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THE INTELLIGENCE CORPUS, AN ANNOTATED CORPUS OF DEFINITIONS OF INTELLIGENCE: ANNOTATION, GUIDELINES, AND STUDENT RESEARCH PROJECTS

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Abstract

Intelligent systems are transforming the way we interact with technology, with each other, and with ourselves, and knowing at least what artificial intelligence (AI) means is becoming essential for designing, developing, deploying, using, and even regulating intelligent artefacts. Although defining intelligence has been one of the most controversial and studied challenges of both ancient and modern human thinking, a lack of consensus on what intelligence is has remained almost constant over the centuries. We argue that a better understanding of contemporary technologies, AI-based but not only, starts with a grounded exposure to their conceptual pillars. These include fundamental concepts like the concept of intelligence, in general, and of AI, in particular. Learners and decision makers at all levels should face them, as well as be able to discuss their importance and limitations critically and in an informed way. For doing that, they must be confronted with definitions of (artificial) intelligence and understand their meaning well, for instance. If these contents are already part of study programs, the better. In this paper we present how several definitions of intelligence were annotated, i.e. their properties and characteristics systematically analyzed and commented, in order to construct a corpus (i.e. a collection) of definitions of intelligence for further uses in AI and other fields. The work and the concrete application domain presented here have not yet been considered in the extended work on linguistic annotation (i.e. annotating definitions). Even though, both the annotation and the data merit special attention, for they deal with the elusive, important concept of intelligence, i.e. with definitions of both human and machine (or artificial) intelligence. Undergraduate Computer Science students carried out the annotation process and other related research activities. They were involved in a more general AI research project and included their findings and work as part of their undergraduate student research projects in their last study year. We provide details about how the student research projects were conceived, conducted, and mentored.

Keywords: AI literacy, annotation, artificial intelligence, corpus, intelligence, student research projects.

1 INTRODUCTION

A lack of consensus on defining intelligence has been a shaky stepping-stone not only for the artificial intelligence (AI) community: interested scholars have not come up with a cross-domain accepted definition of intelligence. Neither in the ancient Eastern nor in the ancient and contemporary Western conceptions of intelligence (see e.g. [1], [2], [3]) nor in the more recent perspectives from the last 70 years within the field of AI (see e.g. [4], [5], [6]).

There are several underlying reasons for disagreement on defining intelligence whose analysis would be beyond the scope of this paper (we refer the interested reader to [7] and [8] for related discussions on the lack of consensus). In Hunt and Jaeggi's [7] words, *"[i]t is not surprising that defining the subject matter of intelligence research has been difficult, for in everyday discourse the word intelligence is used in various ways."* Dickson [9] emphasizes that the definition of (artificial) intelligence *"shifts with technological advances and our expectations from computers. That's why it's pretty hard to determine what is or isn't AI."* And Chollet [10] states that *"[t]o make progress towards the promise of [the AI] field, we need precise, quantitative definitions and measures of intelligence—in particular human-like general intelligence."* Furthermore, the pressing need for clearer, good definitions of intelligence has crossed the academic river, reaching the industry, law, and public shores in unprecedented ways.

Delineating the boundaries of the discourse on intelligence may help in defining and understanding its most discussed concept, as suggested in [11]. Furthermore, better insights into definitions and how to define them has proven to be essential for a better understanding of concepts, intelligence and AI included (see for example [12], [13] and [14] for more on properties of good definitions). Knowing those concepts and related cognitive abilities (like defining, analyzing, understanding, discussing, and comparing definitions of intelligence, among others) is expected for AI researchers and practitioners in the first place. Yet, they are also central to extending or at least providing the basics of *AI literacy* to other stakeholders of our society.

It is the main goal of this paper to present how a few hundreds of definitions of intelligence (of both human intelligence and machine intelligence) were annotated by taking into account different properties of good definitions. In doing so, we follow the guidelines for annotation case studies suggested in [15], which also guide the structure of the paper and our methodology in what follows.

2 ANNOTATING DEFINITIONS OF INTELLIGENCE

The annotation case study that is the focus of this paper belongs to a rather uncommon domain in linguistic annotation: definitions of human and machine (or artificial) intelligence are annotated according to quality criteria for definitions. In other words, properties of good definitions are evaluated in order to conclude whether a certain definition of intelligence fulfils these properties or not. To our knowledge, this is the first time that such a problem is tackled in the sub-field of linguistic annotation. Next sections will provide the background and characteristics of this atypical annotation project.

