BIM and IPA – Excerpt of an automated assessment system for an autodidactic teaching concept

Christian Heins[1] **and Gregor Grunwald**[2]

[1,2]Jade University of Applied Sciences, Department of Architecture, Germany

christian.heins@jade-hs.de, gregor.grunwald@jade-hs.de

Abstract -

This article introduces an innovative approach to assessing and enhancing Building Information Modeling (BIM) skills using Digital Process Automation (DPA) and Robotic Process Automation (RPA) based on [1] [2]. Aimed at university BIM courses, the study addresses the challenge of evaluating students' modelling proficiency. The autodidactic teaching concept utilizes a Bizagi-based work portal, offering modules categorized by BIM roles. Learners engage in application-specific tasks, assessed through automated evaluations facilitated by RPA bots. The integrated system successfully combines DPA and RPA components, highlighting challenges and prospects for an error-free portal.

Keywords -

Building Information Modeling (BIM); Intelligent Process Automation (IPA); Digital Process Automation (DPA); Robotic Process Automation (RPA); Information Management System (IMS); Work portal; fully automated BIM-based model checking (BMC); Education and training

1 Introduction

Robotic Process Automation (RPA) technology can automate manual, repetitive and error-prone Computer Aided Engineering (CAE) applications [1]. Particularly in university courses in the field of "Building Information Modeling" (BIM), lecturers are increasingly faced with the challenge of assessing students' modelling skills. For grading purposes, lecturers need to assess not only the geometric representation and causal relationships between the component objects but also whether the associated component information (so-called free characteristics, known as property sets) has been correctly added to the 3D model by the students in response to the client's information requirements. In the BIM Games [3] [4], a new teaching and training format developed and implemented by Jade University of Applied Sciences (Jade-HS), the building model check was previously carried out manually by downloading the Industry Foundation Classes (IFC) models [5] from the work portal, checking them in a model checking application and uploading the results back to the work portal. Due to the limited duration of the BIM games developed by the Jade-HS (usually three days [4]), checking the building models represented the greatest effort for the teachers. To reduce this effort, RPA technology is used to activate software robots from the central work portal, that fully automatically verify digital building models, provide initial plausibility statements and check the model skills of the participants. In addition to presenting a work portal based on an information management system used as a Digital Process Automation (DPA), this article presents RPA technology, and it is porting to the work portal to present a fully automated assessment system based on a new autodidactic teaching concept that checks modelling skills using RPA bots and presents and document the learning progress in the work portal in real-time.

2 Autodidactic teaching concept

The learning concept is accessible via a work portal and is shown in principle in Figure 1. The module content is divided into different roles (see Figure 1 (a)). Each module consists of application-related tasks. For each task, a unique example solution has been developed, which is superimposed on the end-user for checking the results. When it comes to acquiring modelling skills, e.g., to obtain a certificate as a BIM author, the end-user logs in to the work portal using any browser on a terminal device (see Figure 1 (b)). After logging in, the user accesses his personalized area, where he has access to his completed, activated and running modules, his login credentials, and the module overview. If the user wants to edit an already running or a new module, he clicks on the corresponding module and is forwarded to the user interface, another front end of the work portal (see Figure 3).

