Introduction to the Development of an Automated Verification and Validation System for the CINEMA

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1. Introduction

It is necessary to establish an automated verification environment to enhance the traceability of history management and improve the reliability of verification and validation (V&V) results for the commercialization of the CINEMA code [1], which is a domestic severe accident analysis code developed by a consortium of KHNP, KAERI, KEPCO E&C and FNC, following its development and application to severe accident analysis. In this paper, we would like to introduce the procedure for implementing a CMS (Configuration Management System) to optimize the management of CINEMA severe accident code and to establish a software quality assurance system through the verification and validation of codes and automation of verification reports using the constructed CMS.

2. Methods and Results

The automated system for verification and validation of CINEMA proceeds with the procedure shown in Fig. 1. First, the user must select the desired execution case and create a yml file that implements it in the GitLab environment. After uploading the file to the GitLab project and running the automation, it automatically runs from code build to the verification and validation report creation.

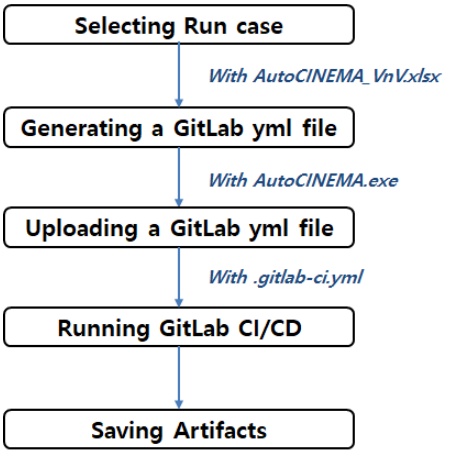

Fig. 1. CINEMA Code V&V Automation Process.

2.1 Creating an Excel file for an Automated Verification and Validation System

We build an input algorithm development environment for developing an automated verification and validation program for CINEMA code. The Excel file performs change management such as creation, modification, and deletion of information on benchmarking files and information management for creating graphs for verification and validation reports.

The Excel sheet consists of a total of 6 sheets, as follows:

1. Path
2. Report
3. CC_INPUT
4. Cases
5. FIGNOW
6. FIGDATANOW

(1) "Path" Sheet

The Path sheet provided by the CINEMA automatic V&V system is where the information necessary to start the CINEMA automatic V&V system for the first time is defined. Fig. 2 shows the Path sheet. In the CINEMA automatic V&V system, the already registered CSPACE executable file is found and displayed in the (A, 3) area, and the path of the executable file is found and displayed in the (C, 3) area.

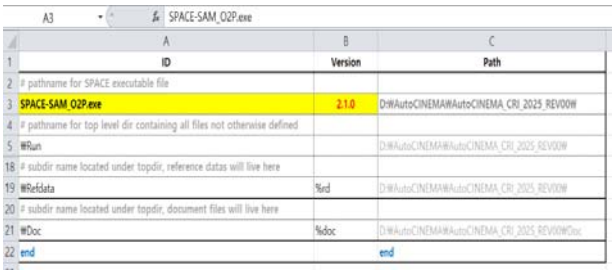

Fig. 2. Screen of Path Sheet.

(2) "Report" Sheet

The Report sheet provided by the Excel file is a place to define the Report ID required for the graph generation using the CINEMA automatic V&V system.

The contents of the items on the Report sheet are shown in Table I.

Table I: Report Sheet Configuration.

Item Name	Description	Remarks
Report ID	Used as an automation program ID	
Run	Option to select the report ID for graph generation	1=Select, 0=No
Old	Option to select the previous results for comparison	1=Select, 0=No
No. of cases	Number of cases to use in program ID	
Description	Description of the Report ID	

(3) "CC_INPUT" Sheet

The CC_INPUT sheet provided by the Excel file is a place to define the number of cases and input file names in order to run the CINEMA code. The contents of the items on the "CC_INPUT" sheet are shown in Table II. Fig 3 shows the excel screen for the CC_INPUT sheet

Table II: CC_INPUT Sheet Configuration.

