Adaptation Content in Robotic Systems: A Systematic Mapping Study

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***Abstract*—This full paper of research category presents a Systematic Mapping Study of the state-of-the-art of research on adaptation content in Robotic Systems, in the fields of cognitive profile, learning style and student model. In general, teachers develop the material that is to be taught and organize pedagogical activities for the students. As a consequence, students have a learning environment that does not take into account activities that have already been completed, actions taken, learning preferences and cognitive profile. Activities and teaching materials in robotic environments are the same for all students, and may end up being insufficient for the effective learning of each one. The initial search of four main academic databases resulted in 137 papers out of which 15 papers were included in the final analysis. Our article presents different researches, which involve adapting content for learning in robotic environments.**

Keywords—robotics; adaptive system; cognitive profile; learning style; student model; systematic mapping.

I. Introduction

Educational Robotics (ER) features learning environments that bring together assembling kits made up of diverse parts, and allows students to program the robots that have been assembled. ER has attracted the attention of teachers and students, being able to be used in an interdisciplinary way, besides serving as motivating element of learning. It promotes the development of system thinking and problem solving by designing, creating and programming tangible artifacts for creating personal objects and addressing the needs of real-world society. As a consequence, it is considered very beneficial if the Teaching Institutions include the teaching of theoretical and practical knowledge about robotics and cognitive robotics.

With the spread of the Internet, several virtual and remote robotics laboratories have been developed to support several areas, given the scarcity of resources and the high cost of installing physical laboratories. In general, the teaching materials and assignments are the same for all students, without considering the learning profile and the difficulty levels, and may end up being insufficient for the effective learning of each one. This process results in a learning environment that presents the same content for all participants, regardless of what is in each of them, or without performance analysis or behavior in the environment.

In this sense, the need arises to investigate whether these robotics laboratories provide an adaptive environment that is capable of contributing to learning, considering the cognitive profile of each student. In addition, it is important to analyze which customization techniques were used, especially in the context of adaptation content.

In this paper, we understand the term "adaptation content in Robotic Systems" as the action of adapt resources (e. g., lessons, tests and teaching materials) according to the students' cognitive profile or learning style using a learning environment.

The method used in this research is a systematic mapping (SM) study. A SM is a secondary study that follow a methodologically well-defined research process to identify, analyze, and interpret the available evidence related to a particular set of research questions, topics or phenomena of interest [2]. It is focused on structuring a research area [5] and aims to classify relevant literature and aggregate studies in relation to defined categories. The scope of an MS is generally broader and a more superficial analysis and synthesis.

From a SM, this document aims to present a survey of the state of the art of research that has been carried out in the aspect of Adaptive Robotic Systems, that consider the cognitive profile, learning style, or student model. This paper is organized as follows: Section II presents the related work. Section III presents the research questions. Section IV presents the methodology of this systematic mapping. Section V presents data extraction, and finally Section VI presents the conclusion of this work.

II. Related Works

Several synonymous terms for adaptive systems are currently in use, including adaptive environment, personalized system, personalized environment, and others. Identifying the students' learning style is one of the ways to obtain their preferences, providing more effective learning materials in the teaching and learning process. Given this context, there is concern about the ways in which learners deal particularly with information, such as cognitive profiles, learning styles, learner model, increasingly present in research in the field of Informatics and Engineering in Education.

Adaptive systems are important for use in educational environments, since a single learning environment for all students, regardless of learning preferences, may become inefficient [14]. There are two approaches recommended to building adaptive interfaces [14]: I) Consider the classification level of user according his/her knowledge (beginner,

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intermediate and advanced). II) Learning environment must me dynamically adapted to suit each user of the system, according to the actions taken.

According to Keefe [8], learning styles are related to the cognitive, affective and physiological characteristics that serve as stable indicators of perception, interaction and response of students in their learning environments. Identification of learning styles has two main applications for Felder & Silverman [9]: it serves as a guide for teachers about the diversity present in their classes and serves to help them design a program to suit all styles. Learning styles should not be considered as characteristics to indicate strengths and weaknesses of students. But they can be modified according to the educational experience of each student.

Users learn different things about the system at different levels and at different times. Adaptation done by the environment can consider different levels of knowledge, in different situations, for different objectives [12]. According [11] adaptation can be divided into three categories: requested by the user, requested by the system, or automatically. The first two are forms of "personalization". Automatic adaptation of systems responds to changes in user behavior [12].

In order to meet the needs of students, the student model must adapt the learning experience [16]. On one hand, student models provide only information about the latest student interaction to which the system has to react; on the other hand, student models provide a detailed description of students' knowledge and cognitive profile [15].

An Intelligent Tutoring System (ITS) is an educational system that support learning activities and incorporate techniques of Artificial Intelligence, like a human pedagogic tutor to assist students [17]. An ITS must evaluates the knowledge that the student possesses, and the tutor must decide how and what to teach based on the student's pedagogical state. However, it is necessary the interaction of a human tutor to

In this sense, [24] presents an agent that interacts with an ITS, associating each mental state to an emotional state, with machine learning techniques. The learners' brainwaves are used to obtain their mental state. Authors make the hypothesis that there is a strong correlation between these signals and emotional states.

A robotic cognitive model based on procedural memory and episodic memory is proposed in [25]. Authors focus on the research of tacit knowledge in robot cognitive model based on the representation of knowledge, acquisition of knowledge, and access to knowledge. This model owns adaptive ability without human intervention, in addition to own planning ability in real time.