2.1 The Annotators

The annotation of data either its nature can be a very challenging and time consuming process. On the one hand, it is a repetitive task fundamentally done by humans (i.e. annotators), mainly because the state of the art in automatic data annotation is still biased, error prone, and far from being entirely satisfactory. On the other hand, data is labelled according to its characteristics, but, even when done by humans, the annotation itself might require special insights into the problem domain. Furthermore, it might need a certain level of agreement on how to interpret and annotate the data correctly, as well as depend on advanced domain knowledge.

Software solutions are available for supporting annotators in their work (see e.g. an extensive review in [16]), but not for all kinds of data and certainly not for all kinds of situations that require specialized knowledge for annotating the data. This is the case when annotating definitions of intelligence according to several quality criteria, where AI-related knowledge might be critical and, thus, a pre-requisite for annotating.

In the case of our annotation project, undergraduate Computer Science students in their third-year studies are the annotators, the majority of them also attending a parallel course on AI. Furthermore, they were involved in related research tasks and completed corresponding student research projects that were especially considered as part of their term evaluation. This way, they could include the knowledge and practice they acquired by annotating the data into their learning and study, directly.

2.2 The Annotation Data

The annotation corpus consists of four collections of definitions of intelligence. Participants to a survey on definitions of intelligence [17] were asked to provide their level of agreement with definitions of both human and machine intelligence from the literature (for more on the survey, please consult the provided reference). They were also asked to justify their selection, as well as to provide new definitions of intelligence, if desired. A total of 567 responses from experts worldwide were received and contained more than 4000 comments or arguments in favor or against the literature definitions that were presented to them. Respondents also provided more than 300 new, suggested definitions of intelligence (213 definitions of human intelligence and 125 definitions of machine intelligence). This is how a mixed pool of what experts in other domains call “implicit theories” of intelligence (or people’s conceptions or what intelligence is) and “explicit theories” of intelligence (i.e. theories proposed by experts) was created (see [3] for more on implicit and explicit theories).

Tab. 1 shows the information contained in each collection. The four collections conform what we call *the Intelligence Corpus*.

Table 1. The Intelligence Corpus.

Collection	Content	Definitions
A	New, suggested definitions of *machine* or artificial intelligence by participants to the survey on defining intelligence [17].	213
B	New, suggested definitions of *human* intelligence by participants to the survey on defining intelligence [17].	125
C	Definitions of intelligence *from the literature* to agree upon in the initial edition of the survey on defining intelligence [17].	34
D	Definitions of intelligence from the collection presented in [18].	71

The following examples give an idea of the kind of definitions that are part of the Intelligence Corpus:

> *"Machine Intelligence is concerned with building systems that can adapt and learn in unstructured noisy domains." (From collection A)*
>
> *"[Human intelligence is] the ability to use information to accomplish goals." (From collection B)*
>
> *"Intelligence measures an agent's ability to achieve goals in a wide range of environments." (From collection C)*
>
> *"[Intelligence is] the capacity to learn, reason, and understand." (From collection D)*

As it can be seen, and compared to other case studies in linguistic annotation, the Intelligence Corpus is very small. Actually, it is very unlikely (indeed, not expected at all) that considerably many new definitions of intelligence are defined by experts and non-experts alike in a long-term future.

2.3 The Annotation Scheme

The annotation scheme referred to in this paper builds upon different works on properties of good definitions some of which were referenced to in Section 1. It uses most of the properties or quality criteria for definitions suggested in [14], which includes a compendium and thorough analysis of the literature on definitions together with their most desirable properties.

The following examples give an idea of the kind of quality criteria that were considered when annotating the aforementioned definitions:

> *A good definition of intelligence defines the "what," the thing to be defined. It defines [machine | artificial | human] intelligence.*
>
> *A good definition of intelligence is affirmative.*
>
> *A good definition of intelligence is comprehensive, in that it omits no essential attribute of the thing to be defined; it omits nothing which is a part of [machine | artificial | human] intelligence.*
>
> *A good definition of intelligence is clear, in that it avoids metaphorical, ambiguous language, and obscure terms. It is clearly written; it is perspicuous.*

Notice that some quality criteria are intuitive and easy to understand (and, thus, to verify), whereas others might be more complex, could require a deeper understanding (and, consequently, a thorough evaluation) as well as corresponding added efforts and time for assessing whether a certain definition fulfils the quality criteria or not.

From the 30 quality criteria for definitions introduced in [14], 21 were considered for annotating each definition from the Intelligence Corpus.

