A Periodic System of Artificial Intelligence as an Effective Means of Communication between Machine Learning Experts and Military Operators

Marlon Mylo
Bundeswehr
GERMANY
marlonmylo@bundeswehr.org

Paul Dykta
Bundeswehr
GERMANY
pauldykta@bundeswehr.org

Detlef Schoepe
Bundeswehr
GERMANY
detlefschoepe@bundeswehr.org

ABSTRACT

This publication addresses the problem of identifying potential applications of artificial intelligence (AI) and machine learning (ML) algorithms within the command and control (C2) process. Software components with weakly intelligent behaviour have been part of C2 for at least three decades now. Not only is there still much space for improvement and acceleration but it is also necessary due to the hybrid warfare characteristics to react faster and more flexible and to monitor threats which did not exist until recently.

To exploit the potential of AI solutions in the field of C2 it is inevitable to reach a better mutual exchange of thoughts between military leaders and AI-experts. A basic requirement for this mutual exchange is to standardize a common vocabulary and to convey the fundamental ideas of the different AI-approaches to the military personal. Both of which may be done by the use of a fitting abstraction of AI-approaches.

Here we present a real world software project to discuss three levels of abstraction to distinguish between different granularities of information exchange on AI-software solutions. While the lowest level of abstraction is too complex to allow for creating a standardized vocabulary the highest level of abstraction is too rough for many problem cases to design a fitting algorithm. Still this highest level of abstraction is important as we will show, as it is the best level for information exchange between the military operator and the AI-specialist. The highest level of abstraction is represented by a tiled AI-scheme, called the periodic table of AI (PTA). We suggest a novel guided workflow based on PTA to support the exchange between military personal and AI-experts to leverage the outcome of automation efforts. We will show that PTA is well suited as means of communication between the military operator and the ML-expert.. In future work it can be examined, if the existing PTA should be refined particularly with regard to the requirements of security forces.

1.0 OVERVIEW

A system developer is confronted with the problem of determining the actual needs of the customer. This is particularly difficult in the case of the complex military process of C2 – especially in the broad field of hybrid warfare. Here we have e.g. to take into account the speed of “Decision making by Algorithms” or “Deploying new Applications”. Hybrid warfare produces new challenges like what we will call here “Situational Twitter Awareness”, which may be seen as a part of the “Situational News Awareness”.

The necessity to determine the user needs is, in the classical customer product management workflow, met by gathering the stakeholder concerns. But this approach is too rough in the scenario in question. To set a time frame which is wide enough to enable human decisions without decelerating the leadership process, it is necessary to have a clear understanding of defined steps of the actual tactical mission throughout all touched levels of the military hierarchy. AI-experts do not have this military expertise, whereas military leaders are in most cases not trained enough in AI to identify opportunities for the usage of AI-software components.

In the first step (Section 2.0) we will introduce the necessary definitions which include our use of the technical term AI (Subsection 2.1), a description of the C2-process (Paragraph 2.2.2), a description of the PTA (Paragraph 2.2.3) and our understanding of hybrid warfare (Subsection 2.4). In the next step (Section 3.0), we will introduce a software-project, currently part of our product portfolio in our software development unit, which contains significant AI-components and describe this software-project from the point of view of the different abstraction levels. Then (Section 4.0) we will present a user study and conclude (Section 5.0) that the PTA is a decent way to convey an idea of the opportunities which are opened by the use of AI.

2.0 AI AS PART OF THE LEADERSHIP-PROCESS

We aim at supporting the C2-process and the involved sub-processes by the use of AI-based automation. In this section we want to clarify the use of the relevant terms. First we will give our definition of AI, and then we want to give an overview over the C2-process as it is used in the NATO and in the Bundeswehr. In the following we have to introduce the PTA. This serves as starting point for a comparison between the C2-process and the method of causal inference which is the underlying idea of the PTA (Subsection 2.2.3).

To close this Section we illuminate our task from the viewpoint of hybrid warfare.

2.1 Definition of AI

Here we follow the description of AI which is given in the service regulation of the German Bundeswehr:

> *AI is a set of technologies in which machines take over tasks with the help of highly developed algorithms, which require some kind of intelligence to be able to cope with them and which until now primarily or exclusively required human decision-making or action.*

Note that this abstract definition does not define any requirements concerning underlying algorithms. For the course of the publication it is important to note that in some cases a heuristically determined threshold may well solve the same problem as a deep neural network. To decide which technique brings the most reliable results, expert knowledge is indispensable.

