Chapter 5

A knowledge level account of inference

5.1 Introduction

In order to discuss relevant aspects of abductive inference as a type of knowledge, a framework for knowledge analysis and modeling is needed. Recent research in the area of knowledge modeling and engineering has produced several methodologies for analyzing and modeling knowledge and information at a conceptual and implementation-independent level. This level of system description is often referred to as the knowledge level, after Newell’s influential paper [Newell 82], while the level of implementation and representational constructs is referred to as the symbol level. Influential examples of methodologies that support knowledge analysis and modeling at the knowledge level are the Generic Tasks approach [Chandrasekaran 92], the COMMET methodology [Steels, 92], and CommonKADS [Breuker 94]. So far, context has not been systematically studied within a knowledge level framework. By building on results from each of the three example methodologies, we have found this level of analysis useful in order to understand the nature and the method of abductive inference. We will first outline the aspects important for knowledge level modeling. Additionally, we give examples from practical applications of knowledge level modeling. We will identify the components of a knowledge level model, and then illustrate the role of inference in this model.

In this chapter we form a link between philosophical and computational approaches to inference. We show how philosophical accounts of logical inference as described in chapters 3 and 4, can be used to analyze knowledge at the knowledge level (see Figure 5.1).

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FIGURE 5.1 Philosophical approaches to inference have guided us in modelling inferences and various reasoning tasks at the knowledge level.
In modeling abductive inference at the knowledge level, logical accounts of the second stage of abduction is particularly important, that is, ranking the hypotheses, and selecting the ones to be tested first.

As Hookway explains [Hookway 1992, p. 224]:

In other words, we might think of a number of theories of the phenomena that puzzle us and we order them, testing first those that rank higher in this ordering. The progress of science would be held up, first, if the true theory did not appear on the list at all; our imagination might fail us so that the true explanation of the phenomena does not occur to us. Secondly, if the correct theory received a very low ranking, we might never get around to testing it. Therefore, we have to explain how we are good at making guesses about the nature of phenomena; and we have to clarify the rules we follow in ranking explanations as more or less plausible. The logic of abduction is concerned with the second of these issues; in what circumstances are we justified in the opinion that a particular hypothesis is worthy of inductive testing?”

So, he considers two reasons for why a generated hypothesis may turn out to be wrong; the correct hypothesis is not generated, or it is generated but not considered worth to testing. Logic is concerned more with the criteria used in ranking and selection of hypotheses. However, the reasons for formulating certain hypotheses, in the first place, and not the others have been explained in other ways than by using logic. For example, Peirce referred to minds as having a capacity for guessing right. He states, with respect to intelligent guessing, that “the human mind is akin to truth in the sense that in a finite number of guesses it will light upon the correct hypothesis”, that is we have a “natural instinct for truth” (Peirce 7.220). On the other hand, Hookway presumes that “we cannot provide any reason for our best guesses, and they do not result from self-controlled logic” [Hookway 92, p 224]. These issues are related to the psychological aspects of abductive inference which we study in relation to the notion of experience, in later chapters.

In this chapter we deal with the logical aspects of abductive inference, and how the logical accounts of it have been useful for developing a computational model of abductive inference. Inefficiency is a well-known problem in computational accounts of abductive inference. We investigate possible context utilization in abductive tasks, in order to improve abductive efficiency by focusing on only relevant regions of the explanation space. It has been acknowledged, in artificial intelligence as well as in cognitive science, that context facilitates a selective and focused processing of information. So, in this chapter we propose an ‘information processing level’ [Chandrasekaran 86] account of abductive inference.

### 5.2 Knowledge level in practice

In contrast to Newell’s rejection of structure, practical knowledge level descriptions give a special importance to structure. In Van de Velde’s view [van De Velde 93], what is important in a practical knowledge level model “is not only the knowledge that the agent seems to be using but, more importantly, the structure within which this knowledge is being used
for achieving goals”. So, the trend has been to capture both the content and the structure of knowledge at the knowledge level.