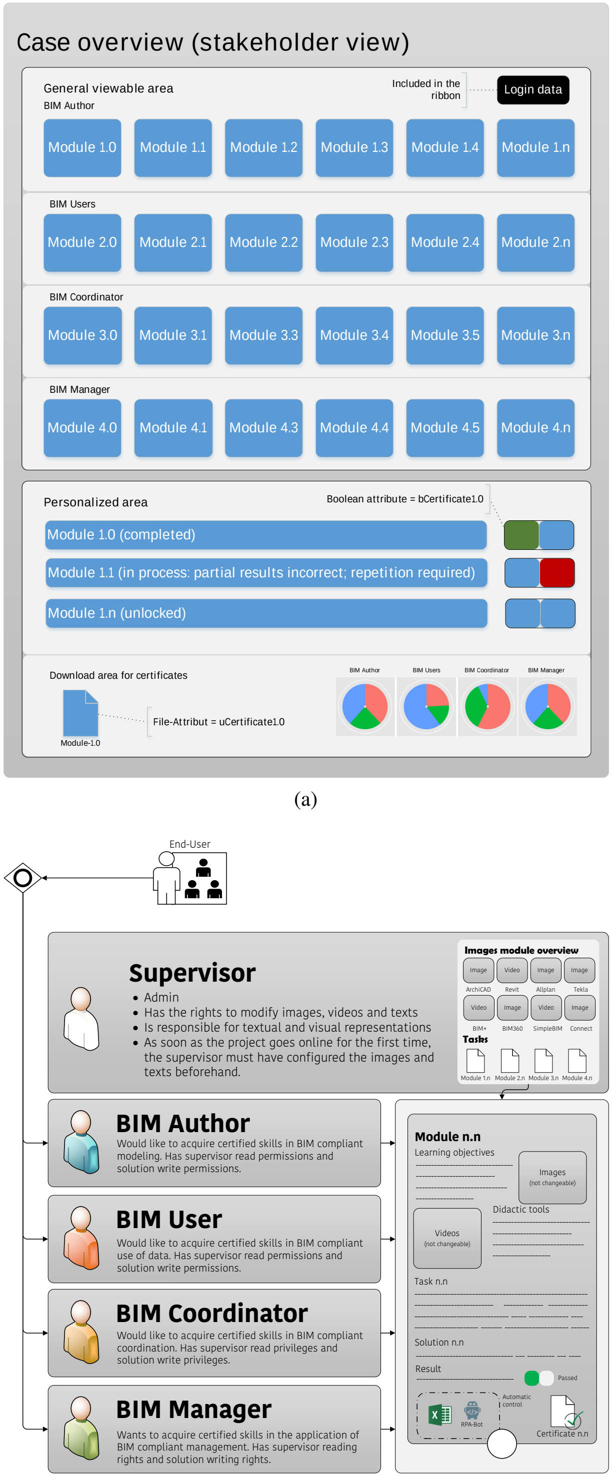
The interaction between man and systems takes place in the user interface. Here, the end-user is provided with the corresponding learning objectives, tasks, and didactic aids as well as input fields for his solutions and value fields for reading the respective result check (cf. Figure 1 (b) bottom right). The solutions uploaded to the work portal are checked as soon as the end-user clicks the "Check Solution" button. The check is fully automated by the system, either by a tabular check using Microsoft Excel or by a check of a third-party CAE application performed by an RPA bot. The principle of the autodidactic learning concept thus offers the end-user the possibility to apply the most common CAE applications and their interoperable workflows in a standards-compliant manner based on the interest-specific selected BIM roles (BIM Author, BIM User, BIM Coordinator, BIM Manager) selected according to their interests. Here is an example from the first task of a BIM author in module 1.1 "Revit", which an end-user would have to process:

Scenario for Module 1.1 "Revit" – Task 1.1 [2]: *"Model the foundation of the single-family house shown in Figure 5, using the general plan in Figure 6 and the project origin specified. Note the orientation of the project. You must model exactly within the predefined reference plan and use the correct materials. Once you have modelled the foundation, export the foundation as an IFC file (using the didactic tools) and upload the IFC file in the work portal under the appropriate input field (see Figure 8 (a)). Once your IFC file has been uploaded, click on the button "Check solution" to automatically check your result. If your result is correct, you will be notified that you have passed the task and the "Next" button will be enabled to proceed to the next task. If your result is incorrect, please read the result log carefully and adjust your model. Then repeat the above procedure until you have fully completed the task."*

If the first task is solved correctly, the following task "Modeling the first floor" is unlocked. The tasks in this module are repeated until the single-family house has completely been modelled according to the standard. In module 1.2 "Allplan" the CAD program is changed, and the task is repeated. In total, the user must select three CAD programs to fully understand the differences between the most common CAD programs. Provided that the user has completed three modules, the person will receive a BIM Author certificate. For the acquisition of modelling skills, various CAD programs are provided (e.g. Revit, ArchiCAD, Allplan, Tekla, Vektorworks) to independently acquire BIM-compliant modelling skills using didactic tools for topics such as modelling guidelines, input, and organization of property sets, IFC export settings, text files for IFC mapping etc.

3 DPA-based work portal

For the teaching concept, the work portal of Bizagi, a process-oriented information management system (IMS) is used. For this purpose, Bizagi offers a low-code portal which can be adapted to the needs of an autodidactic teaching concept based on process and data models, business rules, read and write permissions, software distribution and an open integration layer [6, p. 779 ff.].



(a)

(b)

Figure 1. Principle of the autodidactic teaching concept: (a) Module concept; (b) Roles and rights of the work portal

As shown in Figure 2, the Bizagi suite consists of the Modeler, Studio and "Automation to Map" process flows (Modeller) to develop process instances (Studio) and to make the portal executable and persistent for end-users via a browser (Automation) [6, p. 36 ff.]. For the work portal presented here, Bizagi is used to provide the task packages, request the solutions, activate the RPA bots and display the achieved RPA results back to the end-user as well as to document the learning success through integrated reports. In terms of technical requirements, Bizagi requires a database and an application server to host the web server instance. Bizagi offers two ways to develop the integrated runtime environment (a predefined work portal) as a learning portal: Editing as a single user, for which a quick start setup is provided, and editing in multi-user mode, where further development as teamwork is supported [6, p. 324 ff.]. It should be noted that the Bizagi work portal is also accessible via various mobile devices running iOS (e.g. iPad, iPhone) or Android. The different user interfaces, shown as an example in Figure 3, present the end-user with the modules as cases in an overall overview (Figure 3 (a)) or the user interface in which the interactions described in Chapter 2 take place. Learning progress is displayed in the Reports ribbon (see Figure 3 (a) and (b) above).

