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ANALYSIS OF THE SYSTEMATIC APPROACH TO DEVELOP COGNITIVE PRODUCTS IN ACADEMIC RESEARCH PROJECTS

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1. Introduction

In recent years, research and development have advanced enormously in the research fields of robotics and artificial intelligence. The first milestones of this research were accomplished by pioneers like Newell and Simon [1961] with a computer model for human problem solving behaviour. Since then, the development of cognitive products has been growing with increasing demand for autonomous and smart products. One scenario, where cognition in products will become necessary in the future, is the growing ratio of elderly people in Germany: The increase of the ratio of over 65 year olds is estimated to 14% from 2008 (20% ratio) to 2060 (34% ratio) [Statistisches Bundesamt 2009], so that the demand for cognitive products that help managing every-day life, e.g. grocery shopping or cleaning, is increasing rapidly. This makes the development of cognitive products and the research into supporting design methods an important research topic.
A systematic approach using special development methods guides the designers through the development process and allows a complete documentation of all development steps and their results so that the development process becomes transparent and more transferrable to other areas. This makes conducting future developments more efficient and faster. Due to the characteristic that development methods are typically used and discussed in teams, they support the developer's collaboration as well as their solidarity. From industry it is well known that development methods and procedural models like the V-Model [VDI 2206] are used to develop standard mechatronic products. However, what remains unknown is if and to what extent those models and methods are used in the development of cognitive products and products with cognitive functions. This paper presents the results of a review, analysing systematic approaches to develop cognitive products in literature and in academic research projects, and a procedural model supporting the development. Over 20 publications presenting the results of different cognitive product development processes were analysed regarding what procedures, models and methods were used and 13 researchers from academic research projects in this area were interviewed to investigate their individual development approaches.
In section 2, procedures, models and methods which are currently available for the development of cognitive products are summarized and the surplus value of this support is explained. In section 3, it is analysed which procedures, models and methods were actually used and it was explored if a systematic order to develop cognitive products exists in academic research projects. Further, it was investigated which development steps seem reasonable for a systematic development approach using development models and methods and a reasonable order of development tasks is proposed. With the results, the V-model was adapted regarding development steps especially relevant for cognitive product development. Cognitive products are multi-disciplinary products grounded in a mechatronic platform and thus the V-model, a procedural model for mechatronic product development, is suitable.

2. Background

Cognition is a process through which a system acts effectively in its environment, and in doing so its cognitive capabilities (its repertoire of executable actions and its ability of anticipating events) are improved continuously [Vernon et al. 2010]. A cognitive system is defined as an enactive system: Accordingly, cognition arises only when the five key elements "autonomy", "embodiment", "emergence", "experience" and "sense-making" are achieved [Vernon et al. 2010]. A cognitive product picks up the aspect of embodiment in its definition as a durable and tangible system with cognitive capabilities that are embodied by mechatronic components (hardware and software) [Metzler & Shea 2010]. The cognitive capabilities are responsible for the product's surplus value.

Vernon et al. [2010] give a first hint for a chronological order to develop cognitive products by introducing the term "cognitive architecture" and placing it chronologically at the beginning of the development of a cognitive system. A cognitive architecture is a software infrastructure of an intelligent system where common and constant features of a cognitive system are specified. Hawes et al. [2006] further divide the development of a cognitive architecture in three steps: "identify requirements for a cognitive architecture", "develop an architecture-scheme" and "instantiate architecture schema in a physical system".

To date, development methods for cognitive architectures as well as development methods focussing on other parts of the development process can be found in literature, e. g. the Cogaff-Scheme is designed to support developing a modular cognitive architecture [Sloman 2001]. Further support in the field of cognitive architectures is proposed by Dittes & Goerick [2011] with the unified systematic language "Systematica 2D" which can be used to compare different cognitive architectures. By identifying the structural characteristics of a cognitive architecture and then translating it into this language that consists of uniform structural components of an architecture, several features of the cognitive architecture, e.g. different process flow directions or functional components of sub-architectures, can be compared and evaluated. This allows to find and select the most appropriate architecture. Metzler & Shea [2010] propose a standard definition for the term "cognitive product". Several requirements can be extracted from this definition and Metzler & Shea classified them in a catalogue of cognitive functions. Metzler & Shea [2011B] further propose a taxonomy of cognitive functions designed to model cognitive products with functional models. To create a functional model, the functions of a product are defined and put into a chronological order or into a relation with each other. This functional modelling approach supports developers of cognitive products during the conceptual design of a cognitive product. Furthermore, Metzler et al. [2013] describe a development method to systematically extend the product's cognitive functions by systematically integrating cognitive user functions and thus extending the product's system boundary. A holistic analysis of different representational models for cognitive products is given by the Causal Diversity Matrix which classifies different types of suitable representations according to the complexity of the system [Minsky et al. 2004].