2.4 The Physical Representation

The collections from Tab. 1 were available in the form of MS Excel tables, one definition of intelligence per row. It was both a logical and straightforward step to extend them with new columns, each representing a property or quality criterion. The new tables were then imported into Google Sheets and prepared to make them available to the annotators, i.e. to the students, in a later step.

Because of the characteristics of the annotation schema and the size of the Intelligence Corpus, it was not necessary to use any other software or system for annotating. The concrete form and type of the annotated data will be clearer in Section 2.5.1 below.

2.5 The Annotation Process

The annotation process was done manually. On the one side, a reliable and consistent automatic or semi-automatic annotation of data for this very specific case study was not (and we do not think it will be in an advisable future) available: human language understanding continues to be an unsolved problem in the field of AI. On the other side, the advantage of having a small corpus did not merit the investment in extra resources that might slow down the annotation process as a whole.

Six annotators were involved, three female and three male, all of them undergraduate students in their third year of Computer Science studies, as introduced above. This allowed for at least a satisfactory level of knowledge about the definition of concepts, in general, and of AI, in particular. Crowdsourcing mechanisms for annotating were discarded: not only the size of the corpus was small, but we also assumed that the high-level subject matter might require an added, special training of the annotators, thus at least some exposure to related fields and topics was a requirement.

Three pairs of annotators were formed. Each pair annotated one third of the definitions from the corpus, i.e. 147 or 148 definitions of intelligence in total for each pair of annotators (see Fig. 1). Each annotator annotated her/his definitions independently.

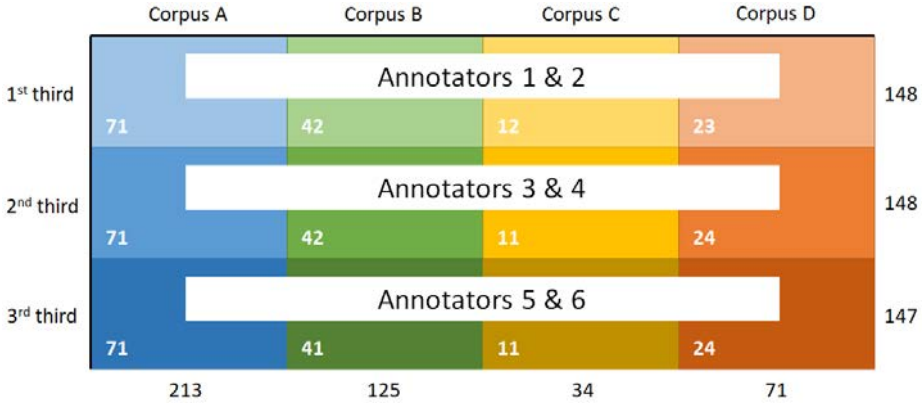

Figure 1. Distribution of definitions per groups of annotators.

The annotators were trained before the annotation process started. An initial meeting was held for this purpose. The training consisted of a general introduction to research topics involving the definition of the concept of intelligence, to the quality criteria for definitions, to related literature including the survey introduced in Section 2.2 (see [17] for more), to the collections of definitions that should be annotated, as well as to the annotation guidelines that will be presented in short. Furthermore, examples of definitions and how to annotate them when considering the quality criteria for definitions were also discussed.

Additionally, all annotators received the same information about the annotation process per email, as well as the annotation guidelines and the URLs with tables in Google Sheets containing both “their” to-be-annotated definitions and the quality criteria to evaluate them. As it was introduced in Section 2.4, the annotation tables contained as many rows as there were definitions of intelligence to be annotated (at most 148 definitions per annotator), and as many additional columns as there were quality criteria to be considered (a total of 21 quality criteria).

Feedback from annotators was collected at the end of the annotation process. The feedback included the time the students spent annotating the definitions of intelligence, which strategies they followed for the annotation, as well as general comments and remarks, if they had any. The annotators sent their results in a period ranging between less than two and up to nine weeks. It worth mentioning that they annotated the definitions and worked on the corresponding student research projects parallel to their attending other learning modules and classes.