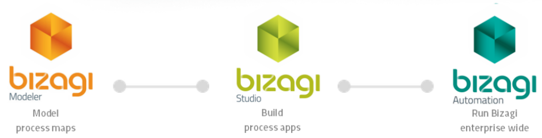


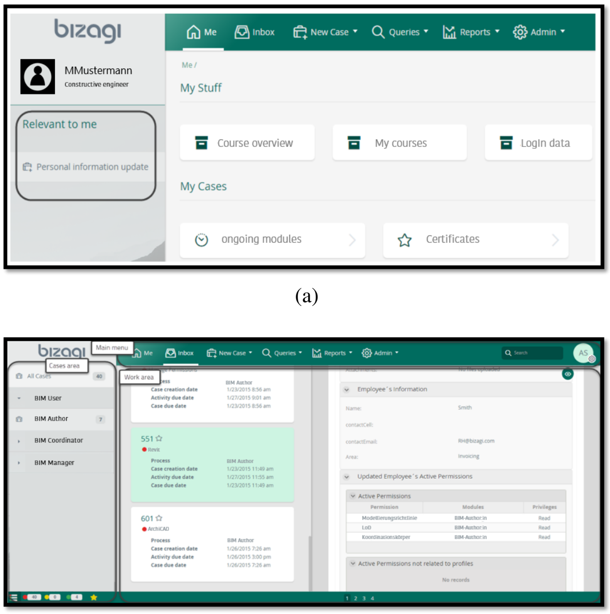
Figure 2. Building blocks of the Bizagi Suite

3.1 Processes

The processes stored in the work portal are shown in Figure 4 (a) – (extracts for modules 1.1 to 1.3 only). Once the end-user has logged into the work portal and clicks on module 1.1 in the general overview, he is taken to an information page of the user interface. There he can inform himself about the selected module and decide whether he wants to edit the module or to look at another module. If the user does not wish to edit the module or view another module, the user interface is closed, and the user returns to the general overview. If the user wishes to edit Module 1.1 for example, he will be taken to the tasks to be completed, as shown in Figure 4 (b). Module 1.1 is completed as soon as the end-user has completed all tasks.

3.2 Data models

To match the solutions to the requirements of the different tasks, unique attributes must be stored in the process



(a)

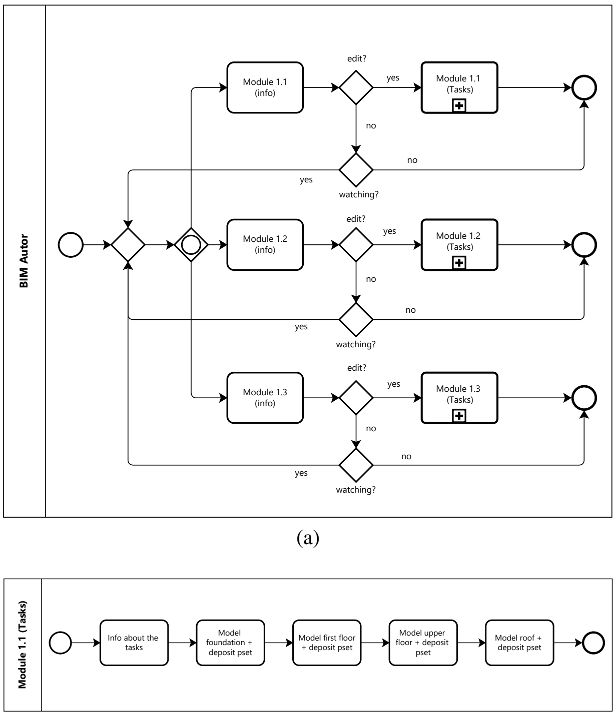
(b)

Figure 3. Frontend of the work portal: (a) Stakeholder view; (b) User interface

instances of the user interface. The attributes are listed in different entities to store the information in data models and to structure the information flow. A master process entity combines all the individually extendable entities. This ensures, among other things, that the RPA bots integrated into the work portal deliver their results in the right place and the right order. For example, if the end-user has finished modelling the foundation in Module 1.1, he will upload the corresponding IFC model in the work portal by inserting the IFC model into the "Solution 1.1" input field (see Figure 8 (a)). This field stores the file attribute <uSolution11> belonging to the master entity <M11_Revit_ModelFoundation>. The RPA bot receives this information to execute the activities and to provide the results to the end-user again in the value field "Result 1.1" with the file attribute <uResult11>. Following this principle, the attributes of the work portal are migrated with the attributes of the RPA bots [6, p. 3216 ff.].

