Automatic Inspection of E-Portfolios for Improving Formative and Summative Assessment

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Abstract: The concept of e-portfolio is finding a ever-growing uptake in secondary and post-secondary education as a tool to measure holistically the effects of learning. Learners document their development process in form of a collection of documents. In this research, we propose an automated method to support teachers in their assessment of e-portfolios by evaluating e-portfolios using automated analysis tools, which operate descriptively and semantically. A first formative evaluation of the system has been performed, to assess how much the quality portfolios are detected by descriptive indicators, which have proven to be already partially expressive. Delivered insights on e-portfolios were considered valuable by lecturers.

Keywords: E-portfolios, formative assessment, summative assessment, learning analytics, teaching analytics.

Introduction

E-Portfolios as a modern method to support self-regulated learning and competence-oriented learning find increased recognition and application, especially in higher education. They allow for individual learning paths and provide learners with increased freedom, the possibility to follow own learning objectives, to emphasize self-chosen topics of a learning domain, to present the results of individually performed activities and projects in the context of modules or single classes in learning activities, and to reflect on their learning processes. Compared to paper-based portfolios, they provide students with means to document their experiences and achievements within the world and with the means of their preferred media domain, contributing to the development of desired media competences at the same time.

E-portfolios may be applied as a basis for summative assessment in examinations, introducing a new flexibility compared to classical oral or written examinations by allowing for individual learning paths and focusing on competences.

A holistic assessment and evaluation of portfolios requires teachers to get an in-depth impression of student portfolios. Important aspects are the comprehensiveness with respect to the covered subjects of the learning domain, a distinct and reflective treatment of individual topics, but also formal aspects such as a sufficiently clear structure of the portfolio, an appropriate connection to and reference of existing work

as well as corresponding citations as an approach to prevent plagiarism. Such an in-depth analysis of student portfolios requires substantial effort and resources from a teacher, and, as a consequence, is difficult to achieve in practice.

In this paper we describe an experiment and its results to support teachers in the evaluation of e-portfolios by the means of analytical methods, partially based on semantic technologies. This experiment is based on specific procedures applied in the study program on Media Education and Management at the Univ. of Education Weingarten. However, we think that results may be generalized to other domains and other types of applications of assessments based on e-portfolios. We explore in how far typical criteria for the assessment of e-portfolios may be assessed automatically by means of appropriate analytical methods, and in how far corresponding results may provide support to teachers in their assessment. In specific, we analyze which types of analytics are applicable and may provide valuable results, considering both, statistical approaches and approaches based on semantic text analysis.

As a contribution of this paper we present an innovative approach for the support of teachers in the assessment of students' learning portfolios based on analytical methods, which is based on a toolset to access and analyze student portfolios, a set of analytical methods, and a dashboard utilizing various form of visualization to provide an overview on the set of portfolios under assessment, a specific view on the various aspects of an individual portfolio, as well as means to analyze such individual portfolios in detail, thus allowing teachers to provide valuable feedback more efficiently in reduced time and to get an objective and criteria-driven overview on portfolios supporting a better summative assessment. We describe a concept and corresponding technologies developed to implement this approach, as well as the results of a first evaluation of a practical application.

State-of-the-Art

Portfolios can be considered both, an instrument for documentation and assessment of learners' efforts, progress and achievement, as well as a concrete artifact in terms of a collection of representative individual work and products, which may provide evidence on a learner's skills and competences [9]. E-portfolios represent the electronic equivalent to these, often implemented in terms of individual learner's weblogs or Wiki pages. E-portfolio systems such as Mahara (mahara.org) und Elgg (elgg.org) extend corresponding functionalities with social media functionalities, allowing for feedback from tutors and peers, and fostering collaboration.

E-portfolios are attributed with a number of potentials and benefits, such as fostering the development of learner skills and competences, especially in the areas of media literacy, problem solving, and communication; enhanced documentation of learning; more possibilities for individual feedback; motivation to reflect on individual learning processes; support self-directed learning with the possibility to focus on topics on an individual basis. Their application as a basis for (summative) assessment is often motivated with an intended shift to more competency-based education and training. Here, the typical approach is an assessment center or face-to-face consultation, where it is being used as a basis for discussion and reflection of learning processes. However, cyclic approaches are recommended, with formative assessments preceding

the final summative evaluation, involving the suggestion of improvements and changes, and fostering reflection ([3]). However, especially in case of large-scale assessments with large numbers of students the requirement for several assessment cycles can often not be met, and, in practice, teachers may provide only limited formative feedback to individual portfolios.