Maia et al. [10] performed a study to overview the use of learning styles in introductory programming courses, and investigate students' difficulties, abilities and characteristics. The results showed that learning style affects the ability to learn, but does not indicate success or failure. Authors suggest incorporating learning styles into their teaching material, to meet to the majority of students.

A systematic review about adaptation resources supported by Constructivism in virtual learning environments is presented in [30]. About adaptation techniques found in the selected publications, context-awareness was the technique with highest number of matches found, followed by adaptation by agents, and collaborative learning. Authors inform the most commonly used techniques in the literature and which of them are used in a constructivist manner. Overall, SM or Systematic Literature Review (SLR) studies provide the state of the art in the field of learning styles [10] and adaptation resources in learning environments [Anonymous 2015]. We did not find any work that presented adaptation content in robotic learning environments.

III. Research Questions

This paper offers a systematic mapping of state of research on adaptation content in robotic systems. The goal/question/metric (GQM) paradigm is based on the premise that to gain a practical measure, one must first understand and specify the objectives of the software artifacts being measured and the objectives of the measurement process [1]. Based on the GQM paradigm [1], the aim of this systematic mapping is to **analyze** scientific publications, **with the purpose of** characterizing them, **with respect** to adaptive robotics systems, who recommend activities based on the students' cognitive profile, **from the** researchers' point view, **in the** academic context. Research questions in mapping studies are broader and should respond to trends related to research (e.g. number of publications over time, research areas, publication sites, subjects approached) [5].

This study focus specifically on robotic systems that personalize content to students, in learning environments. At the end of this systematic mapping, the following research questions must be answered: **RQ1.** What systems adapt content to students? **RQ2.** What techniques of adaptation content are used? **RQ3.** What are the features analyzed in these papers? **RQ4.** Is there any need to improve existing adaptation techniques? Which are?

IV. Methodology

To carry out a mapping study, the initial steps are similar to a systematic review of the literature, with the feature that the research questions are of a broader character [7]. To answer the above research questions, we have performed a systematic mapping study following the guidelines proposed by Budgen et al. [7], and it was divided into three stages:

1) Identify primary studies that may have relevant results for the research.

2) Select the primary studies from reading the meta data (title, abstract and keywords).

3) Perform a complete reading and qualitatively evaluate the selected studies.

To conduct the systematic mapping, we selected four main digital libraries: ACM Digital Library (http://dl.acm.org), IEEE Xplore (http://ieeexplore.ieee.org), Science Direct (http://www.sciencedirect.com) and SCOPUS (http://www.scopus.com). The search was also performed using the snowball process [6], following up the references in papers.

We restricted the search to studies published up to December 2017. The search string was defined according to the PICO (population, intervention, comparison, outcomes) [2], according to the structure below:

- Population: publications describing adaptations of robotic systems aiming at improving student learning.
- Intervention: how the adaptation content process has been carried out.
- Comparison: not applicable.
- Outcomes: qualitative evidences (positive and negative) and recommendations for improvements in the context of adaptation content in robotics system.

Search strategy was defined considering the most used keywords in the research questions. The initial set of keywords (see Fig. 1) was refined after a preliminary search returned too many results with few relevance.

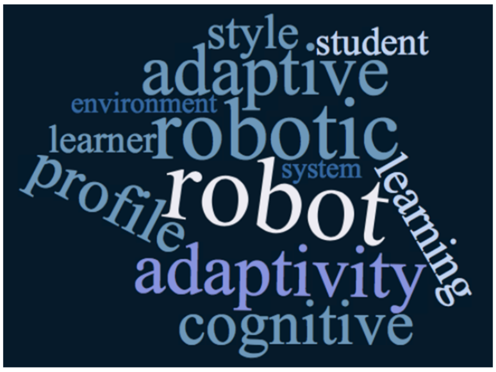


Fig. 1. Initial set of keywords.

Search string was constructed by combining keywords and synonyms, and the terms used in it are shown on Table I. It should be noted that the search string has been adapted for each digital library.

TABLE I. SEARCH STRING

((adapt* OR personaliz* OR "intelligent tutoring") AND ("system" OR "environment" OR laborator* OR "learning management system" OR "lms" OR "moodle"))
AND
("cognitive profile" OR "cognitive model" OR "learning style" OR "student model" OR "learner model" OR "user model")
AND
(robot*)

B. Studies Selection

Selection process is essential to help answer research questions. The selection process of the publications took place in three stages:

- Identification of studies: The researcher performs the search in the selected sources using the search string that was elaborated (the searches were carried out considering the meta-data).
- [1° filter]: For the selection of the publications in the first filter were read the title, abstract and the keywords. In which, the set of articles is selected from the verification of the inclusion and exclusion criteria.
- [2° filter]: In the second filter the publications extracted in the previous step are reanalyzed and read integrally, following the inclusion and exclusion criteria. In this way, only articles that have had their information accepted according to established criteria are analyzed.

After performing the searches, each candidate study passed through a set of stages until its eventual selection (see Fig. 2). First, we assessed the title and read the abstract and keywords, looking for papers that described adaptive systems, or personalized systems, or intelligent tutoring systems, that consider cognitive profile or learning style. Papers unrelated to robotic systems were excluded. Second, we retrieved each study, read it entirely, and critically appraised it based on similar criteria as in the previous round.

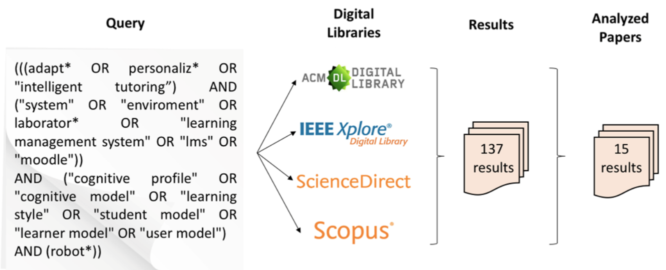


Fig. 2. Selection process.