The importance of the structure of knowledge has been noticed in other disciplines as well. Schmidt and et al. [Schmidt 93] recognizes the ability of structuring the medical knowledge and being able to properly use those structures as a characteristic which distinguishes medical experts from novices. Their research aimed at identifying the distinctive characteristics of high performance medical experts, for the purpose of determining the curriculum that is most adequate for medical studies. In chapter 2, we have elaborated this subject in connection with the explication of the knowledge in medical domain.

A diversity of perspectives have emerged for describing a knowledge based system at the abstract level. Some examples are ‘hierarchical classification’, ‘generic task’, and ‘problem solving methods’. These vary in their focus. Also, terms which do not occur in the original knowledge level view have been introduced, such as task, task structure, inference structure, and knowledge roles.

The notion of knowledge level has had a large impact on two related fields: knowledge acquisition and re-usability of model elements. Re-usability is not our particular concern, as we are primarily interested in analysing context as a knowledge type and determining its proper usage. Neither is knowledge acquisition in itself our deliberate concern, but only to the degree that one may spontaneously be involved in it, on main occasions of interviews with a medical expert. Nevertheless, from time to time, especially when it comes to abductive inference, which is heavily related to the use of contextual knowledge, we express our ideas which may incidentally fall into the scope of knowledge acquisition and re-usability issues.

**Knowledge acquisition and the knowledge level.** The knowledge engineer builds a model, together with the human expert, of the knowledge that is involved in generating expert behavior. The knowledge acquisition community has been seeking a methodological framework that meets the demands of doing this job. This involves finding ways to structure the knowledge they get from human experts, as well as to perform computations of that knowledge in a systematic way. The theoretical basis of such a framework lies in the knowledge level descriptions. Independent from the particular implementation, this level provides a list of the types of knowledge needed to be extracted from human experts, as well as how various types can be related to each other. That is, it gives clues as to how to structure and organize extracted knowledge into a ‘whole’, analogous to a natural expert’s memory.

**Reusability and the knowledge level.** Another important issue that has recently been addressed in AI is finding the commonalities between different domains and problem types. This aim has been reflected in the form of a search for tasks and methods that can be re-used across a diversity of domains and problems. Several researchers have been occupied with classifying tasks and methods (which are inevitable elements of practical knowledge level models) for the purpose of creating task or method libraries. The idea is that model elements used in one application may often be adequate elements in other applications. The intention is to support knowledge acquisition with predefined sets of model elements [Wielinga 93]. For example, classification, data-retrieval, plan selection, abductive
assembly are all considered re-usable subtasks which can be used across various complex tasks.

5.2.1 Some practical perspectives
We will roughly divide practical approaches to knowledge level modeling into two main groups: domain-model oriented and task oriented approaches. These groups differ in their focus on the elements of the knowledge model. They also differ in their terminology. However, some terms such as domain model, task model, and problem solving method are commonly used in almost all practical approaches.

**Domain-model oriented perspective:** A domain model is described in terms of domain objects and the relations between these objects. It offers a vocabulary and an ontology which allows to express knowledge pertinent to the domain. Understanding and predicting the behavior of the system is dependent on the content and the structure of this model. For example, in a medical domain, the anatomical parts, the pathology underlying the organs, and the way these organs work may all be included in the domain model.

This approach emerged as an alternative to heuristic based approaches [Davis 83]. Heuristic based expert systems suffered from steep performance degradation as the first examples of expert systems relied only on heuristic rules. While heuristic systems only implicitly represented the structure and behavior of the target phenomenon, domain models explicitly describe that knowledge. A big step toward the separation between the domain knowledge and the inference structure, as well as explicitly representing both, is taken from Davis’s [Davis 84] emphasis of the necessity of a deep model of domain knowledge. Research following this line focused on the ‘domain model’. Domain model oriented approaches can be considered one of the earliest applications of the knowledge-level notion, and focused on the theoretical account of the content and structure of the knowledge.