Portfolio development may be supported with rubrics, which may clearly state the specific requirements for portfolios for learners, make the criteria for assessment transparent in advance, and provide teachers with guidelines for their assessment. While the provision of such rubrics may provide a means to standardization especially in such cases when several tutors and teachers are involved in the assessment, the inspection of portfolios according to rubric's criteria will still prove time-consuming and cumbersome. Clearly, approaches and tools are required to support teachers in the inspection of e-portfolios.

The here presented approach can be related to the fields of Learning Analytics (LA) and Teaching Analytics (TA) in specific. LA denotes the "... measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimizing learning and the environments in which it occurs" [11. Teaching analytics (TA) can be considered a sub-field of LA, focusing on "… teachers' professional practices with visual analytics methods and tools ... " aiming at „... innovative solutions to assist and augment teachers' dynamic diagnostic decision-making in the classrooms of the 21st century" [12]. In general, most approaches in both fields are based on data collected within learning management systems (LMS). While such LMS access data is typically too coarse-grained, and it seems difficult to rely instructional decisions on such data, learning objects delivering fine-grained information on learning processes are largely lacking.

In the context of e-portfolios, examples for the introduction of methods from LA and TA are rare. Aguiar et al. [1] apply analytical methods to learner history and specific data on the usage of an e-portfolio system (e.g., number of logins, number of articles added to the portfolio, number of hits of these articles for searches of other students) to assess engagement and predict performance. Aspects of portfolio contents are not being considered, though.

Approaches on text processing and semantic analysis in the context of e-portfolios are also rare. CONSPECT presents an approach to analyze the network based on LSA generating concept maps automatically from RSS feeds, blogs or portfolios [15]. An overview on approaches for text analysis in the context of learning analytics is presented in [16].

Computer based tests, especially in terms of "Short-answer free-text", have been the object of several research initiatives, such as [9]. Here, the objective is however on the automatic assessment of features, and the general approach cannot necessarily be considered as broad as LA.

A broad spectrum of text-processing tools exists to analyze e-portfolios, being (rich- and interactive-) text documents. However, we have been able to observe very few applications of these tools to e-portfolios environments. In this section we describe several applicable text-analysis strategies.

The first family of processing tools are the descriptive statistical tools. Typical measures such as the lexical density the text-length (words, characters), the number of links or the count of pictures all are analysis dimensions that allow the comparison of

e-portfolios. Further, configured analysis dimensions can be introduced: Measures such as the thematic fields (as measured in the frequency of chosen words in the text), the expected length of sections or the appearance of typical concepts that describe the process and are described as expected in portfolio methodologies. All these measures allow to compare the portfolios and to evaluate how careful the realization of a portfolio is. Visualization of highest word frequencies, for example, can be created automatically; for example, tag-clouds (e.g., [6]).

Finally, an even larger class of text processing tools can be found in the machine learning world, which use the sophisticated tools of natural language processing. They base on the practice of creating a model by selecting samples and their expected labels. These models and labels are specific to the applications and require teachers to *input* these samples and label. While this input can be a considerable task, the analysis possibilities are very broad. Among the classical such approaches, the *Essay Grading* experiment [7] shows that it is possible to get close to the expectations of a teacher using latent semantic analysis (LSA), a process which creates a triple of matrices based on word-frequencies in each document of the training set which then allows to compute a distance between documents or between terms: these matrices can then be used with any other portfolio expected to contain similar words; this document can then be analyzed for its closeness to other model portfolios. Clearly, these indications are insufficient to assess the deep quality of a portfolio, since much freedom is left.

Other approaches based on machine learning include the automatic tag generation using naive Bayes' classifiers. These tags can denote a family of topics, but they can also denote other instructional aspects of the portfolios: dimensions such as the amount of reports of difficulty or progress, the use of scientific jargon, or the quantity of style annotations can indicate important development aspects.

Methodology and Conceptual Design

Portfolio assessment typically follows guidelines and observes well-defined criteria, often defined in terms of a rubric. For our purposes, we followed the criteria defined in the guidelines of our study program and defined the levels of achievement. In terms of four levels: level 0 - not satisfactory; level 1 - basic; level 2 - advanced; level 3 - excellent. Hence, the main goal of the automatic portfolio analyzer system was to support the teacher in assessing the students' e-portfolios according to this rubric. For a detailed requirements analysis, we used a scenario-based design methodology. Based on concrete usage scenarios, the relevant requirements were derived and a design for the automatic analysis system was developed. A first prototype of the system was used and evaluated in the summer term 2016. In the evaluation, various automatically calculated statistics were compared with the human assessment results. In particular, we investigated whether the statistics can provide additional insight into the portfolios' structure, and thus can be used to enhance the overall assessment process.