A broader range than those development methods is addressed by two procedural models that pick the development of cognitive products out as a central theme: Metzler & Shea [2011A] propose a procedural model that had originally been designed for integrated new product development (iNPD). They adapted this model for the development of cognitive products. Further, Dumitrescu [2010] presents a procedural model for the systematic development of cognitive products which contains a set of methods and tools that are designed especially for cognitive product development. This procedural model is based on the VDI guideline 2206, tailored to the development of mechatronic products, and focuses on the early development phases like the concept phase during the product development process. The aim of the model is to integrate cognitive functions into mechatronic systems.

3. Analysis of the practical approach to develop cognitive products

3.1. Method

In order to structure the research process, the Design Research Methodology (DRM) [Blessing & Chakrabarti 2009] was applied and the analysis divided into three phases: first descriptive study, prescriptive study and second descriptive study. In descriptive studies, aspects of the research problem are analysed, whereas in prescriptive studies the descriptive studies are interpreted and support is proposed. Later phases built on information gathered in earlier phases. The authors investigated whether the existing support described in section 2 is known to and used by developers of cognitive products in academic research projects. Further, it was analysed if a strategic approach to develop cognitive products exists in academic research projects and if patterns in the order of development steps can be identified because they re-occurred frequently. The first descriptive study was used to assess the most important development procedures, models and methods that developers used during their projects. The goal was to limit the scope of the second descriptive study and to substantiate its focus. For this, a literature analysis was chosen as research method where several procedures, models and methods were classified according to their frequency of use. Infrequently used models and methods were disregarded in the second descriptive study. For this, an extensive questionnaires accompanied by personal interviews was used.

3.1.1. First Descriptive Study

The first descriptive study was used to limit the huge amount of existing procedures, models and methods to a number which had already been applied to develop cognitive products and is acceptable to be assessed in this study. As the second descriptive study was conducted using personal interviews, this study was particularly important.

First, appropriate literature sources for the analysis were found by an internet search for scientific publications about previously developed cognitive products. It was tested whether the potentially relevant sources really broached the issue of the development of one or more cognitive products and qualify as a research object. As an orientation the definition for cognitive products from Metzler & Shea [2010] was used and all functions of a cognitive product were extracted and weighted with weighting factors (wf) according to their relevance (little relevant: wf=1, relevant: wf=3, very relevant: wf=9, extremely relevant: wf=81, see Table 1). Next, the criteria from the definition were written into the first column of Table 1 and every source was analysed whether it fulfils the criteria.

Table 1: Assessment of Cognitivity of Products (left: weighting factors).