4 Automated evaluation system

The evaluation system integrated into the work portal consists of the third-party systems Microsoft Excel [7] and an RPA bot from the company UiPath [8]. Both systems are embedded in the integration layer of Bizagi (cf. [6, p. 2893 ff.], [6, p. 3216 ff.]), so that an automated evaluation can take place at either tabular, based on alphanumeric values (e.g. for the comparison of GUIDs to check the one-time submission), or by any external third-party sys-



(a)

(b)

Figure 4. Excerpt from the technical process model of the work portal: (a) process model for modules 1.1 to 1.3; (b) sub-process 1.1

tems. In the course of the autodidactic learning concept, the evaluation of content-related knowledge is done in tabular, whereas the evaluation of modelling skills is done by the RPA bot with the help of a model checker of the company Solibri [9]. For example, to check the modelling capabilities of an end-user fully automatically, the RPA bot takes the uploaded IFC file of the end-user, opens a Solibri project – in which the corresponding IFC example model already exists – and compares the two IFC models. The RPA bot then saves the corresponding Solibri result message and transfers the file to the work portal. The end-user can then view the results in the work portal and, if necessary, improve his IFC model until the task has been fully solved.

4.1 BIM-based model checking (BMC)

Before RPA automation could be implemented, it was first necessary to determine which rules should be used as the basis for comparing the end-user's IFC model with the IFC example model. It was also necessary to determine the behaviour of Solibri's BMC system in the presence of error-free and minor and major errors. For this purpose, different IFC models with different errors were generated and compared with the IFC example model. The following cases were considered:

Case-1: IFC test model too small
Case-2: IFC test model too large (cf. Figure 7)
Case-3: IFC test model on the coordinate origin 0.0.0
Case-4: IFC test model rotated by 1 degree

For testing purposes, an automated test process was carried out for the foundation of a single-family house (cf. Figure 5). The test process is therefore initially focused only on the geometric and alphanumeric modelling of the foundation. Solibri's BMC software is used as a test tool for the scenario described in Chapter 2.

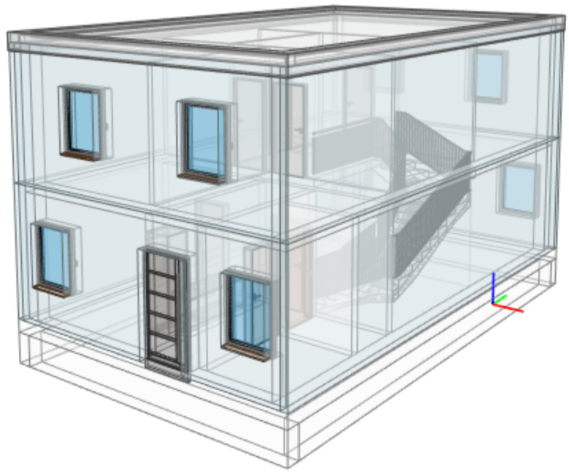


Figure 5. Example project for acquiring modelling skills in the role of a BIM author [2]

In the case of Module 1.1, the strip footings in Revit must be modelled as beams or walls, as shown in Figure 6, because Revit does not provide objects for strip footings without a direct connection to the wall above. For example, since civil engineers focus primarily on shell construction, and it is common to model wall openings as individual walls connected by a lintel rather than walls with door openings, a beam object should be used instead of a strip footing object. This information is important for the IFC export as the strip footing to be exported will not be exported as `IfcFooting` as intended, but as `IfcBeam` (if no adjustments are made), which could cause other third-party systems to misinterpret e.g. the fabrication costs or the load-bearing function.

In addition to the geometric checks, the alphanumeric information to be added to the component objects must be checked. Table 1 shows the required alphanumeric information.

The results of the manual tests show that with modified rules the modelling skills of the end-user can be checked in an automated way, provided that the following requirements are met:

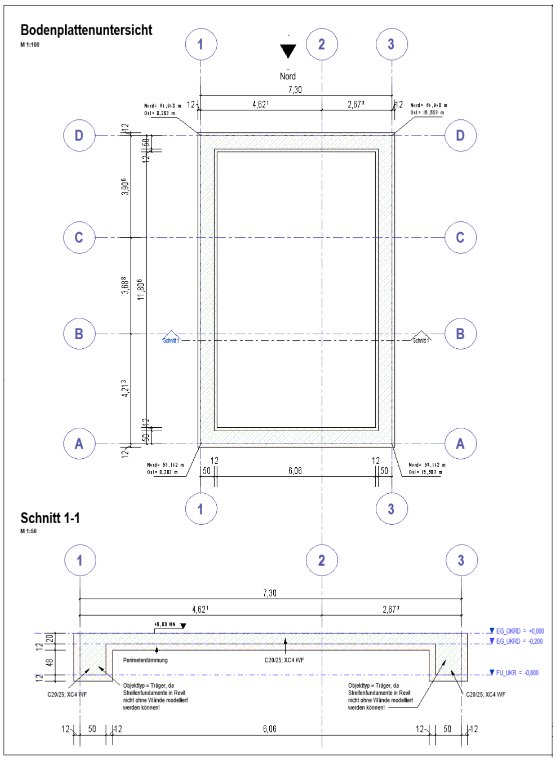


Figure 6. Reference plan for post-modelling of the foundation [2]