2.2 The C2-process and its embedded business process

The C2 process is the core of the command-chain. As leading is a perpetual process and is, with respect to a given hierarchy-level and decision making, bundled in one person, the C2-process is modelled as a circle.

2.2.1 The C2-process, as it is described within the NATO

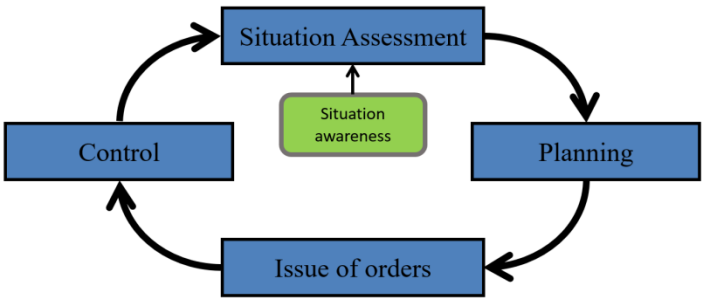

Figure 1-1: The C2-process as it is defined in the NATO.

In Figure 1-1 you can see a diagram-representation of the C2 process as one can find it in NATO-stipulations. Starting with the Situation Assessment this circle follows the same line as a Causal Inference Chain.

We gain the necessary Situational Awareness by *assessing* the relevant information from all operational nodes and our environment, from those information we *infer* a situation picture and possibilities of action and *respond* to the situation by decision making and issuing the necessary orders. The last step is to start the process again by controlling the results and assessing the new situation. Being part of a hierarchy, this diagram needs an incoming interface to receive orders from the hierarchy-level above, which is the situation assessment and an outgoing interface, the issue of orders to the underlying hierarchy-level.

2.2.2 The periodic table of artificial intelligence

Here we want to introduce an approach to classification of AI algorithms, developed by Kristian Hammond in 2016 [2] and presented by the Bitkom academy [1]. The idea is, to operationalize AI with respect to its application in business processes, by categorising it systematically into fields of application, represented by tiles in a particular sorting scheme, and assigning those fields to the three stadiums of the causal inference chain, consisting of *Assess*, *Infer*, and *Respond*. Here is not the place to describe the single tiles of the PTA or the systematic used to achieve the sorting grid; for an overview see Figure 2-2, for further information see [1].

The PTA-manual [1] presents four questions to be approached by the use of the PTA, one of which is:

> *How can AI-experts communicate with the domain-specialists on the potential of AI solutions to formulate plausible prospects in an understandable manner and to revise exaggerated expectations early?* (Freely translated by the authors).

Evaluating that question is exactly the issue of this paper.

2.2.2 Comparison

The causal inference chain is an integral part of any business process. In fact Hammond sees it as a part of any intelligent behaviour. The C2-process is specialized with respect to the indivisibility of responsibility, which leads to the following two characteristics: it is circular, with the implication that any inference chain may be unique and the decision making is an inherent part, which may not be omitted or substituted by machine decisions. With this in mind, we see and model the causal inference part of the C2-process where it is possible as business process starting with the Situation Assessment and ending with the Issue of the Orders and approach it by automating the underlying business process.

2.4 Hybrid Warfare

According to the German Federal Department of Defence [3], hybrid warfare is a combination of classic military operations, economic pressure, computer attacks and propaganda in the media and social networks. Large parts of hybrid warfare are located in the cyber information space. By automating parts of the C2-process in order to cope with threats stemming from hybrid strategies we gain:

1. an accelerated processing chain which may decide over success and failure of an operation,
2. the opportunity of continuously monitoring all available sensors and
3. a way to ensure continuous situational awareness.

In the next section we want to discuss the three levels of AI-abstraction using the example of a software component for news awareness, which is, according to the definition of the German Federal Department of

Defence, a particular case of situational awareness in the context of hybrid warfare.