A paper was discarded if it was out of scope (e.g., the paper did not describe adaptive robotic systems), or of no credibility, or short paper (e.g., papers of insufficient length, or low quality prose that prevented understanding and assessing the proposal/contribution). Then, a data extraction form was filled out for each selected study to gather evidence for the review goals. Finally, we removed duplicate papers or preliminary versions of works already being analyzed (unless they described different aspects).

Inclusion and exclusion criteria are presented on Subsections C and D, and are used to exclude studies that are not relevant to answer the research questions [3].

C. Inclusion Criteria (IC)

The following inclusion criteria were applied to titles and abstracts:

- IC.1. Papers present studies related to cognitive profile, learning style or student model.
- IC.2. Papers are in the field of robotic systems.
- IC.3. Papers that present studies related to recommendation or personalization of activities.
- IC.4. Papers that are available on the web.
- IC.5. Academic journal, conference and workshop papers.
- IC.6. Papers written in English.
- IC.7. Publication date until December 2017.

D. Exclusion Criteria (EC)

The following criteria state when a study was excluded:

- EC.1. Articles short paper.

- EC.2. Papers not available in full format.
- EC.3. Publications that are courses, books, tutorials and the like.
- EC.4. Duplicate studies already returned in another digital library.

V. Data Extraction

In a first evaluation, still on the page of the search engine, the first study was carried out, where the meta-data were considered for reading: title, abstract and keywords. In order to organize the relevant data from the identified studies, information was entered into a table (see Table II), where each row represents an item, which is accompanied by a value, and may be associated with a research question or not.

TABLE II. Data Extraction Form

Data Item	Value	RQ
Title	Title of the article that adapt content to students.	RQ1
Author(s)	Set of names of authors.	-
Year	Year of publication of the work.	-
Type of study	Type of study.	-
Robot	Simulated or physical robot.	-
Techniques of content adaptation	How did the customization process take place in the environment used.	RQ2
Features analyzed	Features analyzed.	RQ3
Recommendation for improvement	Recommendation for improvement.	RQ4
Contributions	Contributions of research.	-
Future perspectives	Suggested research question for future work, if any.	-

A. Quantitative Analysis

Quantitative analysis consists in providing the number of publications selected to be part of the systematic mapping, data cataloging and charting presenting a general approach of these studies (divided by year and place of publication). Table III shows the number of articles analyzed in the first and second filters, as well as the number of duplicate articles.

TABLE III. Number of Articles

Databases	Returned	1° filter	2° filter	Duplicated
ACM	19	6	3	1
IEEE	28	18	8	1
Science Direct	8	2	0	0
Scopus	82	29	4	14
Total	137	55	15	16

A total of 137 papers were obtained by running the query in the databases. Out of these 137 papers, 55 title/abstract/keywords passed the first stage, and 15 were thoroughly reviewed (16 papers were duplicated, and 6 papers were not accessible). Fig. 3 presents the quantitative of articles that were selected to be read in full, according each digital library.

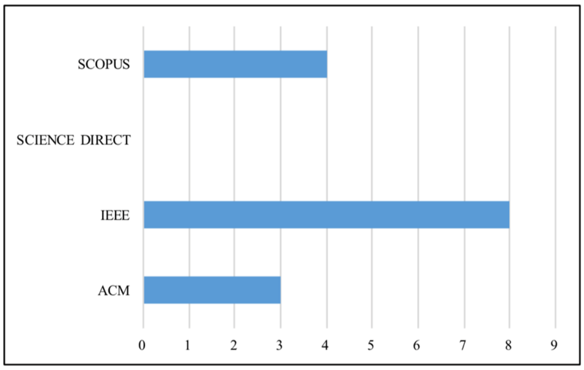


Fig. 3. Number of articles selected in digital libraries.

After removing non-relevant papers, finally, 15 papers passed all the aforementioned filters and were included in the review presented in this section. The list of included papers as well as information about their contexts, data sources, and evaluation are presented in Table V. Even though no temporal filter was applied when the queries were executed, all included papers were published until 2017. The number of articles published per year is presented in Fig. 4.

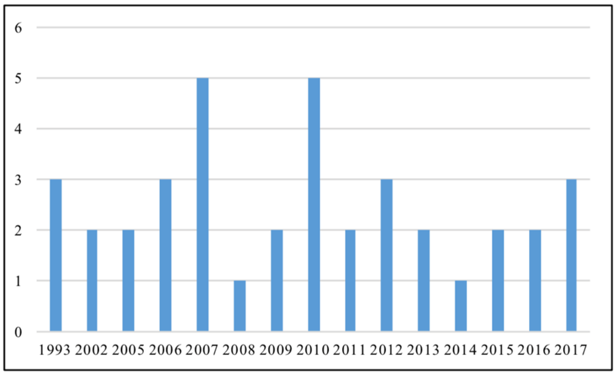


Fig. 4. Articles published by year.

B. Qualitative Analysis

Below, we present an overview of the types of contributions made by the reviewed papers, according to the inclusion criteria and research questions that were defined previously.

1) *Types of Contributions*

To categorize the studies selected in this SM, we used the facet classification presented in Petersen et al. [3] because it is a good way to organize search types. Our classification scheme assembled one facet structured the topic in terms of the type of research. The classes that form the research facet are described in Table IV.