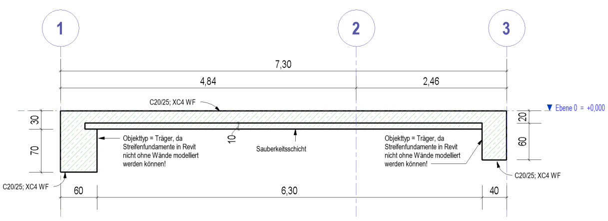


Figure 7. Example for the self-test error in Case-2

- During the automated verification, the BMC software Solibri must always remain open with the predefined classification.
- The IFC example model is never removed as an architectural model
- The IFC model of the end-user is added to Solibri as a static model (short name "B")
- The static model is removed after each check and added again before each check, as described above.

4.2 RPA-BIM-based model checking (RBMC)

For automated model checking, an attended bot from the company UiPath is used for testing purposes [10]. This robot (RPA bot) mimics human software activity on

Table 1. Required property set

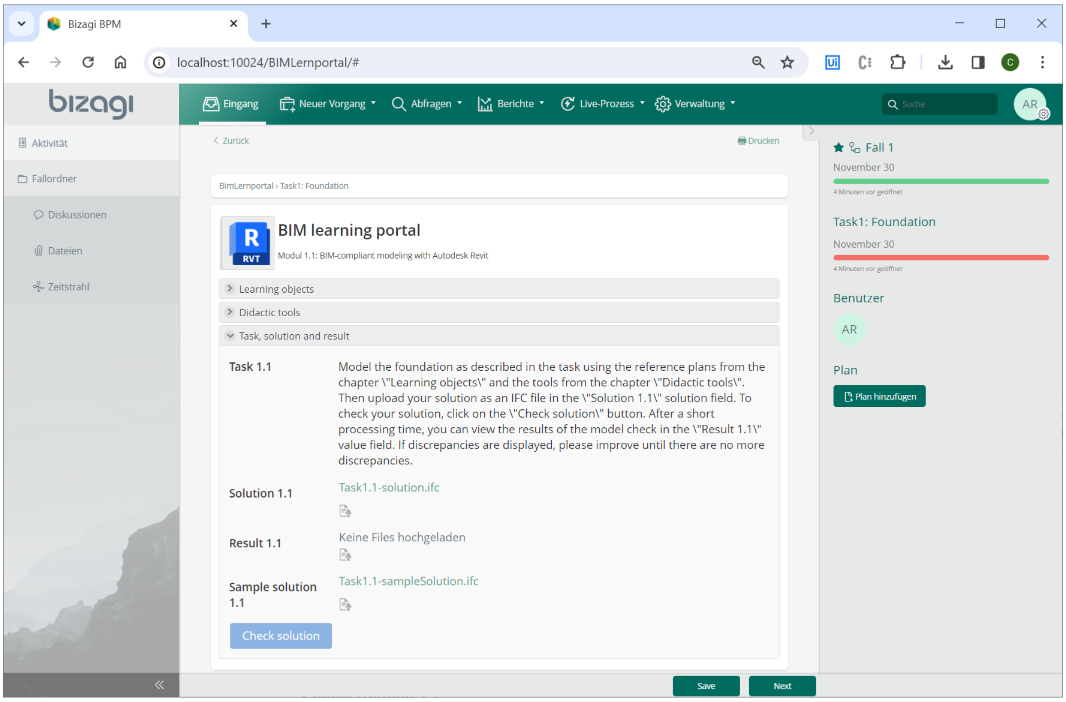
Name	Material	IFC entity	PSet
Base plate	C20/25	IfcSlab	Loadbearing = yes
Foundation	C20/25	IfcFooting	Loadbearing = yes
Insulation	EPS	IfcCovering	Loadbearing = only under foundation

the screen by reconstructing the corresponding actions in a sequence. Once programmed, the RPA bot can be activated at any time by pressing the "Check solution" button via the work portal, as shown in Figure 8 (a). For automated model checking, the sequence flow of the RPA bot is shown in excerpt form in Figure 10.