Using a scenario-based design approach, we illustrate the requirements for an automatic portfolio analyzer software by describing a typical scenario of how the software can be used. The actor of the scenario is Peter Taylor, a fictional professor, who is using the analyzer software as a supporting tool for assessing e-portfolios.

Scenario: Summative assessment of e-portfolios
Peter Taylor is a professor at the University of Education in Freiburg and is currently preparing the oral exams for this year's Information Technology module. The exams will be based on the e-portfolios developed and published by the students. As a preparation, Peter has to go through every single e-portfolio and assess it based on a set of predefined criteria. First, Peter logs into the portfolio analyzer software and gets a list of all available e-portfolios. Only e-portfolios that are explicitly shared with him by their owners are displayed in the list. Peter selects the first e-portfolio and is presented with the automatic analysis results from the software. In order to get a rough overview over the e-portfolio's structure, Peter scans the automatically generated table of contents containing headers and word counts for each section. Based on this information, he can find out quickly which sections are well elaborated and which are not, or whether there are topics that are missing completely. Additionally, he checks the number and type of external resources that are used in the e-portfolio, the number and type of integrated media content, as well as links between the individual sections. In the external references list, most of the stated resources have been used in the lectures already. Only a few resources have been investigated and added by the student herself. However, in the miniature view of embedded media artefacts, Peter discovers a lot of interesting material for the focus topic chosen by the student. He finds many graphics and videos related to state-of-the-art research and development, as well as a YouTube video produced by the student herself. Based on this preliminary evaluation, Peter fills out part of the rubric for the student and then links directly from the analysis view to the e-portfolio in order to scan the portfolio contents and complete the assessment.

Fig. 1: Scenario "Performing summative assessment for an e-portfolio"

From the scenario the following claims for a portfolio analyzing system can be derived:

- The main structural characteristics of the e-portfolio have to be easily accessible, e.g., being displayed in a dashboard, presenting information such as an index of contents, the portfolio size, word count per section, thumbnails of all contained images, and a list of references.
- The dashboard view should support focus-and-context analysis, i.e., by supporting zoom-in/zoom-out between summary views and detail views.
- Links have to be provided between analysis views and the corresponding e-portfolio content to provide detail views.
- Adaptable interactive visualizations, e.g., hide or display elements according to the users' needs, should be provided.
- Semantic analysis results indicate the completeness of the portfolio and the level of detail of individual topics should be included.
- Only teachers who are granted access to the portfolios should have access to the results of the analyzer software.