TABLE IV. Research Type Facet [3]

Category	Description
Validation Research	Techniques investigated are novel and have not yet been implemented in practice.
Evaluation Research	Techniques are implemented in practice and an evaluation of the technique is conducted (informing what are the consequences of the implementation in terms of benefits and drawbacks).
Solution Proposal	A solution for a problem is proposed, and it can be either novel or a significant extension of an existing

	technique. Benefits of the solution can be show by a small example or a good line of argumentation.
Philosophical Papers	Sketch a new way of looking at existing things by structuring the field in form of a taxonomy or conceptual framework.
Opinion Papers	Express the personal opinion of somebody whether a certain technique is good or bad, or how things should been done. They do not rely on related work and research methodologies.
Experience Papers	These papers explain on what and how something has been done in practice, being a personal experience of the author.

Table IV presents categories to rank the studies, and it was applied after filtering process. The classification was performed considering only the articles included after the application of the second filter. The review distinguished between three types of contributions (see Fig. 5): 80 percent presented a solution proposal, 13 percent study of evaluation research, and only 7 percent a search of validation research. The description of the papers is presented in the next subsection.

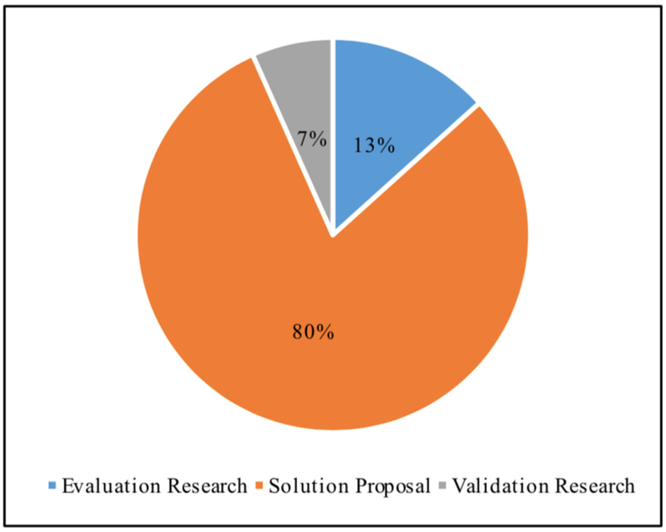


Fig. 5. Research types.

2) *Description of papers and Research Questions*

There are many research areas in adaptive systems selected in this SM, and they are described below. To answer **RQ1** ("What systems consider the learning style or cognitive profile of each student?"), we provide below a brief description of the papers selected in this systematic mapping.

In research developed by [12], authors identify individual cognitive and personality characteristics to designing systems which can adapt to individual differences, validate them and discover appropriate design to deal with differences. Authors explain how individual characteristics are identified and describe how they were incorporated in an operational. At the end of the paper is presented the development of a system that integrates a set of tools and facilitates the creation and amendment of adaptive systems to allow rapid changes.

User Interface Design Environment (UIDE) is presented in [13], and aim to provide adaptive behaviors both on interfaces and help as interface design options. This paper show how user's knowledge can be modeled to carry out tasks, and help automate the user interface design process at run time. The UIDE application model and user model will allow several forms of adaptive behavior provide explanations of how to carry out tasks based on the user's knowledge, in addition to rearranging menus and dialog boxes.

An adaptive interface system named DB_Habits is presented in [14], and aim to incorporate knowledge about the underlying system to recognize repeated sequences of commands issued by the user. The system provides an adaptive user interface which discovers the tasks that each user performs from observation of that user's behavior those tasks are then made available to the user as meta-commands or macro scripts. The system builds a model of the user's tasks, and produce hypothesis about the tasks, in addition to provide methods for the user to teach novel knowledge directly to it through the collaborative interface.

An ITS coupled with a semi-open learning environment is presented in [15]. The objective of this paper is to develop a student model representation for an intelligent tutoring system of a virtual laboratory, using probabilistic relational models. In this environment it is necessary to register student data and background to obtain an initial model of a new learner. As a case study, authors selected a simulated mobile robotics laboratory to be used, and evaluated the tutor and the student model, using the virtual robotics laboratory.

In the same research area, an ITS coupled to a virtual laboratory for learning mobile robotics is proposed in [17]. It presents a model which integrates information from the students' pedagogical state, affective state, and the tutorial situation, to decide the best tutorial action from a pedagogical and affective point of view. Authors implemented a tutor that recognizes the affective state of the student and interacts in real time, and may be able to motivate students and improve the learning process. This proposal is based on emotions models, personality theories and teachers' expertise, and provides the student with the opportunity to learn through exploration within simulated experiments.

An Affective Behavior Model (ABM) for ITS is presented in [18], and tutor considers the student' affective and pedagogical state, to select the best tutorial action. This model was integrated to an intelligent tutor for mobile robotics, allowing to the student receives a tutorial action composed by an affective and a pedagogical action (with the purpose of convey knowledge the student needs to know). In this sense, the tutorial action to be delivered to the student is determined by the affective behavior model.

A framework for an Interactive Robot-based Tutoring System (IRTS) is described in [19]. The proposed system has a a robot tutor that interacts with a user, and combines computer-based expert systems to simulate a human tutor, and systems which help users with physical interaction using robotic devices. The system train the user considering his ability and habitual weakness, measure his performance using its sensors during the training, generates the user model and provides appropriate training tasks.