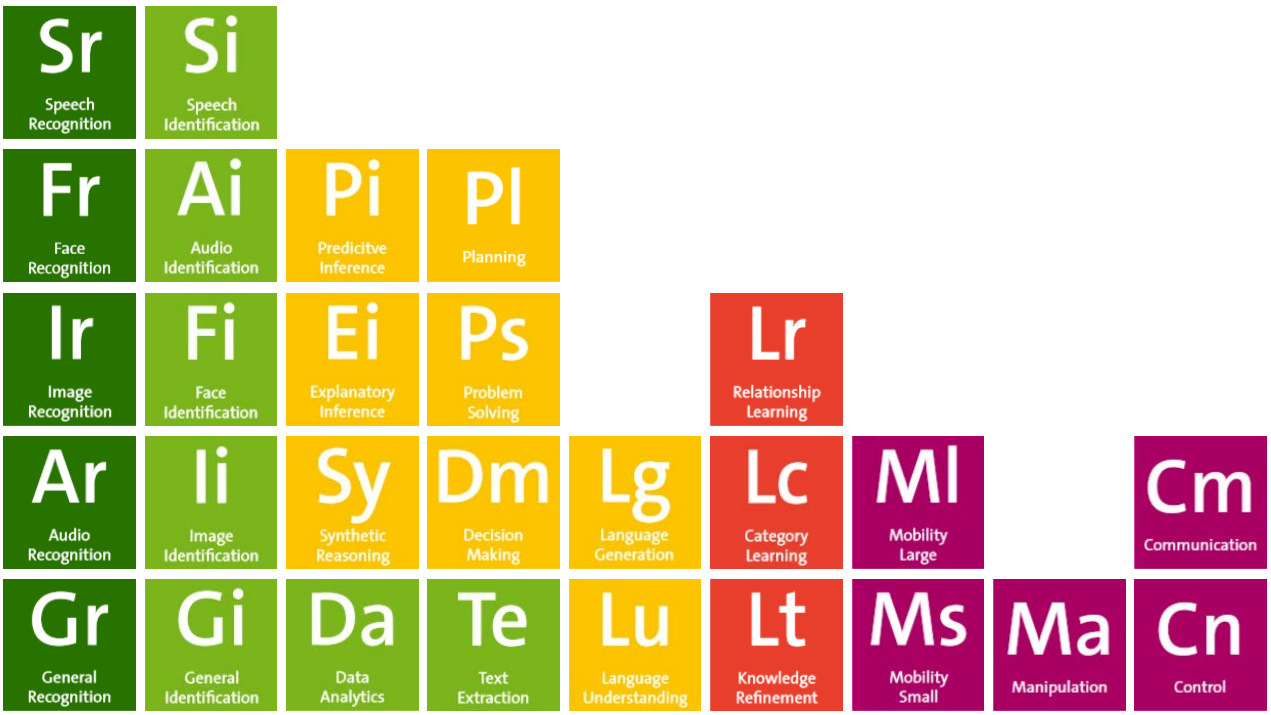

Figure 2-2: The periodic table of AI-elements. Elements of the *Assess*-phase are green, elements of the *Infer*-phase are yellow and Elements of the *Respond*-phase are red.

3.0 THREE DIFFERENT LEVELS OF ABSTRACTION

The software application, we want to present here, is a system for news-awareness. It is a specific project, which is currently handled in the Centre of Digitalization of the German Bundeswehr.

The Software scans a given dataset for relevant news which pass than a processing chain of six stages: the news are collected by a sensor and are preselected in a grabbing step. The preselected articles are compared to former results in a deep memory and go through a stage which we call cortex. In this stage the information is semantically augmented. Priorities are assigned during the second and the fourth step. The interface makes the prioritized topics available to the operator.

We want to illuminate the Grabbing mechanism from the viewpoint of the three different abstraction levels. The Grabber disassembles the given article formally. The fractures are classified and, based on this classification, prioritized.

1. From the highest level of abstraction, the viewpoint of the PTA, the grabbing mechanism is simply a text extraction (TE, see Figure 2-2).

2. In the midmost level of abstraction, you may use an algorithm taxonomy as e.g. provided by scikit-learn [4], to identify a suitable set of algorithms to classify the text modules.

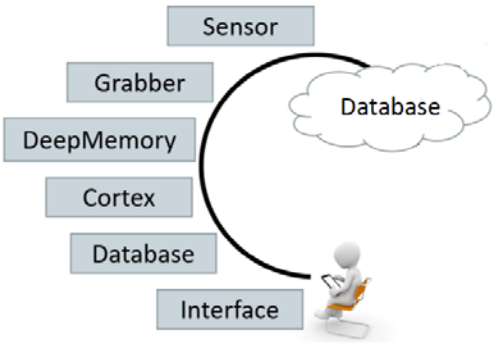

Figure 3-1: A software application for news awareness

3. On the lowest level of abstraction, a programmer has to decide, how to implement this classification step: he could make use of simple regular expressions to isolate certain keywords. Or, a more sophisticated approach, might search for certain word stems. And, of course, the programmer might use supervised learning on manually classified samples or make a classification based on clusters found by an unsupervised learning step. All of those approaches have different pros and cons.