		Al-Safi & Vyatkin 2007	Kuratate et al. 2011	Kranz et al. 2007B, Kranz et al. 2007A	Kanda et al. 2002	Schmidt et al. 2004	Cook et al. 2003	Holleis et al. 2005	Ryland & Cheng 2010	Melhuish et al. 2006	Jones, J. L. (2006)	Sandini, G., et al. (2007), Metta, G., et al. (2010)	Wimmer et al. 2007A, Wimmer et al. 2007B	Beetz, M., et al. (2008)	Laird, J. E., et al. (2012)	Le, C. D. (2002)	Chella, A., et al. (2007)	Srinivasa, S. S., et al. (2010)	Lanigan, P. E., et al. (2006A), Lanigan, P. E., et al. (2006B), Narasimhan, P. (2006)	Gerlinghaus, F., et al. (2012)	Rogers, A., et al. (2012)
Weight	**Parameters**	**V***	**V***	**V***	**V***	**V***	**V***	**V***	**V***	**V***	**V***	**V***	**V***	**V***	**V***	**V***	**V***	**V***	**V***	**V***	**V***
1	tangible	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1
1	durable	0	0	0	1	1	1	0	1	1	1	1	0	1	1	1	1	0	1	1	1
9	cognitive capabilities	9	9	9	9	9	9	0	0	0	9	9	0	9	9	9	9	9	0	0	0
1	physical carrier system	1	1	1	1	1	0	1	0	1	0	0	1	0	0	0	0	0	0	0	0
3	embedded mechatronix	3	3	3	3	3	0	3	3	3	0	3	3	0	3	0	0	0	0	0	0
3	embedded electronie	3	3	3	3	3	3	3	3	3	3	3	3	0	0	0	0	0	3	3	0
3	embedded microprocessors	0	3	3	0	3	0	3	0	3	3	0	3	0	0	0	0	0	3	3	0
3	embedded software	3	3	3	3	3	3	3	0	0	3	3	3	3	3	3	3	3	3	3	0
1	surplus value	1	0	1	0	1	1	1	1	1	0	0	1	0	0	0	0	0	0	0	0
3	cognitive capabilities are responsible for surplus valus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	flexible control loops	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	cognitive algorithms	9	9	0	9	0	9	0	0	0	0	9	0	9	9	9	9	0	0	0	0
1	satisfaction of customer needs	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0
9	intelligent behaviour	9	9	9	9	0	9	9	9	9	0	0	0	0	0	0	0	0	0	0	0
3	flexible behaviour	3	3	0	3	0	3	0	3	0	3	3	0	3	0	0	0	3	0	3	0
3	robust behaviour	3	3	3	0	0	0	0	3	0	0	0	0	0	3	3	0	0	0	0	3
1	customers needs are met/ exceeded	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
81	all/some characteristics of a Cognitive Technical System**	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81
138	**Sum**	126	128	117	123	106	120	105	105	103	105	113	96	108	110	107	104	96	92	95	86
	Percentage (rounded by 1 decimal)	91,3	92,8	84,8	89,1	76,8	87	76,1	76,1	74,6	76,1	81,9	69,6	78,3	79,7	77,5	75,4	69,6	66,7	68,8	62,3
	*V = weighted value																				
	** characteristics: collect sensor data from internal and external state, process and interpret data according to sensed situation, different output with same input possible, flexible & adaptable, reflection of environment, goal: increase own performance, minimize resources, high degree of interaction with humans)																				

If a source was stated irrelevant, it was disregarded. All other sources were assessed according to the criteria. A fulfilled criterion was marked with the number “1“ in the corresponding cell of the table and multiplied by the weighting factor, non-fulfilled criteria were marked with a “0“. The cells of each column were added up separately. Those sources that fulfilled at least 50 % of all functions of a cognitive product were investigated further. With this approach 20 products were identified.
Next, a systematic analysis of development procedures, models and methods was conducted. The selected literature sources were re-read and it was assessed whether they contain any of a predefined set of different development procedures, models and methods, e.g. procedural models like the V-model, strategies like “systematic thinking”, computer tools like CAD, product development methods like “QFD or FMEA” as well as the models, methods and cognitive architectures referred to in section 2. The predefined set of development procedures, models, methods was derived from product development textbooks. If a source contained such a procedure, model or method, it was labelled in an Excel spreadsheet. Finally, for each method it was calculated how often it appeared in the sources.

3.1.2. Prescriptive Study

In the prescriptive study, the literature results were evaluated and interpreted in order to classify the different procedures, models and methods according to their relevance. The evaluation of the literature analysis was based on the number of occurrence of the development procedures, models and methods, described in section 3.1.1. Overall, 49 development procedures, models and methods were identified in the Excel spreadsheet. In order to classify them, an ABC-analysis was performed. The development procedures, models and methods were first sorted by their number of occurrence in the literature. Then their individual percentage share was calculated. Subsequently, those percentages were accumulated so that all development procedures, models and methods together perform a 100%-contribution to the development. To determine the key support, the development procedures, models and methods were then divided into three groups A, B and C, using the axis “value of the used method“ as orientation. Those that had a share of 0 to 70% in the development of cognitive products were classified as “A“, the ones with values between 70% and 85% as “B“ and the rest (>85%) as “C“. Though group A contains only few procedures, models and methods, these represent 70% of the development support for cognitive products (in terms of usage, not effort). This indicates the relevance of these procedures, models and methods for the development of cognitive products. In contrast, support from group C was used only infrequently. The ABC-classification enabled a substantiated selection of development procedures, models and methods that were assessed in the questionnaire. All from group A were integrated into the questionnaire, the ones from group B were selected by expert judgement and those from group C were disregarded.