An adaptive e-learning system that identifies the initial user typology based on static features is presented in [20]. Authors divide groups of learning typologies according to the theoretical learning styles present in the literature. Clustering experiments were performed using the implementation of k-means algorithm, divided into two parts: the first focused on both study activities and motives and views, the second focused on study activities.

Relying on the students' learning style, [21] presents a user model to enhance an Adaptive Intelligent Web Based Education System. In this paper, authors used an implicit method where users' actions on mouse clicking can be detected, processed and kept in the user model, and adapt the course content using an adaptive presentation technique. About learning style prediction, Production-Fuzzy Rules Technique had a better result when compared to Naive Bayes.

An ITS named CanadarmTutor for learning to operate a robotic arm is presented in [22]. This research was developed to support tutoring services, and consists in build a cognitive task model, a data mining approach for automatically building a constraint-based modeling, and a 3D path-planner to integrate an expert system into an ITS. The system was developed to train astronauts to operate a 7-degrees-of-freedom robotic arm, having tutoring services as support.

The architecture of an adaptive robotic laboratory is described in [23]. The system allows robotic experiments to be performed via internet, and students autonomous control robotic devices. The system offers an environment flexible and configurable, and maintain a student model for each learner, storing their knowledge and skills, according to their performance in the environment.

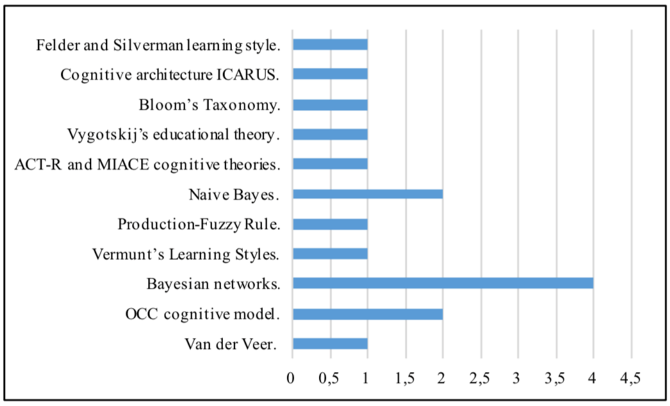
In [26], an adaptive educational system that supports constructing the user model was introduced to teach stepper motors to the students more effectively. In this system, students can express their learning preferences, stores the knowledge level in a separated user model, with custom content that considers learning style for each student.

[27] presents the development of a system to materialize cognitive tasks by applying the cognitive architecture ICARUS to the humanoid robot platform Mahru-Z. Robot performs the task of stacking the blocks in conducted experiments, by sorting them according to colors, and can can send various sensor data to external servers. Authors build a TCP based communication interface for the communication between the cognitive architecture and the robot. Information change periodically, and the architecture and the robot easily adapt to the environmental changes.

A robotic educational agent integrated into a math learning scenario to reengaging students using behavioral strategies is presented in [28]. Authors apply behavioral strategies comparable to that of a human teacher, and they focus on the math testing scenario to evaluate the role and students' engagement using a robotic agent. The user' behavioral state is determinate according student's interactions with the tablet. Three information were analyzed to measure engagement: time required to answer a question, definition of answers, and suitable function executions.

[29] outlines a set of design processes and considerations necessary to construct a Socially Assistive Robot (SAR) system, to help in teaching number concepts to preschool children. The approach developed support number concepts learning, and authors collected data to capture child performance applying learning style inventory questionnaire. This paper presents a hybrid approach through which the learning styles of the child participants and the exercises are defined by literature-based features. This paper presents an approach in which participants' learning styles and exercises are defined by characteristics based on the literature.

To answer **RQ2** ("What techniques of content adaptation are used?"), we describe below the techniques identified in the studies: 1 paper was based on Felder and Silverman learning style [29]; 1 paper grounded the research in cognitive architecture ICARUS [27]; 1 paper used Bloom Taxonomy and Vygotskij's theory [23]; 1 paper grounded the research in ACT-R and MIACE cognitive theories [22]; 2 papers used Naive Bayes [21], [26]; 1 paper used production fuzzy rule [21], 1 paper was based on Vermunt's learning style [20]; 4 papers used Bayesian networks [15], [17], [18], [20]; 2 papers were based on OCC cognitive model [17], [18]; and 1 paper used cognitive factors analysis of Van der Veer [12]. Fig.5 presents the graphic with techniques used. Fig.5 presents the graphic with relating amount and techniques used.



To answer **RQ3** ("What are the features analyzed in these papers?"), we found some and thye are described below: improvement of the interface, accessible interaction mechanisms, representation of the student model for tutoring systems, virtual laboratory that provides simulated experiments, cognitive model of emotions integrated to the tutor, improvement of user skill, association of techniques with Index of Learning Style. More details can be found on Table V.

Finally, to answer **RQ4** ("Is there any need to improve existing adaptation techniques? Which are?"), the information of each paper is described on Table V, followed of it' contribution and future perspectives.

VI. Conclusion

This paper presented a systematic mapping study to overview about adaptation content in robotic systems. We summarized papers that were published up to 2017. For this propose, we defined research questions and search strings to guide the automatic search on four databases. After running the search, 137 articles were selected. We filtered them based on the inclusion and exclusion criteria resulting in 15 studies. Inclusion and exclusion criteria were defined to help us answer the research questions.

We have found little research related to adaptive robotic learning environments. This indicates that this area of research is still being developed. From all the results described above, we can extract several main responses to our four research questions. Most of the proposed are not associated with robotic systems. [15], [17], [18] and [22] use robotic programs simulated. [23], [27], [28] and [29] use robotic devices. [23] uses Arduino and Lego Mindstorms, [27] uses the robot platform Mahru-z, [28] uses Darwin robot., and [29] uses Aldebaran NAO robot.