Item Name	Description	Remarks
Report ID	Used as an automation program ID	
No. of INPUT	Number of inputs to use in program ID	
Case ID	Used as an case file name	
Input Filename	Input name used in automation program	
STR or RST	Option to select the run type	STR=start RST=restart
@	Execution order	
Input Filename(Origin)	Original input name of computer code	

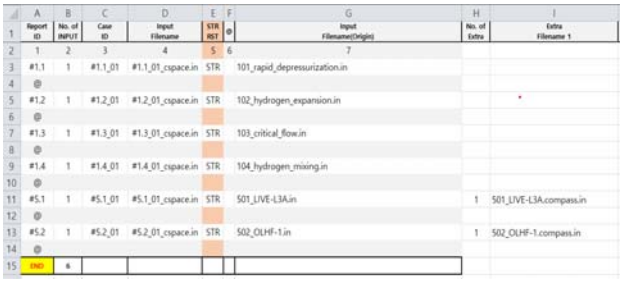

Fig. 3. Screen of CC_INPUT Sheet.

(4) "Cases" Sheet

The Cases sheet provided by the Excel file is a place to define the cases required for graph generation using the CINEMA automatic V&V system. The user must input basic item contents for graphing of results. The contents of the items in the Cases sheet are shown in Table III. Fig. 4 shows the excel screen for the Cases sheet.

Table III: Cases Sheet Configuration.

Item Name	Description	Remarks
Report ID	Used as an automation program ID	
No. of case ID	Number of cases to use in case ID	
No Time	User can select and change the row data	0=Use calculated value 1=xy change
Case ID	Used as an case file name * Same as Case ID used in CC_INPUT sheet	
Output File Name	Output file name in automation program	
No. KIND	Number of KIND	
KIND	File properties according to Case value	REF : Calculation EXP : Experiment
SKIP	Number of lines to skip in the data file to use only the actual data	
SKIP(OLD)	Number of lines to skip in the (OLD) data file to use only the actual data	
PLOT FROM	From *_XX.dat file number in PLOT-XX-YYY	SPACE only
PLOT TO	To *_XX.dat file number in PLOT-XX-YYY	SPACE only

Fig. 4. Screen of Cases Sheet.

(5) "FIGNOW" Sheet

The FIGNOW sheet provided by the Excel file is where the basic details of the graph are defined for drawing user-defined graphs for each case calculated using the CINEMA automatic V&V system. The user must input the basic item contents to draw the result graph, and the FIGNOW sheet should be prepared in parallel with the FIGDATANOW sheet. The item contents of the FIGNOW sheet are shown in Table IV. Fig. 5 shows the excel screen for the FIGNOW sheet.

Table IV: FIGNOW Sheet Configuration.

Item Name	Description	Remarks
Report ID	Used as an automation program ID	

No	The first line value is the total number of graphs in each Report ID, and the other values are the graph sequence number	
Fig ID	The first line value is the free name declared in each Report ID, and the other values are the graph name	
No. of Lines	Number of lines to use in the graph	
No Time	Graph x-axis value (0 if the graph x-axis is time, 1 if not time)	0=x-axis: Time 1=x-axis: Not time
y=x	y=x lines along the distribution 1 if needed, 0 if not needed	0=none 1=create
Title	Decide whether to use the graph title, and if used, use the title text	YES=use NO=not use
Title text	Graph title name	
Subtitle	Decide whether to use the graph subtitle, and if used, use the Subtitle text	YES=use NO=not use
Subtitle text	Graph subtitle name	
Location	Folder location where graph file saved	/COMP
Axis Scale Type	Definition of graph axes (using graph axes provided by GNUplot)	xy, logx, logy, logxy available
x Axis Label	Graph x-axis title text	
y Axis Label	Graph y-axis title text	
Font	Font of character to use in graph	
Font Size	Font size to use in graph	
xmin	Graph x-axis minimum value	Automaticall y calculated when the user inputs AUTO
xmax	Graph x-axis maximum value	
ymin	Graph y-axis minimum value	
ymax	Graph y-axis maximum value	

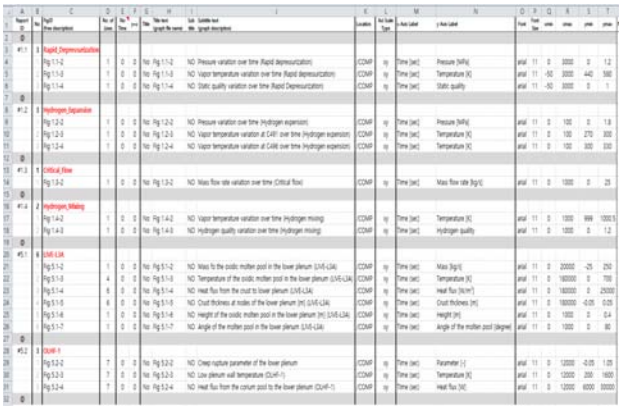

Fig. 5. Screen of FIGNOW Sheet.