**Task-oriented approaches:** These approaches show variance in their use of different terms as well as applying different meanings to the same terms. Also they use different terms to refer to the same concept. So, there is sufficient grounds for confusion. Something common to this group of research is that they utilize tasks as reference points for analysing both the domain model, and the methods that accomplish the tasks. That is, they start by determining the tasks that the system requires to accomplish. Common to all approaches in this group is that the task decomposition has been utilized in order to organize knowledge.

The term “task” is one of the terms that has been given very different meanings within the knowledge level community. As Chandrasekaran [Chandrasekaran 86] analyses, it may be used as a problem instance, a class of problem instances, the basic subgoal which includes a high level description of method, as a part of generic methods, or a sequence of operators that the system performs. This implies that there are two directions regarding the meaning of “task”. One trend is to couple the task to a method. The other trend separates task from method. Separation of tasks and methods means that there is not a 1:1 relationship between a task and a method. For example, in Chandrasekaran's generic task approach, a generic task consisted of a couple of tasks and a method. Thus, there is a pre-
defined method for each task. Also in [Wielinga 93], a task refers to a sequence of operations. Chandrasekaran’s present “task-structure” approach [Chandrasekaran 93] distinguishes between a task and a method as to allow dynamical selection in run time, among possible methods that can realize a task. In this approach, thus, Chandrasekaran abandoned his task-method couples in favor of the idea of multiplicity of methods for a task.

Other terms often used are ‘method’, ‘operators’, and ‘inferences’. Methods are the ways to accomplish a task and decompose a task into its subtasks.

In the KADS methodology, an application task is decomposed into a set of generic tasks. Task knowledge is organised in a task structure which corresponds to a task tree, having inference structures at the leaves. The inference structures are independent of the domain model. KADS-I identifies four layers of description: domain layer, inference layer, task layer, and strategy level. A task in the task layer is described as consisting of a set of inferences. The inference layer describes the roles of objects in the problem solving process. That is, inferences link the domain layer to the task layer. KADS attempts to identify generic classes of such roles. Each inference plays a “role” that is necessary for achieving the task goal, for example, “classify” or “select”.

If the sequence of operators or inferences, that is the control regime, is coupled to the task, the system suffers from inflexibility. This is because the way to accomplish the task is (in a sense) predefined. In order to add flexibility to a system, a problem solving method is integrated into the system description. A task can be accomplished by several problem solving methods. Thus, there may be several lines of reasoning in order to accomplish a task. This issue is elaborated by Benjamins [Benjamins, 93].

In cases where a task is attached to only one method, the types of domain knowledge that are required for task accomplishment lie in the task description, while this knowledge is moved to the method description in cases where a task can be realized by several methods.

Re-usability of tasks or methods is less relevant for our purposes, and the question of flexibility with respect to the number of methods that can accomplish a task is not in the scope of our work. Even though we recognize the importance of flexibility, we will assume a single method for a task. Therefore we will integrate the specification of the types of domain knowledge required for task accomplishment, into the task description.

Our stance considers what has been called “inference” or “operator” in various approaches as subtasks. We will differentiate between primitive subtasks that can be directly achieved, and complex subtasks, which, through a method are decomposed into lower level subtasks.

Another task-oriented approach is “components of expertise” [Steels 90]. In this approach, the domain model is augmented by case models which are created as products of specific problem solving sessions. Problem solving methods can refine and expand the case model after each problem solution.
5.3 The connection between various abduction accounts

Within the knowledge level community, inferences are considered at the knowledge level in relation to terms such as task and method. Inferences are low level tasks which can be realized by dedicated methods.

If we apply an evidential approach at the knowledge level, inference types would be distinguished to the extent that their conclusions differ with respect to a certain criteria. As we have seen in figure 4, Peirce classified inferences as to the characteristics of their premises (input) and conclusions (output). In this classification, abduction and induction differ in their having different types of input and output. This explains why Peirce identified abductive, deductive and inductive inferences as distinct types; if he would describe abductive and inductive inferences at the knowledge level, he would describe a distinct task for each of these inference types. Such an ontological approach considers inferences as black boxes of which inputs (premises) and outputs (conclusions) are known, but what is inside the box is not interesting (see figure 5.2). Such a pure evidential view says nothing about the process- the method- at the knowledge level description of inferences.