This study identified studies in several areas: systems which can adapt to individual differences in personality and cognitive style [12], knowledge base model of the user interface design environment [13], adaptive interface system [14], intelligent tutoring system [15], affective behavior model [17] [18], framework for an interactive robot-based tutoring system [19], adaptive e-learning system [20], comparison between Production-Fuzzy Rule and Naive Bayes [21], multiparadigm approach to support tutoring services [22], adaptive remote robotic laboratory [26], cognitive architectures [27], robotic educational agent [28], and assistive robot tutoring system [29].

We hope that this work help researcher interested in working with adaptive robotics systems that associate learning styles, student model and cognitive profiles.

REFERENCES

[1] V., Basili, G., Caldiera, and D. H., Rombach. (1994). "The Goal Question Metric Paradigm: Encyclopedia of software engineering". John Wiley & Sons, Inc.

[2] B. Kitchenham and S. Charters. (2007). "Guidelines for performing systematic literature reviews in software engineering", Keele Univ., Keele, U.K., Tech. Rep. EBSE-2007–01.

[3] K., Petersen, R., Feldt, S., Mujtaba, and M., Mattsson. (2008). "Systematic Mapping Studies in Software Engineering". In EASE (Vol. 8, pp. 68-77).

[4] P. A. D. M. S., Neto, I., do Carmo Machado, J. D., McGregor, E. S., De Almeida, and S. R., de Lemos Meira. (2011). "A systematic mapping study of software product lines testing". Information and Software Technology, 53(5), 407-423.

[5] K., Petersen, S., Vakkalanka, & L., Kuzniarz. (2015). "Guidelines for conducting systematic mapping studies in software engineering: An update". Information and Software Technology, 64, 1-18.

[6] S. Jalali, and C. Wohlin. (2012). "Systematic literature studies: database searches vs. backward snowballing". In: Proceedings of the ACM-IEEE International Symposium on Empirical Software Engineering and Measurement, ACM, pp. 29–38.

[7] D., Budgen, M., Turner, P., Brereton, and B., Kitchenham. (2008). "Using mapping studies in software engineering". In Proceedings of PPIG. Vol. 8, pp. 195-204. Lancaster University.

[8] J. W., Keefe. (1979). "Learning style: An overview. Student learning styles: Diagnosing and prescribing programs", 1, 1-17.

[9] R. M., Felder, and L. K., Silverman. (1988). "Learning and teaching styles in engineering education". Engineering education, 78(7), 674-681.

[10] M. C. O., Maia, D., Serey, and J., Figueiredo. (2017). "Learning styles in programming education: A systematic mapping study". In *Frontiers in Education Conference (FIE)* (pp. 1-7). IEEE.

[11] E., Edmonds. (1987). "Adaptation, response and knowledge". Knowledge-Based Systems, v. 1, n. 1, p. 3-10.

[12] D., Benyon, and D., Murray. (1993). "Developing adaptive systems to fit individual aptitudes". In *Proceedings of the 1st international conference on Intelligent user interfaces*, pp. 115-121. ACM.

[13] P. N., Sukaviriya, and J. D., Foley. (1993). "Supporting adaptive interfaces in a knowledge-based user interface environment". In *Proceedings of the 1st international conference on Intelligent user interfaces* (pp. 107-113). ACM.

[14] D., Crow, and B., Smith. (1993). "The role of built-in knowledge in adaptive interface systems". In *Proceedings of the 1st international conference on Intelligent user interfaces*(pp. 97-104). ACM.

[15] J., Noguez, and L. E., Sucar. (2005). "A probabilistic relational student model for virtual laboratories". In *Computer Science, 2005. ENC 2005. Sixth Mexican International Conference on* (pp. 2-9). IEEE.

[16] Self, J. (1994). "The role of student models in learning environments". *IEICE TRANSACTIONS on Information and Systems*, *77*(1), 3-8.

[17] Y., Hernández, J., Noguez, E., Sucar, and G., Arroyo-Figueroa. (2006). "Incorporating an affective model to an intelligent tutor for mobile robotics". In *Frontiers in Education Conference, 36th Annual* (pp. 22-27). IEEE.

[18] Y., Hernández, G., Arroyo-Figueroa, and L. E., Sucar. (2008). "Evaluating a probabilistic model for affective behavior in an intelligent tutoring system". In *Advanced Learning Technologies, 2008. ICALT'08. Eighth IEEE International Conference on* (pp. 408-412). IEEE.

[19] D. H., Lee, and J. H., Kim. (2010). "A framework for an interactive robot-based tutoring system and its application to ball-passing training". In *Robotics and Biomimetics (ROBIO), 2010 IEEE International Conference on* (pp. 573-578). IEEE.

[20] F., Trif, C., Lemnaru, and R., Potolea. (2010). "Identifying the user typology for adaptive e-learning systems". In *Automation Quality and Testing Robotics (AQTR), 2010 IEEE International Conference on* (Vol. 3, pp. 1-6). IEEE.

[21] R., Mokhtar, S. N. H. S., Abdullah, and N. A. M., Zin. (2011). "Classifying modality learning styles based on Production-Fuzzy Rules". In *Pattern Analysis and Intelligent Robotics (ICPAIR), 2011 International Conference on* (Vol. 1, pp. 154-159). IEEE.

[22] P., Fournier-Viger, R., Nkambou, E. M., Nguifo, A., Mayers, and U., Faghihi. (2013). "A multiparadigm intelligent tutoring system for robotic arm training". *IEEE Transactions on Learning Technologies*, *6*(4), 364-377.