2.5.1 Annotation Guidelines

Extra, specific to the case study annotation guidelines were especially conceived for the project. They followed some recommendations introduced in [19] and [20]. The guidelines include particular characteristics of as well as some relevant aspects that should be considered when evaluating quality criteria for definitions, together with the activities for doing so. They are listed in what follows in the form that was presented to the annotators:

- **How to proceed**: You can select one column (i.e. one quality criterion) and go row by row (i.e. definition by definition) to evaluate the same criterion for all rows. This could be faster than fixing a row (i.e. fixing one definition) and then analyzing all columns (i.e. all quality criteria) for that row. But you could also go the other way around because some columns are related or refer to similar criteria, plus you need to consider the same definition only once. It is up to you!
- **Write a 1** on a cell if the corresponding definition fulfils the quality criterion on the top of the column. For example, if a definition *d* defines machine intelligence (or human intelligence or intelligence, depending on the collection it belongs to) then write a 1 on the cell corresponding to the quality criterion *It defines the "what," the thing to be defined*. Leave the **cell empty** if not.
- Mark a cell in red (i.e. set the **background color** of the cell to red) or write an email asking for clarification, in case you don't have any idea about how to evaluate a given quality criterion for that cell. Such cases will be discussed in the team later.
- Notice that you **don't have to justify** your annotation. But, if you prefer, you could use the free columns on the right to write any **comments** or questions related to some particular "difficult case" that needs discussion. This should not be the normal case, though.
- **Annotate alone**. Do not discuss with other annotators about how to annotate a particular definition because this could introduce some bias in yours' or others' thinking. If necessary, write an email asking for clarification.
- **Do not fix** grammatical errors you might find in the definitions.
- How long did it take? **Record the time** you spend annotating whenever possible. This will be very useful for the upcoming publication about the annotation process!
- Write an email when you are **finished** with the annotations!
- Got any new **idea or suggestion** that could be included in these guidelines? They are welcome! Drop a line in any case.
- **Extra**: At the end of the annotation (or, better, during the process, if you prefer) write down your "strategy," i.e. what did you do and how; which problems, difficulties, or positive things did you find, etc. This could be part not only of the research documentation about the annotation process but also of your student research paper later!

As it was already mentioned, these guidelines for annotating definitions of intelligence were also presented and explained to all annotators in the initial meeting.

3 RESULTS AND DISCUSSION

This section summarizes the most important results and lessons learned.

3.1 Feedback from the Annotators

The time spent on the annotation by each annotator was between 4.5 and 8.5 hours, with an average time of 7 hours. One of the annotators did not record the time and gave as reason the varying conditions under which his annotation sessions took place (at home, at the university, in the train). A second annotator reported having consumed between 8 and 9 hours. In this case, a middle point was considered when calculating the total average time. On average, each annotator invested about three minutes on each definition and more than eight seconds on each quality criterion.

Evaluating whether a definition is *affirmative* or not is easy: for humans, it is straightforward to detect adverbs that denote negation. For example, the definition *"[Intelligence is] the capacity to learn, reason, and understand"* is posed in an affirmative way, there is even no need to read it until the end. Yet, evaluating whether the same definition is *comprehensive* might require a more complex thinking process. This shows how complicated or time consuming the annotation of a definition could be.

Four annotators reported their individual strategies for annotating. All of them proceeded by fixing a quality criterion and then annotating all definitions according to that criterion. General remarks concerning the annotation process included concrete interpretations of the quality criteria. Such remarks were reported by three annotators.

3.2 Inter-Annotator Agreement

The data from the annotators was easy to process once all annotations were available. Before that, the project leader checked the annotations for consistency, randomly.

Then, the inter-annotator agreement (IAA) was computed following Cohen's work [21]. Tab. 2 shows the results for each collection from the Intelligence Corpus and each group of annotators, together with averaged values. This part of the project was the particular research topic and focus of one of the students.

Table 2. Cohen's κ per collection and group of annotators.

	A	*B*	*C*	*D*	*Avg. per group*
Annotators 1 and 2	0.390	0.455	0.344	0.411	0.400
Annotators 3 and 4	0.346	0.361	0.457	0.465	0.408
Annotators 5 and 6	0.404	0.431	0.372	0.361	0.392
Avg. per collection	0.380	0.416	0.391	0.412	**Absolute:** 0.4

The IAA in the same group was between *fair* and *moderate* for all collections (i.e. Cohen's κ ranging from 0.344 to 0.465, and according to Landis and Koch's [22] interpretation of the values).

In general, the number of agreements among annotators was higher for the collection containing definitions of human intelligence, followed by the collection from [18], which includes many dictionary definitions of intelligence that, in general, are clearer and easier to understand. One possible interpretation is that definitions of artificial intelligence, both those provided by participants to the survey and from the literature, are still needing some work regarding expressiveness.