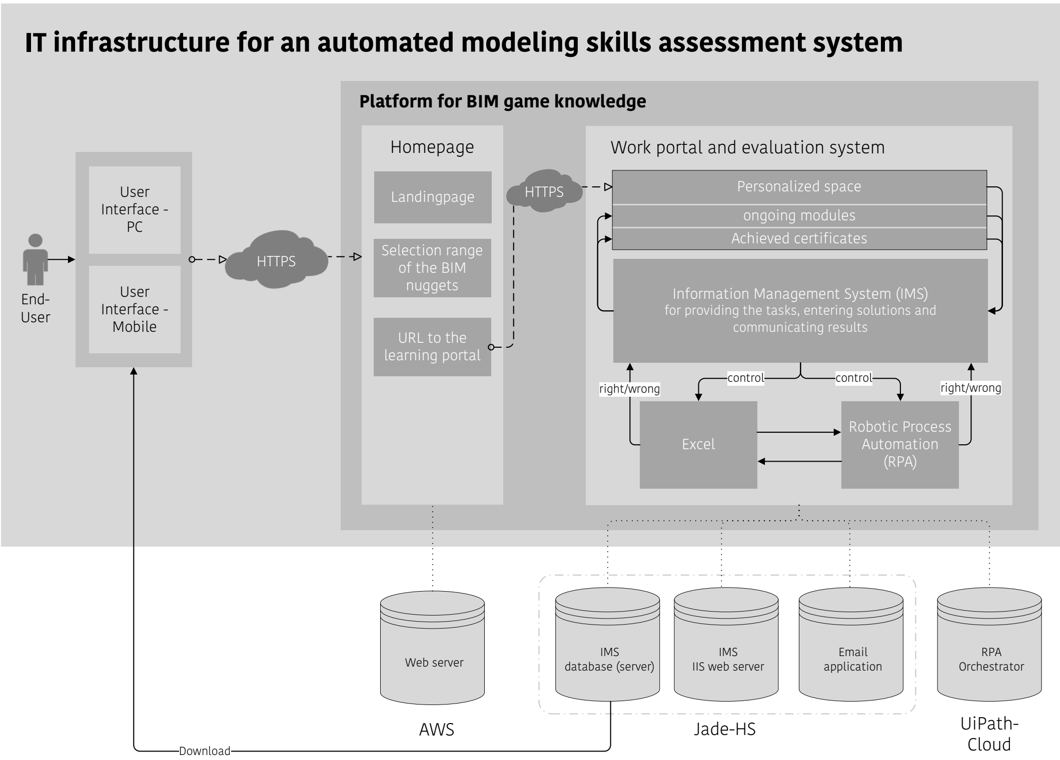
Performing an automated check with Solibri is relatively simple compared to report output, provided the above requirements are met. With a detailed report output, the RPA bot would now have to recognize the anomalies identified by Solibri, expand the corresponding categories, select the corresponding categories, select the corresponding messages, recognize the number of error messages in the results and create a presentation slide with predefined content for each error message. This type of reporting would be relatively complex for the RPA bot to program and would result in high throughput times for the RPA bot. Therefore, the initial focus is on the internal reporting of the underlying rules. To do this, the independent rules are combined into a rule set to create a summary report using RPA click applications (see Figure 9).

5 IT-Infrastructure

Bizagi's DPA can be hosted locally in an older version, see Figure 8 (b). Among other things, Bizagi offers a personalized space and can be accessed via an API or a web service on external websites or portals. However, it can be assumed that the field of view of the embedded user interface remains limited by the design of the home page during execution, so immersion in the learning process is distracted by other information that may interfere with the field of view. Furthermore, when embedding Bizagi into a third-party system, it is necessary to run Bizagi as a web service or an application integrated into the homepage. For this integration, it is necessary to coordinate the data models and clearly define the corresponding instructions on the homepage via program code. Figure 8 (b) shows the chosen IT infrastructure in which the learning portal is executed separately from the home page [11]. The learning portal is accessed via a link on the homepage. As soon as the end-users want to complete a certified course, a new, independent program is opened. There is therefore no need to transfer data between the home page and the IMS.

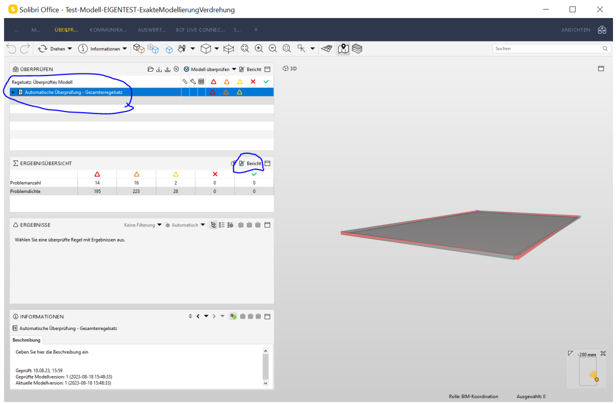


(a)

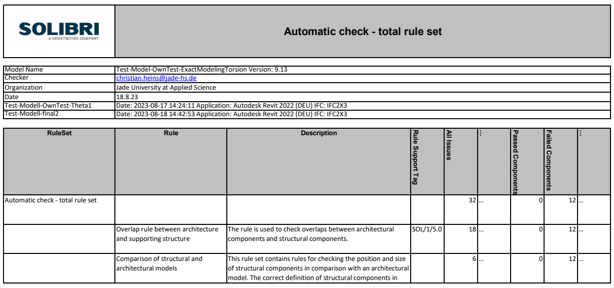


(b)