[23] P., Di Giamberardino, and M., Temperini. (2017). "Adaptive access to robotic learning experiences in a remote laboratory setting". In *Carpathian Control Conference (ICCC), 2017 18th International* (pp. 565-570). IEEE.

[24] A., Heraz, R., Razaki, and C., Frasson. (2007). "Using machine learning to predict learner emotional state from brainwaves". In *Advanced Learning Technologies, 2007. ICALT 2007. Seventh IEEE International Conference on* (pp. 853-857). IEEE.

[25] Z. W.,Wang, and R., Zhang. (2009). "Research on Robot Cognitive Model Based on Tacit Knowledge". In *Intelligent Systems and Applications, 2009. ISA 2009. International Workshop on* (pp. 1-4). IEEE.

[26] H. T., Kahraman, I., Colak, and S., Sagiroglu. (2007). "A web based adaptive educational system". In *Machine Learning and Applications, 2007. ICMLA 2007. Sixth International Conference on* (pp. 286-291). IEEE.

[27] K., Kim, J. Y., Lee, D., Choi, J. M., Park, and B. J., You. (2010). "Autonomous task execution of a humanoid robot using a cognitive model". In *Robotics and Biomimetics (ROBIO), 2010 IEEE International Conference on* (pp. 405-410). IEEE.

[28] L., Brown, R., Kerwin, and A. M., Howard. (2013). "Applying behavioral strategies for student engagement using a robotic educational agent". In *Systems, Man, and Cybernetics (SMC), 2013 IEEE international conference on* (pp. 4360-4365). IEEE.

[29] C., Clabaugh, G., Ragusa, F., Sha, and M., Matarić. (2015). "Designing a socially assistive robot for personalized number concepts learning in preschool children". In *Development and Learning and Epigenetic Robotics (ICDL-EpiRob), 2015 Joint IEEE International Conference on* (pp. 314-319). IEEE.

[30] V., Bremgartner, J. F., de Magalhães Netto, and C. S, de Menezes. (2015). "Adaptation resources in virtual learning environments under constructivist approach: A systematic review". In *Frontiers in Education Conference (FIE),* (pp. 1-8). IEEE.

TABLE V. DATA FORM

Title	Author(s)	Year	Type of study	Robot	Techniques of content adaptation	Features Analyzed	Recommendation for improvement	Contributions	Future perspectives
RQ1					RQ2	RQ3	RQ4		
[12]		1993	Solution Proposal	-	Cognitive factors analysis of van der Veer.	Level of spatial ability and field dependence and the characteristics of the command interface which they took to be the openness and flexibility of the dialogue.	The user interacts directly with the target system which then exploits its knowledge of users and the domain to adapt the system appropriately.	An interface style which minimizes navigation and constrains the dialogue, is suitable for users with both a low spatial ability and low experience of using command language style interfaces.	Interfaces should not be designed which require users to traverse a number of systems or a multi-level hierarchy and which do not provide adequate reference points: such systems require users to have a high level of spatial ability and many users do not have this characteristic.
[13]		1993	Solution Proposal	-	-	The model represents some of the application's semantics and the interaction mechanisms used to access those semantics.	Though performance time data are used, UIDE adaptations are not aimed at making users type faster or move the mouse quicker. We are more interested in interfaces which are dynamic and keep up with the users.	Allow to provide several forms of adaptive behavior. We will be able to provide explanations of how to carry out various tasks based on the user's current knowledge. Similarly, the amount of detail and extent to which detail is repeated in an explanation can be adapted.	Their long term goal is to make UIDE self-adapted; that is continually being able to evaluate adaptations automatically using collected user performance data and pre-defined analysis techniques.
[14]		1993	Solution Proposal	-	-	Uses pattern recognition techniques, enhanced by a number of small-scale knowledge-based systems (KBSS) communicating via a blackboard, to locate repeated sequences of commands in recordings of the user-system interactions.	Because of the wide range of user variability, the system can only produce hypothesis about a user's tasks and must seek advice horn that user to verify and refine the models it builds.	Authors advocate building systems which adapt their interface to the individual user, based on observation of that user.	A perhaps surprisingly small amount of low-level Domain Syntax Knowledge improves the quality, both subjectively and objectively measured, of the results produced by DB_Habits.
[15]		2005	Evaluation Research	Simulated.	Bayesian networks	Develop a student model representation for an intelligent tutoring system of a virtual laboratory, using probabilistic relational models.	-	Offers a semi-open learning environment providing the students with the opportunity to learn through exploration with different aspects and parameters for the experiments. A system to assess the effectiveness of learner exploration behavior and experiment performance at different levels of granularity is developed.	Extend the evaluation of the tutor with more experiments, and designing a model to integrate an affective behavior to the intelligent tutoring system in order to provide students with a suitable response from a pedagogical and affective point of view.
[17]		2006	Evaluation Research	Simulated.	OCC cognitive model of emotions, and dynamic Bayesian networks.	Developed an intelligent tutoring system coupled to a virtual laboratory. This environment provides the student with the opportunity to learn through exploration within simulated experiments.	-	Affective behavior model is being integrated to an ITS coupled to a virtual laboratory for teaching mobile robotics.	The next phase is to integrate the affective behavior model to the ITS. Then, they will conduct some experiments to compare the improvements in learning and affect of the students with the incorporation of the affective components, against the ITS without affective components.
[18]		2008	Solution Proposal	Simulated.	OCC cognitive model of emotions, and dynamic Bayesian networks.	The affective behavior model integrates an affective student model based on the OCC cognitive model of emotions and relies on a probabilistic network. The tutor model is rooted in teachers' expertise and intuition.	The study consisted in presenting to students three different tutorial scenarios and the affective and pedagogical action selected by the affective behavior model considering the affective student state and the tutorial situation presented in the scenario.	Development of a decision-theoretic affective tutor model, which selects a tutorial action, based on the affective and the pedagogical state of the student; and the refinement of this model based on the opinions of experienced teachers in the domain.	The next step is to complete the integration of the ABM with the ITS for learning mobile robotics; and then to conduct another user study.
[19]		2010	Solution Proposal	-	-	The results demonstrated that the system was able to improve user's ability as well as correcting the habitual weakness.	-	A robot tutor interacts with a user in a real environment, and trained the user considering his ability and habitual weakness. The system was able to provide a suitable training task to the user by combining the proficiency-based and propensity based training units.	The experiments will be expanded to various types of subjects with different ages and abilities to validate the effectiveness of the system.
[20]		2010	Solution Proposal	-	Vermunt's Learning Styles model. Bayesian Network.	New techniques for investigating the correlation be- tween the intermediate attributes and learning types.	The discrepancies observed in the results can be eliminated by careful design of the psychological test which measures the initial user static features.	Employment of a clustering method to determine the different groups of learning typologies, corresponding to the theoretical learning styles present in literature. The model for the adaptive e-learning system combines features from aptitude-treatment and the micro-adaptive model, enhanced with the constructivist collaborative approach.	To eliminate discrepancies, authors propose the following measures: (1) removing the regional and cultural scores from the analysis (and the corresponding initial questions) and (2) applying the questionnaire on samples from all the interest groups (from all the study years).
[21]		2011	Solution Proposal	-	Production-Fuzzy Rule (PFR) and	Which technique is better for replacing Index of Learning Style (ILS) as a	Production-Fuzzy Rules Technique is more suitable	Adaptive Intelligent Web Based Educational Systems, which is developed for this	-