The quality criteria with the highest IAA values were those simpler, more intuitive, and easier to understand, as expected. However, the quality criteria for definitions with the highest number of disagreements (and thus, smaller IAA values among the annotators) were the following ones, in this order:

> A good definition of intelligence is *exclusive*, in that it includes nothing which is not a part of [machine | artificial | human] intelligence.
>
> A good definition defines the *"why,"* the purpose of the thing to be defined. It defines the purpose of [machine | artificial | human] intelligence.

In future annotation processes, it might be advisable to abound and explain better to the annotators what certain criteria mean, as well as to use more already (correctly) annotated definitions as examples.

Similarly, it was analyzed which definitions of intelligence received the highest and lowest number of agreements (or disagreements). For example, the annotators were more agreeable when evaluating the fulfilment of the quality criteria for the following definition:

> *"Intelligence is a very general mental capability that, among other things, involves the ability to reason, plan, solve problems, think abstractly, comprehend complex ideas, learn quickly and learn from experience."*

This result is not surprising: that one is Gottfredson's definition of intelligence [23]. Gottfredson's is not only a widely accepted definition of intelligence among experts in intelligence and allied fields [24], but it was also the most accepted definition of human intelligence in the survey presented in [17]. The annotators confirmed once again what a well-defined definition of intelligence looks like.

3.3 Usage

Both the annotated corpus and the original collections of definitions of intelligence (see Tab. 1, Section 2.2) are available upon request. They could be used by interested readers and practitioners, for

instance, when learning about fundamental concepts like the concept of intelligence, in general, and of AI, in particular.

As an example, we provide part of the Intelligence Corpus as a separate collection with 148 definitions of intelligence that were annotated by one of the students. It can be found at https://bit.ly/AnnotatedDefsIntelligence (see [25]) under the Creative Commons Attribution-ShareAlike 4.0 International (CC BY-SA 4.0) license. It contains the following information:

- 71 definitions of machine or artificial intelligence (from a total of 213) from collection A,
- 42 definitions of human intelligence (from a total of 125) from collection B,
- 12 definitions of intelligence (from a total of 34) from collection C, and
- 23 definitions of intelligence (from a total of 71) from collection D,

together with their annotations, i.e., whether they fulfill 21 quality criteria for definitions (see Section 2.3).

Furthermore, all definitions considered in the survey on defining (machine) intelligence [17] are available at https://goo.gl/KDPtKT, including their complete bibliographic information.

Finally, there is also an app that was developed by the project leader (also supervisor of the student research projects) for the purpose of supporting end users through the process of defining a definition. For example, all quality criteria for definitions are specified and exemplified there. The *Defintly app*, as it is called, may also assist future annotators in their annotation processes (visit https://defintly.glideapp.io/ for more).

3.4 Mentoring

There was enough prior experience available in mentoring and supervising student research projects of the kind presented in this paper. Further, the course on AI was delivered by the same instructor, what allowed not only for *ad hoc* discussions about the state of the art of the mentioned student research projects, but also about their content and goals in a broader setting. Other students also attended the AI course, thereby enriching their general knowledge and projects they were working on. Further, all necessary information not only key to starting the annotation process, but also the one concerning both project management and mentoring was carefully prepared, discussed with, and used by the students effectively.

4 CONCLUSIONS

This paper presented an annotated corpus of definitions of intelligence, the Intelligence Corpus, as well as details about its annotation, which was performed as part of student research projects in Computer Science. The Intelligence Corpus forms part of a peculiar annotation case study that evaluates whether definitions of human and machine intelligence satisfy desirable properties or quality criteria of good definitions. Future work includes a thorough discussion about some of the quality criteria (like those more difficult to interpret or annotate) and how to ease further annotation processes. Furthermore, a detailed, manually-conducted quality control of all available annotations will be performed in a near future. Occasionally, the corpus may be extended with new annotated definitions and/or new quality criteria.

Other possible uses of the Intelligence Corpus include training on the process of defining a good definition of any concept, which could be of interest to regulators or lawyers, for instance. In their case, it is essential to deal with legal definitions of different terms and, some of the times, they should even define the definitions themselves. Examples from the Intelligence Corpus would illustrate desirable properties for good definitions and help them in their work. In a similar vein, the Intelligence Corpus could be a complement to students, in particular, and academics, in general, that are learning how to conduct (or that are actually conducting) a concept analysis [26], like Philosophy students, for instance. Last, but not least, further uses of the corpus involving machine learning techniques to analyze its content are not discarded.

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