Figure 8. Digital Process Automation for an automated modelling skills assessment system: (a) User interface of the work portal (here is an excerpt for module 1.1) [2]; (b) IT infrastructure with linking via a landing page



(a)



SOLIBRI	Automatic check - total rule set

Model Name	Test-Model-OwnTest-ExactModelingTorsion Version: 9.13
Checker	christian.heins@jade-hs.de
Organization	Jade University at Applied Science
Date	18.8.23
Test-Modell-OwnTest-Theta1	Date: 2023-08-17 14:24:11 Application: Autodesk Revit 2022 (DEU) IFC: IFC2X3
Test-Modell-final2	Date: 2023-08-18 14:42:53 Application: Autodesk Revit 2022 (DEU) IFC: IFC2X3

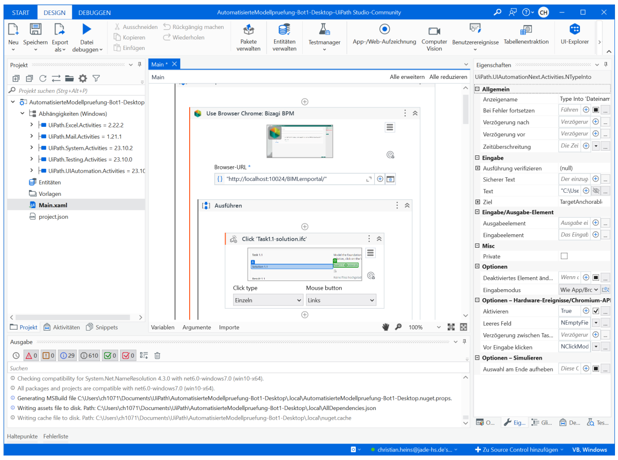
RuleSet	Rule	Description	Rule Support Tag	All Issues	⋮	Passed Components	Failed Components	⋮
Automatic check - total rule set				32	...	0	12	...
	Overlap rule between architecture and supporting structure	The rule is used to check overlaps between architectural components and structural components.	SOL/1/5.0	18	...	0	12	...
	Comparison of structural and architectural models	This rule set contains rules for checking the position and size of structural components in comparison with an architectural model. The correct definition of structural components in		6	...	0	12	...

(b)

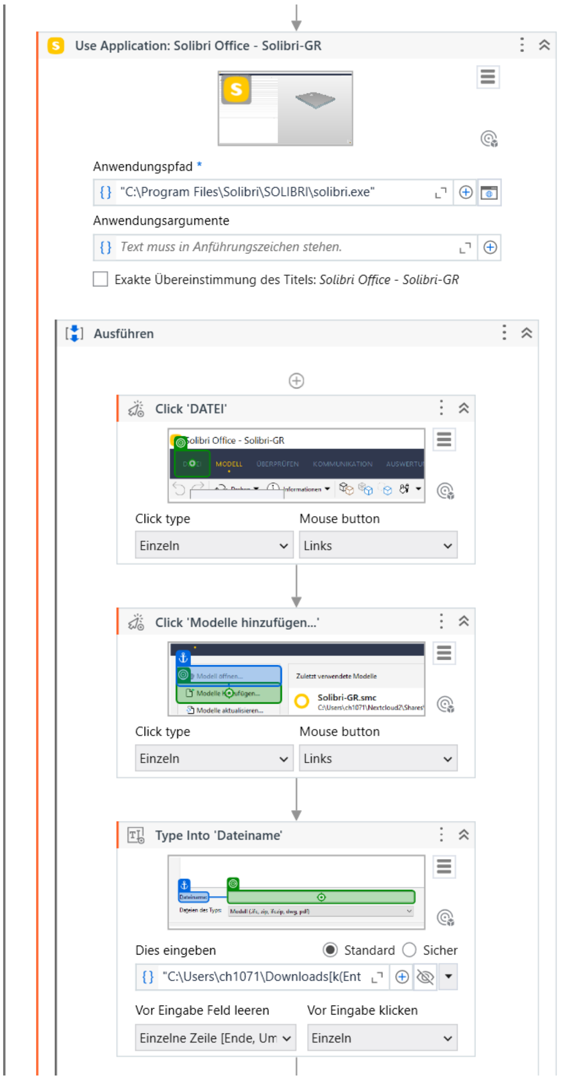
Figure 9. Results report of the automated model check with Solibri: (a) Solibri report button; (b) Results as Excel file

6 Results

The results show that Intelligent Process Automation (IPA) with its individually composable components can provide an automated evaluation system for the assessment of modeling skills. In this work, the DPA and RPA components have been migrated together to provide end-users with tasks via a DPA-based work portal, to demand solutions at a specified time and to display the learning progress already achieved to the end-users in real-time. Furthermore, the DPA was migrated with RPA technology to provide fully automated model checks in addition to the classic Excel evaluations. Especially concerning an always-on portal that enables end-users to have a customized learning experience regardless of time zones and individual scheduling, RPA technology is necessary to evaluate the submitted digital building models at any time. However, it turns out that the RPA bots can only provide their services without any problems if they use a recurring screen layout. If the UI elements [12] (elements of the graphical user interface) change, for example, due to a smaller scaled toolbar, the RPA bot cannot find the UI element to be accessed and the routine of the RPA bot leads to a system abort.