				Naive Bayes techniques.	modality for learning style detection tools.	to predict the user's modality learning style.	research allow users to adapt the most appropriate course to suit their modality learning style.	
[22]	2013	Solution Proposal	Simulated.	Cognitive model is based on the ACT-R and MIACE cognitive theories.	Observed that the tutoring services were generally helpful and appreciated by users and that, in general, users did not repeat the same mistakes after receiving feedback.	-	Simulation-based tutoring system to train astronauts how to operate a 7-degrees-of-freedom robotic arm deployed on the International Space Station (ISS). CanadarmTutor offers a 3D simulation of the arm and the space station, which let learners to operate the arm in a safe environment.	-
[23]	2017	Solution Proposal	Arduino e Lego Mindstorms	Vygotskij's educational theory. Bloom's Taxonomy.	Mindlab2 adds aspects of personalized and adaptive e- learning in a usual environment supporting learning by tele operation of robotic devices.	In MindLab2, adaptive provision of problems is added to the capability of full interaction with the physical devices of the laboratory.	The learner can build her personal learning path, by selecting problems in an available repository, guided by her interest, preferences and learning goals, with the only constraint given by the limitation to choose problems that are in the affordable zone.	Authors have yet to perform a field experimentation, due to the fact that teaching time is still to start at the time of writing the paper. The integration of simulation drivers into the system is a primary aim for future work. The development of the theoretical model underlying the system, regarding specially the definition of a more extended student model.
[26]	2007	Validation Research	-	Naive Bayes.	The system gathers data from the users (students) on-line as well as updates the user models continuously. Moreover, the system has such abilities as guiding and serving additional explanations according to the users' preferences and defects in the knowledge domain.	-	System presents the materials with special media tools and content types considering learning style for each student. Students are tested when the first session is started. Models are updated with interactions applied by users. The system determines the knowledge status of each user for each concept which consists of the domain model.	-
[27]	2010	Solution Proposal	Robot platform Mahru-Z.	Cognitive architecture ICARUS.	System structure also facilitates easy updating of various application services, through the network, so the same robot can be used to provide improved services depending on its environment and commands.	Physical restrictions in the robot platform have added complexities in various dimensions, but the architecture successfully manages to produce a valid procedure to achieve the given goals.	A new system to materialize cognitive tasks in the real physical domain by applying ICARUS. In this paper, experiments are conducted such that a robot performs the task of stacking the blocks by sorting them according to colors in the Blocks World domain.	Verify the capacity of the architecture by a simple task called the "block stacking problem"; so now this architecture might be used in more diverse and complex tasks in near future.
[28]	2013	Solution Proposal	Darwin robot.	-	Math testing scenario to evaluate the role and effectiveness of engagement using a robotic agent.	-	System that integrates a robotic educational agent into a math learning scenario and discuss the processes employed to reengage the student using behaviors comparable to that of a human teacher.	Expand this research to use children as subjects rather than college-aged individuals and older, and implementing a proper robotic tutor that employs machine-learning techniques to build a model of the student with whom it is interacting.
[29]	2015	Solution Proposal	Aldebaran NAO robot.	Felder and Silverman.	Socially Assistive Robot (SAR) tutoring system to support the efforts of educators in teaching number concepts to preschool children.	Train a personalized number concept learning model constructed using literature-based and expert knowledge on number concepts learning.	Presented an interdisciplinary design process, a multimodal data collection, and initial results for a SAR approach to personalized education, specific to preschool number concept learning.	Authors intend to explore the multimodal aspects of the children's interactions in greater detail.