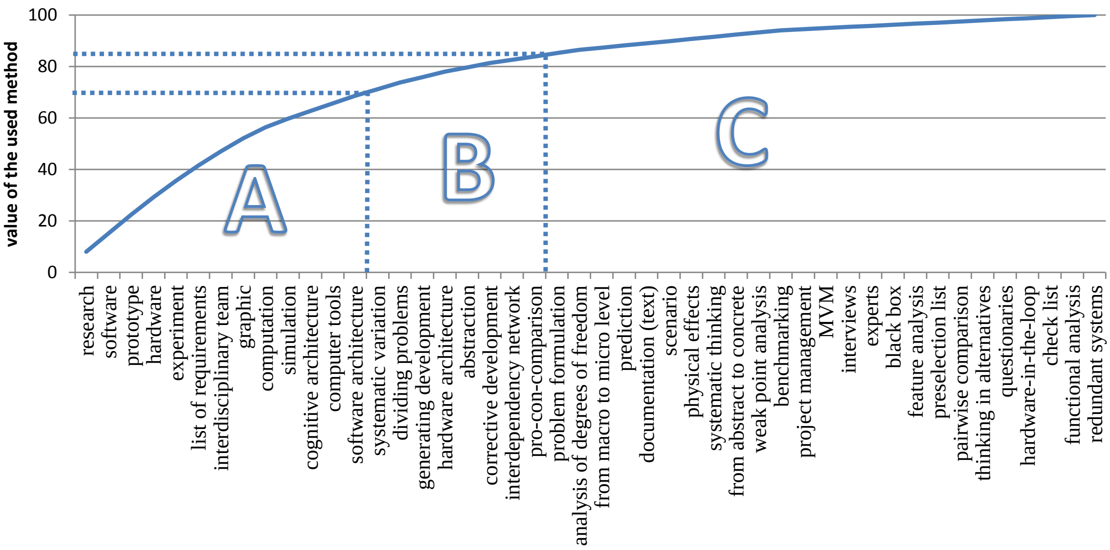

Figure 1: ABC Analysis: Classification of Used Models and Method in Groups A, B and C.

3.1.3. Second Descriptive Study

The goal of this study was to analyse as many and as different aspects as possible concerning the development of cognitive products in academic research projects. The aim was to analyse which procedures, models and methods were used in academic research projects and if patterns of an optimal order of development steps could be identified. For this, 13 research assistants and PhD candidates, personally involved in the development of one or more cognitive products, were asked to answer 47 questions in personal interviews about their approach to develop cognitive products which each took about 60 minutes. The respondents were or are involved in the development of at least one cognitive product or part of it and were working in predominantly interdisciplinary teams (85% of the respondents) in an academic research environment. For the assessment of used procedures, models and methods, the findings from section 2 as well as the results from the literature analysis were incorporated into the questions about development procedures, models and methods. For an analysis of patterns in the order of development steps in academic research projects the respondents were encouraged to name crucial development steps. In order to find a suitable order of development steps in which development steps should be conducted, the respondents were asked to bring predetermined development steps into an order that they would choose if they would start a new development process. For these predefined development phases the V-model was used as orientation, because this model is well known, designed for mechatronic systems and therefore is considered suitable for cognitive products which are based on mechatronic systems. To integrate the aspect of cognitive product development, the steps “plan cognitive architecture“, “choose cognitive architecture“ and “integrate cognitive architecture“(see Fig. 3) were added.

The results of the questionnaire are the following: A quantitative evaluation of the frequency of use of models and methods shows that the development support from section 2 was predominantly unknown and if known, it was only used by a maximum of three respondents. 46% of the respondents searched for support, but only 31% found appropriate supporting material. In contrast to the previous findings, all respondents used a procedural model to develop their cognitive product. The iNPD model from section 2 was used twice, whereas the V-model was used six times. Further procedural models were used once. In contrast to this consistent use of a procedural model, even though they were different, only three of 13 respondents used cognitive architectures.

In a different question concerning the frequency of use of models and methods it was assessed whether methods used in non-cognitive product development were used in academic research projects. Fig. 2 shows the absolute numbers of the given answers, generated by a quantitative analysis. The number of uses of the models and methods were counted from the questionnaire answers and sorted.