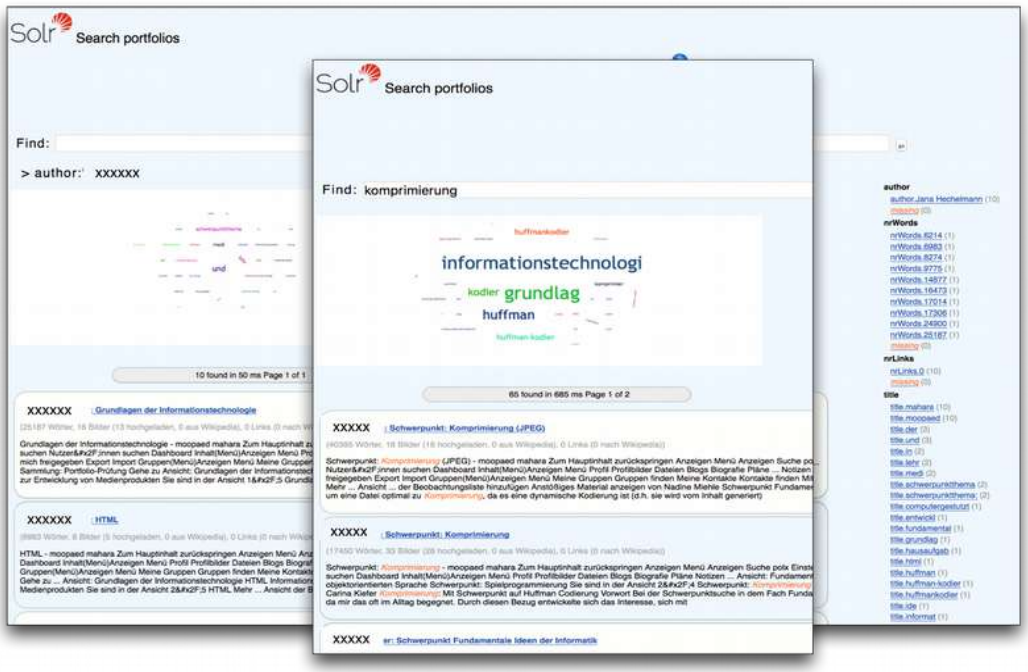

Fig. 2: Student and topic search dashboard

Technical Solution and Architecture

Based on the sketched requirements we conceptualized and implemented a prototypical solution to support lecturers in the assessment of students' e-portfolios. The solution considers specifics of the institution's e-learning software infrastructure. Fig. 3 depicts the architecture of the solution we developed for the analysis of students' e-portfolios. It contains the following central components, complementing the existing e-portfolio infrastructure:

- LMS: Central access point for students and portfolio extractor (*Moodle*),
- e-Portfolio system: Editing and display server for portfolios (*Mahara*),
- Extractor: component for the extraction of relevant information from learners' portfolios (*Ruby based*),

- Statistical analysis: fundamental analysis based on descriptive features and statistical measures (*Ruby based*),
- Semantic analysis: analytics of semantic characteristics of individual portfolios and their relations to others (*to be implemented, e.g. semantic-vectors*),
- Index: the storage of portfolios for searching, querying, and displaying values (*Solr based*),
- Dashboard: Visualization of analytical results and visual analytics (*browser-based*),

Additional components of the analytical infrastructure have not been realized upto now and shall be added in the future. These are:

- Learning model: algorithm specific model of the learning results (*to be implemented, e.g. termvectors.bin*),
- Evaluation:Visualization and input of learning corpus characteristics (*to be implemented, browser based*)

In our solution, the extraction was performed via web-scraping, thus bypassing the otherwise difficult organisational processes to allow for a direct access to the e-portfolio database with the requirement of privileged access. In addition, this solution ensures that teachers may access those e-portfolios, views, and resources only, which have been published for their access by individual learners. The corresponding extractor component was realized as a tool for teacher usage based on the Ruby mechanize framework, exploiting the single-sign-on mechanism of our university via a centralized Moodle-based LMS.

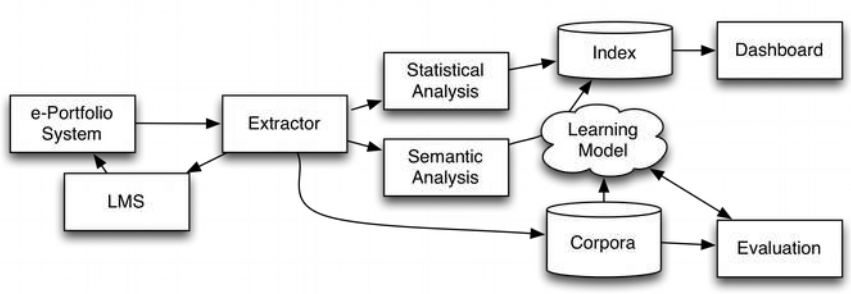

Fig. 3: Architecture of the developed e-portfolio analysis solution

The extraction process triggers a storage of e-portfolio contents in a local database, and a descriptive/statistical as well as a semantic analysis, containing general indicators, such as the total and relative number of hyperlinks and images, as well as the total and relative length (number of words and characters) of the complete portfolio and individual views. In addition, we support the definition of special indicators, such as the frequency of images from dedicated sources (such as Flickr or Instagram) and links to dedicated domains (such as Wikipedia or WordNet).

Semantic analysis, the persistent storage of analytical results, and dashboard functionalities are implemented by the means of data models and views provided based on an Apache Solr server (lucene.apache.org/solr/). The Solr infrastructure takes over the indexing of e-portfolios and the classification of contents. In addition, required functionalities for the navigation between individual portfolios, the search of specific learner portfolios, and the drill-down of portfolio details are realized based on the Apache Solr storage and retrieval functionalities (search, facet and filtering).