4.0 USING THE PERIODIC SYSTEM OF AI TO CONVEY AN IDEA OF THE PROBLEM TO SOLVE

Obviously the lowest abstraction level is not suitable for a domain-specialist to identify possible usage of AI in this business-processes. Here, we will suggest a novel system based on the Nato Architecture Framework version 4.0 (NAFv4) to identify and transport ideas of the usage of AI in the particular business process. Observe that it is an explicit goal of the armed forces to describe all operational nodes and processes by the means of the NAFv4. Our idea is to use those descriptions to identify use cases for AI. The Activity-boxes may be used to drop the tiles of the PTA above it. We will show that the combination of NAFv4 and the PTA provides a good starting point for the description of AI-development requirements (see Figure 4-1).

After introducing the logical activity diagram (L4) from the NAFv4 we will give an overview over our interview-based user-study. Evaluation will be done in qualitative terms, only.

4.1 The Logical Activity Diagram

According to the regulations on customer product management, all business processes within any process of army equipment are to be modelled within the NAF framework. Business processes are modelled as logical activities. So in the long run there should exist an L4 diagram for almost every business process within the Bundeswehr. The L4 diagram is directly comparable to the elementary activity diagram from the unified modelling language.

Wikipedia describes it with the following words: *Activity diagrams are graphical representations of workflows of stepwise activities and actions with support for choice, iteration and concurrency.* In (Figure 4-1) you can see an example of an L4 diagram, as it has been used in our user study. Entrance and exit-nodes have been left out to spare space because the focus was on the recurring process.

4.2 User Study

In this section we want to present method (Subsection 4.2.1) and results of our user-study (Subsection 4.2.2).

4.2.1 Method

Our target was to decide whether a PTA-training of reasonable length leads for non-trained personal to an

enhanced awareness of application-fields of AI. In order to do so, we composed two example-processes: airspace-surveillance (A) and level monitoring at a dam (B).

In a first step the subjects were confronted with one of the both processes. They were asked to explain in their own words how AI may help to automate the given process.

In the second step the subjects should deal with the PTA. They were given the descriptions of the 28 elements of AI and should internalize the meaning of each element. Note that here the reasonable length of this training phase is a relatively strong objection because we cannot expect non-specialist to invest more than half an hour to study a complicated system which may or may not be helpful to their further work. This meant the subjects had not more than 60 seconds for each element. Shorter internalization phases were allowed.

In the last step the other process was presented. Here the subjects should indicate possible applications of AI by copying AI-elements from the PTA-scheme into the Activity boxes of the process-chain.

As the procedure is relatively long and we were only interested in a qualitative result [5], we confined to a small group of four subjects.

Two subjects were in the first step confronted with process A and in the second step with process B and for the other two subjects the order was the other way round.

4.2.2 Results

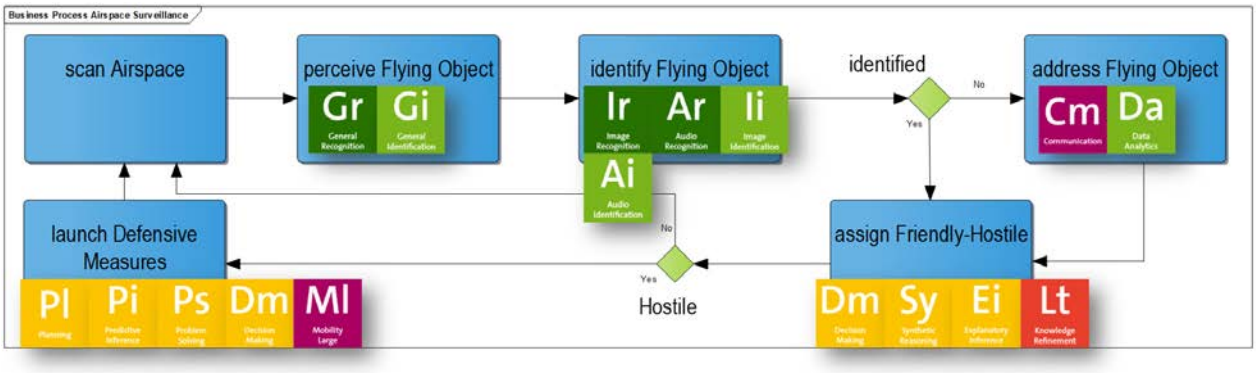

Figure 4-1: An example from the user study. Process A with the solution of subject 1.