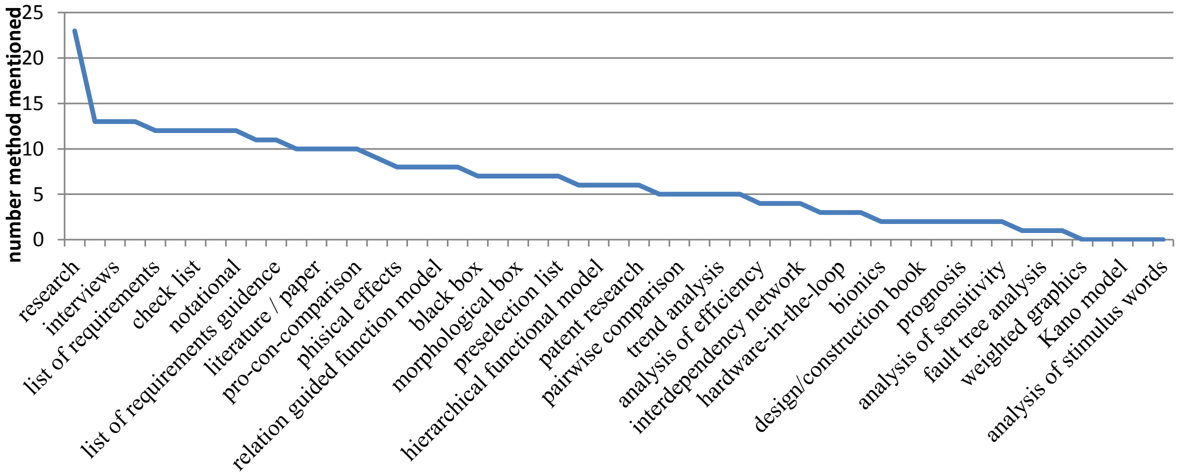

Figure 2: Absolute Numbers of Given Answers in Descending Order.

To determine the order of development steps the respondents followed in their academic research projects, they were asked to write down essential development steps they had gone through. The results are manifold because they were drawn from freely given textual answers so that a qualitative,

systematic evaluation had to be carried out. First, all answers were grouped so that similar answers were in the same super-group. If there were still too many sub-groups in each super-group after the first grouping, the sub-groups were further abstracted into middle-level groups according to their similarity. As a result, the previous super-groups were segmented into middle-level groups which were again segmented into the sub-groups – a three level hierarchy with increasing level of detail. The lowest level groups were disregarded in the further procedure. The super-groups thereby represented different development phases and were given suitable names: “idea phase”, “concept phase”, “solution phase”, “realization phase”, “synthesis phase”, “documentation phase” (see Fig. 3), while the middle-level groups represented different development steps within each development phase. After this classification stage, the development steps were coded with numbers and those numbers were referenced back to the original answers of the respondents. Doing this, every answer belonged to a development step of a certain development phase. This procedure had the goal to develop an order of development steps of the hands-on approach used by the interviewed developers. Therefore, all directly neighbouring successors of each development step were documented (e.g. the respondent did development step 2 after step 4, so number 4 was written next to number 2). Thus, the number of repeating pairings could be counted. In a next step, these pairings were sorted by their number of occurrences. First, the most frequent pairing was identified and all other pairings that oppose to this pairing were disregarded (e.g. if the most frequent pairing is 4-2, 4-3 is not a possible pairing anymore). In the end of this procedure, all winning pairings were connected to each other so that a graphical representation of connected pairings was generated (e.g. 1-4-2-5) that represented the order of development steps. However, the first run through this method did not generate a consistent order but generated more than one possibility – it seemed that the development steps were defined in too much detail to generate a consistent order. Thus, some of the development steps that had very low frequencies were merged to one development step and the sorting process was repeated. The whole procedure was repeated until a consistent order of development steps was generated (in this case after 1 repetition) (see Fig. 3, “order of development tasks in academic research projects”).
Next, it was examined in which order the respondents would execute development steps if they followed their intuition in a new project. They were given the task to order predetermined development phases and steps they could choose from. Additionally they were allowed to add individual development phases and steps. Following, the authors determined the order of development steps with the same qualitative method shown before (see Fig. 3, “reasonable order”).
A comparison between the reasonable order of development steps and the order in academic research projects shows: The two development steps “find ideas“ and “analyse, choose and evaluate ideas“ from the development in academic research projects were merged to one development step: “find ideas (analysis of environment, choice and evaluation)“. Further, the respondents regarded the development step “plan product and procedure, identify requirements and cognitive functions“ as a useful step in the beginning of the development. In both orders, the development phase “idea phase” was set to the beginning of the development. The order of the following development steps “identify, choose and implement solutions“ (part of the solution phase), “identify, chose and evaluate features of finished solutions“ (part of the realization phase) and “combine partial solutions to one solution“ (part of the synthesis phase) was the same in the intuitive reasoning and in academic research projects. One distinction was found according to the use of cognitive architectures: Although this development phase did not appear in hands-on development, it was regarded as useful. However, the respondents could not decide for an exact position of this development phase. Some respondents put it between concept and solution phase whereas others chose a position between solution and realisation phase and a third group opted for a place between the realisation and the synthesis phase. This was interpreted, because these development steps did not have a high number of occurrence but had been mentioned frequently in the answers. A documentation of the results was not mentioned in hands-on development projects but was regarded useful at the end of the development in the reasonable development procedure.