Application and First Results

In the summer term 2016, a first prototype of the portfolio analyzer software was used for the assessment of the e-portfolios in the module "Information Technology" in the degree program Media Education and Management at the University of Education in Weingarten. The main objective of the evaluation was to identify those assessment criteria that can be backed by automatically calculated statistical parameters such as total word count and the number of uploaded images. The applied rubric contains critera in 3 categeories: Contents, e.g., completeness of depiction, contribution, difficulty of own tasks, professional level; formals aspects, e.g., design, language, media usage, references; process, e.g., depiction of work process, curiosity, cooperation, reflection. Based on the criteria's definition in the rubric, the following assignment of parameters seemed to be useful:

- Work intensity and level of detail (*word count, number of uploaded images)*
- Adequate usage of multi-media (*number of uploaded images*)

For a first formative evaluation of the chosen approach, the manual assessments of 12 e-portfolios were analyzed and compared to the automatically retrieved statistical parameters. Three teachers took part in the evaluation and provided their assessments of the rubric criteria according to the four levels of achievement. As an outcome of the manual assessment phase, the average assessment results for each criterion were calculated and used for further evaluation. In the automatic assessment, the statistical parameters were calculated for a total of 78 e-portfolios. For the selected e-portfolios, the statistical parameters were compared to the minimum, first quartile, median, third quartile and maximum of these data sets, and corresponding assignments to the four levels of achievement were made. Figure 4 depicts the comparison of manual and automatic inspection results.

When considering the results of the evaluation, one can observe differences of up to one level between the manual and automatic assessments. As expected, the manual assessment of a complex documentation of learning experiences and outcomes such as an e-portfolio takes much more aspects into account, as can be achieved by statistical analysis. However, the calculated correlation factor (see last column in figure 4) between the manual assessments and the automatic assessments reveals a medium to high correlation between the obtained results. While not providing statistical significant results, this indicates that even simple statistical parameters like the word count or the number of uploaded images can serve as useful information for the human assessor. In addition, all reviewers/lecturers involved in the assessment

used the results of the statistical analysis in their assessment and grading of the students' e-portfolios. All reviewers/lecturers reported the toolset to be very helpful in their assessment, and referred to the extracted information during their assessment frequently.

In order to support the evaluation of additional assessment criteria, one estimates that more parameters should be used and that existing parameters should be further differentiated, so as to become even more expressive indicators of e-portfolios. A need for analyzing the diversity of external links or of different types of media appears. Aside of the analysis measures, the portfolio analysis system should also be extended with visualizations which give an overview of the content and of the structure of portfolios so as to support the teacher by the manual evaluation.

It is also interesting to note that some parameters are precious also because they deliver information which is otherwise extremely difficult to detect by a manual evaluation.

	p1	p2	p3	p4	p5	p6	p7	p8	p9	p10	p11	p12	Correlation
Work intensity and level of detail													
Manual Assessment (Average)	1,8	1,3	1,7	2,2	0,8	1,5	1,8	1,8	1,5	0,8	2,3	1,5	
Word count (Statistics)	2	2	1	2	1	2	3	3	3	0	2	0	
Uploaded images (Statistics)	2	1	1	2	0	2	3	1	3	1	3	2	
Statistical Parameters (Average)	2	2	1	2	1	2	3	2	3	1	3	1	0,67
Adequate usage of multimedia													
Manual Assessment (Average)	2,0	1,3	1,5	2,2	0,8	2,0	2,0	1,5		1,0	1,8	1,5	
Uploaded images (Statistics)	2	1	1	2	1	2	3	1	3	1	3	2	
Statistical Parameters	2	1	1	2	1	2	3	1	3	1	3	2	0,69

Fig. 4: Comparing manual and automatic assessment results
(red: unsatisfactory, yellow: basic, green: advanced, blue: excellent)

Summary and Conclusions

In this paper we presented an approach for an automatic inspection of e-portfolios to support teachers in their assessment. Following a scenario-based design approach, the developed prototype provides functionalities to aid teachers in their analysis and contains components, both, for a descriptive/structural and a semantic analysis of e-portfolios.

The prototype has been applied to two examination series and evaluations of the portfolios by experts have been made. Correlations to the statistical indicator values have been studied: for the considered dimensions, medium to high correlations have been found (e.g. the number of words and uploaded images is correlated to 67% to the completeness of an e-portfolio). Nevertheless, deviations of up to one level of achievement were detected between the manual and automatic evaluation of the e-portfolios.

This confirms the role of such analytics devices as a preparatory and hinting instrument before assessing the portfolios as opposed to an assessment instrument. We suspect that several of the dimensions may be specific to the topics studied.

We plan to further strengthen the components for a semantic analysis of e-portfolios, and to provide further support for visual analytics based analysis of the

portfolios of a cohort. A clear objective is to extend the application of our tool to allow for an enhanced formative assessment, preceding a summative assessment, and, as such, fostering valuable instructional feedback and letting students benefit in the sense of student-centered learning analytics [10].

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