Observations:

1. Independent of the group, the tile-based answers resulted in all cases more detailed than the text-based answers.

2. All text answers were correct, whereas some mentioned steps did not belong to the field of AI.

3. In two of four cases did the text-based answers not refer to the single steps but were general remarks on the use of AI.

4. Not all tiles were in a fitting place. But almost all misfits were due to either very general formulations of the tile title like “Data Analytics” or a misunderstanding of the difference between “Recognition” and “Identification”.

5. Some erroneous applications of tiles were in the same contexts seen on different solutions.

6. The tile-based answers in the group which started with process B were nearly similar (76% of the tiles were identically chosen and distributed).

7. One of the tile-based answers in the A-group was near to being a subset of the other answer (3 of 5 distributed tiles were identically chosen and distributed).

Inferences:

1. The application of the PTA sparks the phantasy of the subjects, with the positive effect of a deeper self-involvement into the problem and the negative effect of a higher susceptibility to errors.

2. The text-answers which did not suggest local applications hint to a very rough understanding of the mechanisms of AI. This rough understanding has been drastically improved by the study of the 28 elements of AI.

3. The high correlation between different subjects hints to a high operationalizability of such a tile based categorization of AI application-fields.

4. The incorrect use, particularly when it occurred in answers from different subjects, is a hint that the PTA-tiling is improvable with respect to its comprehensibility.

5.0 CONCLUSION

It is obvious that the use of the PTA has a positive effect on discovering fields of AI usage.

We have seen that without the pre-formulated tiles of the PTA, customers have problems to locate application opportunities for AI. But this means, that the second abstraction level, the use of algorithm taxonomy, is only for versed customers applicable.

It is still an important question, whether we should use the PTA at all. It might be faster to simply provide the Data-Scientist with the processing diagram and he will find out himself, what to do. Next to the fact that Data-Scientists are a scarce resource, we want to remind of the particularities of the C2-process: responsibility may not be delayed. Which implications does that have for the identification of application-fields of AI?

Our point is that it is necessary for the military leader to have an understanding of the workflow of the software. In Figure 5-1 you can see our news awareness tool. This time the Assess and Infer steps are highlighted. Note that the tool has no Respond functionality. Still there are made decisions by the algorithm. It is essential for the leading officer that he has at least an intuitive understanding of how the results come out. We could show that the use of the periodic system of artificial intelligence is capable of conveying this understanding.

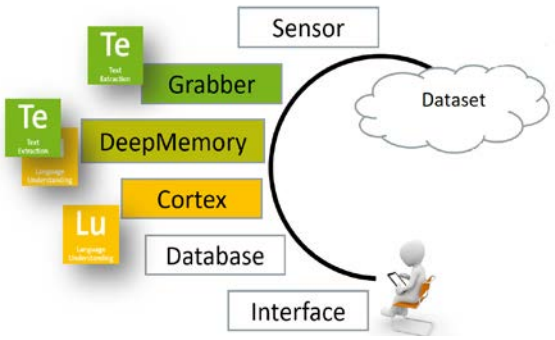

Figure 5-1: The PTA applied to the software application presented in Section 3

7.0 REFERENCES

[1] Bundesverband Informationswirtschaft, Telekommunikation und neue Medien e. V., (2018) *„Digitalisierung gestalten mit dem Periodensystem der Künstlichen Intelligenz“*, Retrieved September 9, 2021, from www.bitkom.org, 2018

[2] Hammond, K. (2016, December 14). *“The Periodic Table of AI”*. Retrieved January 22, 2018, from https://ai.xprize.org/news/periodic-table-of-ai

[3] Federal Minstry of Defence, *Definition Hybrid Warfare.* Retrieved September, 9, 2021, from https://www.bmvg.de/de/themen/sicherheitspolitik/hybride-bedrohungen

[4] https://scikit-learn.org/

[5] Bacher, J., Horwath, I. (2011). *“Einführung in die Qualitative Sozialforschung“*. Johannes Kepler Universität, Linz.