3.2. Result

Based on the results of the literature analysis and the evaluation of the questionnaire an extended procedural model was designed (outmost model shown in Fig. 3).

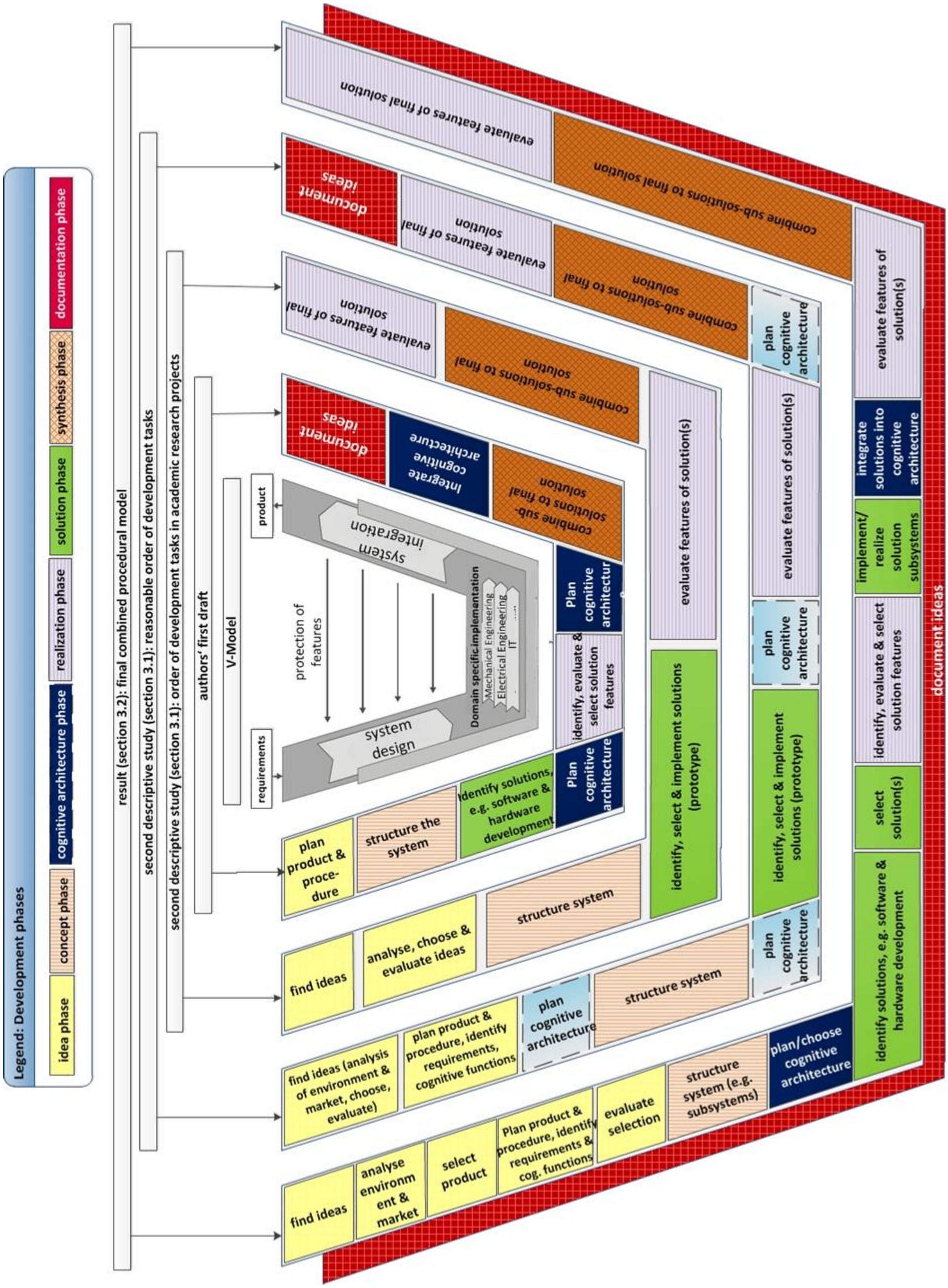

Figure 3: Adaptation Process: From the V-model [VDI 2206] to the Proposed Procedural Model for the Development of Cognitive Products.

Further, the graphic shows the original V-Model, the first draft used in the questionnaire to determine the reasonable order, the order of development tasks in academic research projects and the order of development tasks regarded as reasonable. The final model was derived from the three previous procedural models by harmonizing and complementing all development phases and steps. In this procedural model, demands stated by the respondents are met. For example, instead of a documentation at the end of the development a continuous documentation in the form of models, simulations, reports, presentations and publications is proposed. The structure is set to be modular so that the procedure can be adapted to the individual complexity of the product. This allows leaving out or re-arranging development phases if not needed or inapplicable. Further, iterations among development phases are possible if the goal of a development phase has not been reached in the first run. The proposed procedural model contains (like in the first draft and the approach by the respondents) the idea phase, the concept phase, the solution phase, the realisation phase and the synthesis phase. Each of these phases is divided into development steps and these sub-phases allow iterations and adaptions tailored to the complexity of the product, too.

4. Discussion

The existing development methods described in section 2 were designed to support developers while conceptualizing product ideas, creating solutions or integrating specific simulation methods into a cognitive system, but they lack a procedural model that allows developers to start their project by choosing the right development method and to be guided systematically through the whole process of product development. The existing procedural models described in section 2 seem to represent such an aid for orientation during the development of cognitive products, but they are incomplete and generic. The procedural model for iNPD used by Metzler & Shea [2011A] lacks an explicit support for integrating cognitive functions into the product and the procedural model proposed by Dumitrescu [2010] focusses mainly on early development phases instead of guiding the developer through the complete process. Thus, a procedural model which combines the existing models and methods and optimizes them for the specific development of cognitive products was still missing.