(a)



(b)

Figure 10. Excerpt of the RPA bot automation as a sequence flow: (a) UiPath Studio [2]; (b) Section of the sequence flow

In addition, Solibri issues system-related discrepancies that do not clearly define whether a non-conformity exists. For this error message, the end-user must decide whether the reported comment represents a modelling error. To exclude this room for interpretation, it is necessary to further simplify and concretize the tasks and their example models. For example, an insulation envelope in the foundation should be omitted, as there are different ways of modelling the insulation (e.g. in the case of intersections of abutting components).

The preferred solution is unattended RPA bots that are called up via an orchestrator, instantiated on a local server and triggered via a work portal. This would have the advantage that the software to be automated and installed locally always uses the same screen layout. Furthermore, the tasks and example models are iteratively adapted until the results output by Solibri no longer leaves any room for interpretation. As soon as this process, consisting of DPA and RPA, has been tested several times without errors, the DPA-based work portal is to be expanded to include additional components such as artificial intelligence or machine learning to intelligently check the plausibility of the results achieved based on independent decisions in line with IPA.

Acknowledgement

The results of this work are based on the results of a cooperative doctorate between the University of Wuppertal and the Jade University of Applied Sciences [1] as well as the third-party project "AUFLADEN" funded by Stiftung Innovation in der Hochschullehre [13].

Stiftung
Innovation in der
Hochschullehre

References

[1] C. Heins. Entwicklung eines Statikportals für die partizipative Bearbeitung von Tragwerksberechnungen im Prozess des Vieraugenprinzips (Planen – Prüfen). In *Dissertation*, University of Wuppertal, Germany, Submitted: 21/06/2023; Disputation: 11/12/2023.

[2] C. Heins, T. Luhmann (ed.), and T. Sieberth (ed.). Intelligente Prozessautomatisierung im Weiterbildungs- und Bauplanungsprozess. In *Photogrammetrie-Laserscanning-Optische 3D-Messtechnik – Beiträge der 21. Oldenburger 3D-Tage*, Wichmann Verlag, Berlin/Offenbach, 2024.

[3] C. Pütz, C. Heins, M. Helmus, and A. Meins-Becker. Gamification and BIM: Teaching the BIM method through a gamified, collaborative approach. *ISARC. 37th International Symposium on Automation and Robotics in Construction*, 37:272–277, 2020. doi:10.22260/ISARC2020/0039.

[4] C. Heins, G. Grunwald, and M. Helmus. Gamification and BIM - The didactic guidance of decentralised interactions of a real-life BIM business game for higher education. *ISARC. 38th International Symposium on Automation and Robotics in Construction*, 38:932–939, 2021. doi:10.22260/ISARC2021/0126.

[5] ISO 16739-1:2018. Industry Foundation Classes (IFC) for data sharing in the construction and facility management industries. On-line: `https://www.iso.org/standard/51622.html`, Accessed: 04/12/2023.

[6] Bizagi. Bizagi Digital Business Platform. User Guide. On-line: `https://download.bizagi.com/docs/suite/1124/en/SuiteHelpEng.pdf`, Accessed: 04/12/2023.

[7] Microsoft Corporation. Microsoft Excel. On-line: `https://www.microsoft.com/de-de/microsoft-365/excel`, Accessed: 04/12/2023.

[8] UiPath. UiPath Business Automation Platform. On-line: `https://www.uipath.com/de`, Accessed: 04/12/2023.

[9] NEMETSCHEK SE. Solibri. On-line: `https://www.solibri.com/`, Accessed: 04/12/2023.

[10] UiPath. Robot user manual. On-line: `https://docs.uipath.com/de/robot/standalone/2023.4/user-guide/attended-vs-unattended-robots`, Accessed: 04/12/2023.

[11] AUFLADEN. Website. On-line: `https://www.wissen-aufladen.de/`, Accessed: 04/12/2023.

[12] UiPath. About UI Elements. On-line: `https://docs.uipath.com/de/studio/standalone/2023.4/user-guide/about-ui-elements`, Accessed: 04/12/2023.

[13] Stiftung Innovation in der Hochschullehre. Aus- und Fortbildungslabor für digitales Entwerfen und Bauen. On-line: `https://stiftung-hochschullehre.de/projekt/AUFLADEN/`, Accessed: 04/12/2023.