FIGURE 5.2 Task description, according to pure evidential view. This conceptualization considers only what is concluded from what.

However, as Peirce changed his view, his criterion for distinguishing between two inference types became that of whether two inference types need the same type of processing. And then he considered abductions and inductive generalizations as being of the same kind since he conceived their processing as identical. So, if Peirce is required to describe inferences at the knowledge level, in his late period, he would identify abduction and inductive generalization as the same type of task, based on their being realized by the same method. This indicates that ‘method’ is also an important parameter in addition to input and output, for the description of tasks. We propose to integrate Peirce’s evidential and methodological approaches to inference and transform them into a task description at the knowledge level, as visualized in figure 5.3.

FIGURE 5.3 Task description, integrating evidential and methodological view. This conceptualization considers also how the output is concluded from the input.
This way of thinking reveals some possible benefits of utilizing logic as a tool for analysing which types of knowledge should be used for describing inferences at the knowledge level.

5.3.2 The role of logic in analysing knowledge

Newell mentions in his original paper [Newell 82] that logic may have an important role in analysing knowledge. However, he does not elaborate on this, and thus gives no hint as to what he really had in mind. The idea that logic can be a useful tool for a knowledge level modeling conforms with our intention of utilizing the philosophical accounts of abductive inference as an inspiring guide for the purpose of modeling ‘tasks’ at the knowledge level.

Even though Peirce did not remark on the difference in his motivations as such, in our interpretation he first constructed an inference classification (i.e., a general inference ontology) and then investigated whether and how to use this classification when modeling the pattern of reasoning underlying scientific inquiry (i.e., the task structure of inquiry). Hence, Peirce was first engaged in studying the logic of argument while he later became more and more interested in studying the logic of the strategy of scientific inquiry as well. As his first classification did not afford his account of the logic of inquiry, he modified his inference classification. This led him to modify the definitions of abduction and induction.

A common aim at the knowledge level is to describe the tasks at various levels of abstraction in sufficient detail. Inference, in our view, is a kind of task, or rather subtask. The issue is to identify the type of knowledge that can properly describe a task.

We consider logic of an argument as a means for describing a task at the knowledge level. On the other hand, logic of inquiry is a specific example of a more general logic of an application task and reflects task-method correspondence and task decomposition at the knowledge level. It deals with the role of various inference types in a complex application task, and equally important, how these inferences are carried out.

Our concern is to model the logic of diagnosis which we consider to be similar to the logic of inquiry. When doing that, we put a special emphasis on a special type of knowledge, namely contextual knowledge which is one type of knowledge that should be used in task descriptions at the knowledge level.

5.4 The analysis of abductive inference patterns

In this section we want to make a comparison between two abduction patterns which are respectively due to Josephson and Peirce, according to their value as task descriptions at the knowledge level. Let us first rewrite the abductive inference patterns as proposed by Peirce and Josephson.

Peirce’s:

\[
\begin{align*}
\text{The surprising fact C is observed,} \\
\text{But if A were true, C would be a matter of course;} \\
\hline
\text{Hence, there is reason to suspect that A is true.}
\end{align*}
\]

(1)
Josephson’s:

D is a collection of data (facts, observations, givens) (I)
H explains D (would, if true, explain D) (II)
No other hypothesis can explain D as well as H does (III)

Therefore, H is probably true

For us, the most striking difference between these two patterns is that Josephson seems to try to offer in the premise an answer to ‘why’ question, which is important for some concerns- elaborated in the next section- at the knowledge level. He attempts to capture this by two means:

1) formalizing the relation between the input and output, such as “explains”. One primary condition for justification of plausibility of the conclusion is that the desired relation exist between itself and the premises, in (II).
2) specifying another condition that should be satisfied in order for H to be counted as probably true (i.e., it is superior to the alternative hypotheses), in (III).