The results of the literature analysis show how frequent various development procedures, models and methods were used while developing a cognitive product. If development procedures, models and methods were consciously used but not mentioned in literature, they were not detected by the analysis and their frequency of use could not be measured. Furthermore, unconsciously used development procedures, models and methods could not be extracted from the literature sources. Still, the research method indicates tendencies about the use of support. With the ABC-analysis it was possible to reduce the scope of the second descriptive analysis and to concentrate on the important procedures, models and methods. At last, as the authors of the inspected literature were not only researchers from university, the literature analysis covered a broader range of development backgrounds than the second descriptive analysis which was restricted to academic research projects.

The questionnaire was answered by 13 academics who work(ed) on a variety of different projects addressing different cognitive product contexts. Statements of correlations between different answers (e.g. if the use of a cognitive architecture is linked to the product's degree of complexity) were not possible. For this kind of conclusions a much bigger number of respondents is needed. The analysis whether developers choose a systematic approach for developing cognitive products led to the following conclusions: As a majority of respondents had to adapt the procedural model they were using, a procedural model specifically designed for the development of cognitive products is reasonable. Further, the majority of developers was looking for suitable development methods for cognitive product development but did not succeed. This means: Even if those development methods exist in today's state of the art, they are hard to find. Thus, a scheme of existing models and methods is required. However, it can not be disregarded that some development methods were not used by the developers even if they were known. This means that it has to be investigated if those development methods are relevant. The order of development phases and steps in academic research projects constructed by the respondents' answers shows that the majority of the developers chose a systematic development approach. The pattern of this order of development phases and steps is very similar to the pattern the authors previously chose as a first draft order of development phases and steps. A manipulation of the respondents' answers by the first draft of the authors did not happen because the respondents did not see the draft until they had described their own procedural steps. If the development phases that address the cognitive architectures as a central theme are neglected, the order of development phases/methods and the proposed order by the authors are nearly identical. The only exception is that the documentation was not mentioned by the respondents. Reasons for this could be that the documentation of results was regarded as self-evident or unnecessary. The otherwise very similar order could be justified because the V-model which served as an orientation for our first draft reflects an intuitional order to develop cognitive products. A second reason could be that the respondents consciously acted systematically so that they used the V-model as an orientation. This conclusion is supported by the fact that 6 out of 13 respondents did use the V-model. In the questionnaire, the authors asked only for a sequential order of development phases and steps. Doing this, the possibility of a parallel execution of development phases and steps was not considered.