(6) "FIGDATANOW" Sheet

The FIGDATANOW sheet provided by the Excel file is where the properties of each line of the graph created using the CINEMA automatic V&V system are defined. The basic details of the graph are defined in the FIGNOW sheet, but since the properties of each line of the graph are more complicated, a separate sheet is used to define it. The FIGNOW sheet must be completed in parallel with the FIGDATANOW sheet. The item contents in the FIGDATANOW sheet are shown in Table V. Fig 6 shows the excel screen for the FIGDATANOW sheet.

Table V: FIGDATANOW Sheet Configuration.

Item Name	Description	Remarks
Case ID	First line is the same as Report ID From the second line, enter the sequence number as many as the number of graphs declared in the No column of FIGNOW sheet	
Graph No	The first line value is the total number of lines in each Case ID, and the other values are the lines sequence number	
Plot ID	Graph name that is defined FIG ID in the FIGNOW sheet	
Line	Number of lines in each graph	
Legend Direction	Graph legend direction (Left/Center/Right)	
Legend Position	Graph Legend Position (Top/Center/Bottom)	
Legend Box	Box setting of Graph Legend	0=disabled 1=Use
OLD	Box setting of Old Graph Legend	0=disabled 1=Use
DataFile Ref	Name of data file to draw line of each graph	
Y Axis Modified	If condition 2 is selected as the condition for processing the y value of the calculation result for drawing a graph, a new y value is calculated using items m and b	0=Use calculated value 1=not supported 2=(y' =y*m+b)
Variable X	X-axis variable value of graph	
Variable Y1	Y-axis variable value of graph	
Legend Str (new)	Legend value by graph	
Style No	Graph line style number	See Fig. 7
Symbol	Graph symbol	See Fig. 8
Skip	Number of graph points to skip	
Line Style	Graph line style	Input : 1

Line Color	Graph line color	See Fig. 9
Line Width	Graph line thickness	
m	m value used in Y Axis Modified item	y' =y*m+b
b	b value used in Y Axis Modified item	y' =y*m+b

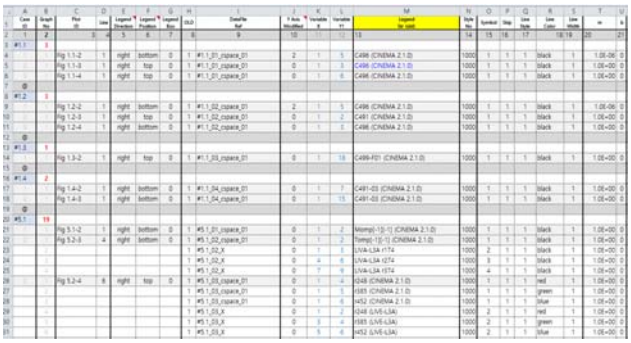

Fig. 6. Screen of FIGDATANOW Sheet.

1000	Line
2000	Point
3000	Line & Point

Fig. 7. Graph line style number

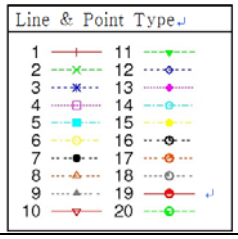

Fig.8. Graph line symbol number

Fig.9. Graph line color

2.2 Establishing an automated system for verification and validation of CINEMA in a GitLab project

To implement automation on the GitLab server, a gitlab-ci.yml file is required to define the tasks for each stage. The program that generates this file uses the C# programming language to generate the CINEMA.csproj file. The CINEMA.csproj file is structured as follows:

(1) DosBat.cs Class

The DosBat class has a MakeBatchDirectory method that creates static variables and directories to be used in the program, and MakeBatch_RUN that creates a batch file for execution. This class is mainly related to setting up directories and paths, and is used to set up the directory structure that the program needs. And batch files help to execute each case to be executed in the CINEMA-VV folder as a script. Since the program creates and manages batch files according to specific conditions, the user can easily adjust the execution for various cases.

