables

N/A

5.2.2 Environmental Variables

N/A

5.2.3 Assumptions

Input Sudoku board is a valid 9x9 2D array containing integers valued 0 to 9.

5.2.4 Semantics of Exported Routines

- **solve(board)**

Input:

- * board: 2D 9x9 integer list containing digits 0 to 9, where 0 represents empty space

Transition-Output:

- * If solvable, the board is solved in place, where all 0s in the array are replaced by solution digits. The method returns True.
- * Returns false if the board is not solvable.

Exceptions: N/A

- **valid(board, position, number)**

Input:

- * board: 2D 9x9 integer list representing the cells on the game board
- * position: integer tuple (row, column) to specify a position on the board
- * number: the integer digit to test for validity at the specified position

Output:

- * True, if number at specified position does not violate Sudoku game rules
- * False, if otherwise

Exceptions:

- * INVALID_POSITION, if for $i = 0..1$ $position[i] > 8$ or $position[i] < 0$
- * INVALID_NUM, if $number > 9$ or $number < 1$

- **find_empty(board)**

Input:

- * board: 2D 9x9 integer list representing the cells on the game board

Output:

- * (row, column) integer tuple of the position of the first empty cell on the input board.
- * returns empty tuple if no free cells found

Exceptions: N/A

- **getSolvedCoordinates** **getUnfilledCoordinates(board)**

Input:

- * board: 2D 9x9 integer list representing the cells on the game board

Output:

- * list of integer tuples with (row, column) indicating positions of empty cells to be solved

Exceptions: N/A

- **solve_randomly(board)**

Input:

- * board: 2D 9x9 integer list containing digits 0 to 9, where 0 represents empty space

Transition-Output:

- * If solvable, the board is solved in place, where all 0s in the array are replaced by randomly selected solution digits. The method returns True.
- * Returns false if the board is not solvable.

Exceptions: N/A

- **validateBoard(board)**

Input:

- * board: 2D 9x9 integer list containing digits 0 to 9, where 0 represents empty space

Transition-Output:

- * Returns true if the board is completed. Also returns true if the board is incomplete but still has a solution, and solves it accordingly.
- * Returns false if the board is invalid.

Exceptions: N/A

6 Generator Module

6.1 Syntax

6.1.1 Exported Routines

Name	Inputs	Outputs	Exceptions
generateRandomValidBoard	int, int	2D int[]	LOW_HINT
hasUniqueSolution	2D int[], int	boolean	INVALID_BOARD

6.2 Semantics

6.2.1 State Variables

N/A

6.2.2 Environmental Variables

N/A

6.2.3 Assumptions

N/A

6.2.4 Semantics of Exported Routines

- **generateRandomValidBoard(hints, uniquenessLikelihood)**

Input:

- * hints: integer; number of hint digits to include in the output puzzle
- * uniquenessLikelihood: optional integer (default = 5); number of iterations to check for non-unique solutions. Higher values increase uniqueness of possible solutions.

Output:

- * 2D 9x9 int list representing a newly generated Sudoku puzzle

Exceptions:

- * LOW_HINT, if the number of hints < 24 which results in guaranteed non-uniqueness.

- **hasUniqueSolution(board, attempts)**

Input:

- * board: 2D 9x9 integer list representing the cells on the game board
- * attempts: optional integer (default = 5); number of attempts to search for a different solution.

Output:

- * True, if non-unique solutions are not discovered after specified number of attempts **the Sudoku board only has one unique solution.**
- * False, if otherwise

Exceptions:

- * INVALID_BOARD, if board is unsolvable

7 GUI Module

7.1 Syntax

7.1.1 Exported Routines

Name	Inputs	Outputs	Exceptions
constructor		HTML GUI	

7.2 Semantics

7.2.1 State Variables

N/A

7.2.2 Environmental Variables

Keyboard input from user

Image file upload from user

HTTP request metadata from user, including browser type, version, resolution

7.2.3 Assumptions

Back-end application has been started.

User is connecting through a major modern browser (Chrome, Edge, Firefox, Safari).

7.2.4 Semantics of Exported Routines

N/A

8 Flask Main Module

8.1 Syntax

8.1.1 Exported Routines

Name	Inputs	Outputs	Exceptions
<code>__init__</code> route	string HTTP GET request	string HTML	ERR_MODEL ERR_ROUTING

8.2 Semantics

8.2.1 State Variables

app: Flask app instance

cv: SudokuCV image recognition instance

8.2.2 Environmental Variables

cvModel: Keras classification model file used for image recognition

home, upload, recognize, solution, play, instructions: HTML template files for HTTP response rendering

8.2.3 Assumptions

Hosting environment is capable of running the Flask application.

8.2.4 Semantics of Exported Routines

- `__init__(modelFile)`

Input:

- * modelFile: Keras classification model file path

Transition:

- * An instance of SudokuCV is loaded into cv using modelFile
- * An instance of Flask is created and referenced in app

Exceptions:

- * ERR_MODEL, if specified model file path is invalid or the file cannot be loaded

- **route(url)**

Input:

- * url: the routing path from the HTTP request

Output:

- * url = "/" renders home HTML
- * url = "/upload" renders upload HTML
- * url = "/game" renders difficulty selection HTML
- * ~~url = "/recognize" renders recognize HTML~~
- * ~~url = "/solver" renders solutions HTML~~
- * url = "/play" renders play HTML
- * ~~url = "/instructions" renders instructions HTML~~

Exceptions:

- * ERR_ROUTING, if url is not a valid routing address

9 Major Revision History

March 15, 2022 - Rough draft of sections

March 17, 2022 - Added MIS for SudokuCV, CVError, and CVResult

March 18, 2022 - Revision 0 complete

April 12, 2022 - Revision 1 complete, red text is new additions and strikethrough text is deprecated.