The orders of development phases and steps were constructed using a method that counts the number of occurrence of possible neighbours of a development step and chooses the neighbours with the highest number of occurrence in iterative steps. It was difficult to identify parallel or sequentially not explicit development steps. By prioritizing the neighbours according to their number of occurrence, it happened that some development steps were cancelled out completely from the final order of development steps. The authors interpreted these cases as follows: The development step "integrate cognitive architecture" was renamed to "integrate solutions into cognitive architecture" during our evaluation and was not a part of the occurrence-based order of development steps according to the results of the used method. One possible reason for this was the possibly unclear formulation of the term "integrate cognitive architecture". Another reason could be that the integration of technical solutions into the cognitive architecture is part of the solution phase in which solutions are identified, evaluated and combined to solution concepts. Due to the fact that only three persons used cognitive architectures during their work, it is not significant to discuss based on the results whether it would be reasonable to conduct this development phase and if it would be, when this development step should best be undertaken. The development steps "plan cognitive architecture" and "choose cognitive architecture" were regarded as reasonable by the respondents, but they could not compete with the other possible neighbours of the examined development steps. The inconsistent order set by the respondents could be a reason for this matter, because then the neighbour of the development steps differs more often so that the pairings have a smaller number of occurrences. The inconsistent order, again, could be caused due to the fact that up to date there is no known standard procedure. Therefore, we first abstracted these development steps and put them to different positions in our procedural model (blocks with dotted lines in fig. 3). The development step "documentation" results as last development step according to the method. In this case it has to be mentioned that this result may have been influenced by our formulation of the term in the questionnaire ("documentation of results") which possibly implied a process at the end of the development. During personal discussions with the respondents it was found that documentation was regarded as necessary and should be conducted continuously during the whole process of product development. Therefore, the exact positioning of the documentation phase should be optimized by further research. Further, while interpreting the idea phase we noticed that the development step "evaluation of the idea" was mentioned more often (three times) than the development steps "find idea", "analyze environment" and "analyze market" which were each mentioned once. Possible reasons for this could be that the idea was already predefined by an existing research issue within the research institute, or given by a supervisor. This seems plausible as 84,6 % of the respondents developed their cognitive product in an academic research project and therefore focussed mainly on the technical development and less on an ideal product selection. The development step "plan cognitive architecture" that was regarded as useful by the majority of respondents supports the assumption that using a cognitive architecture during development is useful.

The procedural model proposed in section 3.2 represents a first draft for an optimized procedure when developing cognitive products. It needs to be evaluated and optimized by further surveys with a bigger amount of test subjects. Further, the development phases of the procedural model must be extended by suitable and convenient development models, methods and tools. To accomplish this, the used models and methods from the questionnaire should be assigned to the most suitable development phase or new development methods that are designed for a specific development phase should be developed.

5. Conclusion

The research presented in this paper analysed the development approaches while developing cognitive products in literature and in academic research projects before deriving a procedural model. In today's state of the art, there exist development methods for cognitive architectures, development methods for different aspects of the development process as well as procedural models that focus on the development of cognitive products. Using questionnaires combined with personal interviews the authors consulted developers of cognitive products from academic research projects about their approach to develop cognitive products. Particularly, the use of cognitive architectures and several state of the art development methods and procedural models was investigated. Those are widely unknown or unused. In contrast, the majority of respondents worked in a development team and used a procedural model as support. A second focus is the analysis of a pattern in the product development processes in academic research projects and how they can help to improve existing support. Based on the results a procedural model is proposed in the form of an extended V-model with a modular structure and iterations. This model must be evaluated and optimized in future development projects.

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