(2) GitLab.cs Class

This class has a MakeGitDirectory method that creates static variables and directories that will be used in the program. It is mainly related to setting up directories and paths, and is used to set up the directory structure that the program needs. This is a task that copies the required code executable and the dependent files of the executable to the folder that needs to be run, and deletes existing files and changes the file names.

(3) Mods.cs Class

This class contains static variables, an Excel object, and several structures that will be used in the program. This class is used to store information related to the Excel file and sheets, and to define structures for effectively managing the data required by the program.

(4) Program.cs Class

This class defines the execution flow of the program and contains the Main method of the Program class, which represents the entry point of the program. When the program starts, the Main method is called, and the methods of each class are executed in order.

(5) WorksheetData.cs Class

This class reads data from an Excel file and extracts the data into an appropriate structure. It reads data such as 'PATH', 'REPORT', and 'CC_INPUT' sheets from an Excel file and stores them in an appropriate data structure.

After completing the Excel file for the CINEMA automatic V&V system, run the CINEMA.csproj file to generate the gitlab-ci.yml file, which is the GitLab CI/CD configuration file to be used in GitLab server. This GitLab CI/CD configuration file automates the process of building and running the CINEMA project using GitLab Runner and generating the V&V report. The automation process configuration is as follows: [2, 3]

(i) build_cinema
(ii) run_for_cinema
(iii) merge_run
(iv) build_docs

2.3 Execution of DOS Batch Operations for GitLab CI/CD

The migration of legacy DOS batch operations to GitLab CI/CD represents a significant step towards modernizing the computational workflow and improving efficiency in scientific computing environments. In this section, we verified that the calculation process was running smoothly on its own before automating the calculation workflow with a DOS batch script as a GitLab CI/CD job. Fig. 10 shows the DOS batch script for CINEMA V&V, and Fig. 11 shows that the DOS batch script alone performs the calculation process well.

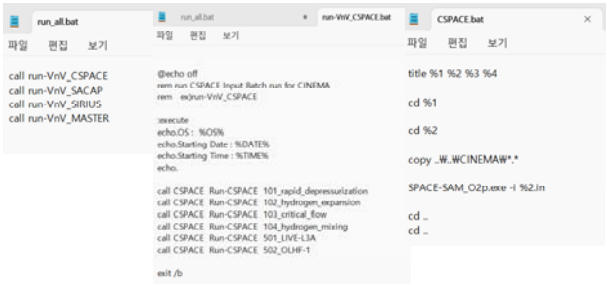

Fig.10. Dos Batch Job for CINEMA V&V

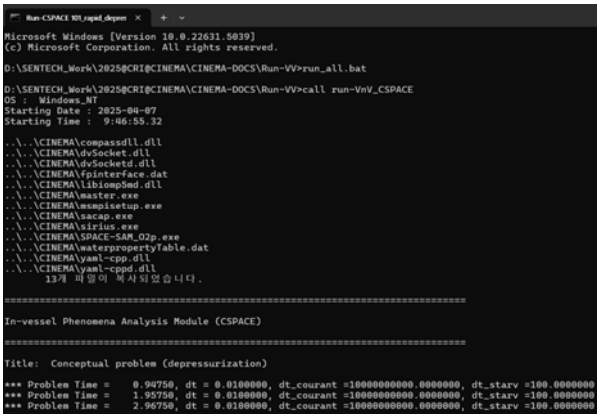

Fig.11. Screen of Dos Batch Job Running for CINEMA V&V

3. Conclusions

The CINEMA, a domestically unique comprehensive analysis program for severe accidents, urgently needed to build an automated V&V system environment to improve the traceability of history management and the reliability of V&V results for commercialization of codes such as application of innovative SMR serious accident analysis. Overall, GitLab's comprehensive features, flexibility, and strong community support make it a powerful tool for modern DevOps practices. Thus, we will use powerful tools to build an environment for verification calculations based on severe accident scenarios and to ensure that the quality assurance process for verification calculations can be performed efficiently, thereby increasing the safety and reliability of the comprehensive severe accident code.

REFERENCES

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