These two items constitute two prominent parameters that can be utilized in order to explain the rationality underlying the abductive reasoning pattern which maintained the formulation and preference of H. These are, therefore, arguments which can be used in order to justify the abductive inference.

5.5 The ‘why’ question

As we mentioned, the knowledge level model describes the behavior of an agent (e.g., an expert, natural or artificial) in terms of domain entities.

Three main points of Newell’s knowledge level notion, according to van De Velde [van De Velde 93] are:

1. Observation creates a ‘what’ model of agent behavior, e.g., a series of episodes of the agent’s activities.
2. Mechanization creates a ‘how’ model of agent behavior, e.g., in terms of agent structure and local laws of interaction.
3. Rationalization creates a ‘why’ model of agent behavior, e.g., in terms of world knowledge and principle of rationality.

According to the principle of rationality “The agent will select an action to perform next which according to its knowledge leads to the achievement of one of its goals”.

van De Velde emphasizes also that the practical models of knowledge level so far, address the ‘what’ and ‘how’ questions, but the ‘why’ question largely remained to be investigated.

As is seen in Peirce’s pattern, the reason why one could consider ‘A’ as probable is because ‘If A then C is matter of course’. What does it mean to be a ‘matter of course’? When does something count as being ‘matter of course’? What are the criteria? All these questions are left unanswered in Peirce’s account. Josephson, however, attempts to expli-
cate this vague expression of ‘being a matter of course’, by replacing it with ‘explains’. This partly makes the ‘why there is a reason to suspect that A is true?’ question easier to handle. Why A?, or ‘why A is a matter of course when C is true?’. Because it explains C; there is an explanatory relation between them. It is exactly this relation which facilitates the answering of a ‘why’ question. For example, why is the conclusion (output) correct? How can it be justified? Peirce’s pattern does not imply any particular type of relationship between A and C. Why it is natural to think A may be probable when we know C, is not mentioned in his pattern. In this sense, Josephson’s justification pattern of abductive inference is superior to Peirce’s as it does not concern merely the characteristics of the conclusion (e.g., whether it derives ‘new’ knowledge) but also the type of the relationship between the given (input) knowledge and inferred (output) knowledge.

In fact, the relationship should possibly be even more specific than in that of Josephson’s pattern, such as “causally explains” or “structurally explains”. For example, if the explanation is a causal one, only a certain set of all relations represented in the domain ontology will be included in the explanation chain. Similarly if the explanation is a structural one, another set of relations will be utilized. The relations help to discover what is relevant and thus provide a sort of focus. In our approach, the particular relation set comprises a part of what we call, in the following chapters, “task perspective”.

Another distinction of Josephson’s pattern originates from (III) in his pattern: ‘no other hypotheses explain C better than A’. These kinds of ‘assumptions’ or ‘constraints’ govern the process of inferring the conclusion, given input knowledge. In this sense, we can consider Josephson’s pattern as more adequate than Peirce’s from a computational point of view. In other words, it seems to fit better as a starting point for a knowledge level model of abductive inference.

5.6 Abductive inference revisited from a knowledge level view

At the knowledge level (i) the components of an application task needs to be identified first and then (ii) it is described how these knowledge components are used for achieving the underlying goal of that application task.

Peirce’s pattern of abductive inference (see (I) in section 5.4) may provide a source for extracting the content of a task description for abductive inference, that is, for (I). So, this pattern can be transformed to a task description, as illustrated in figure 5.4. The task is described in terms of input, output, and domain knowledge requirements. The input to the inference process, which is described by the pattern, is depicted by the letter C, and corresponds to the observed, to-be-explained facts, while the output is depicted by the letter A and corresponds to the hypothesis generated by the inference which the pattern represents.

![Figure 5.4: Task description extracted and transformed from Peirce’s justification pattern](image)
Alternatively, we can use Josephson’s justification pattern (see (2) in section 5.4) for the same purpose, that is for describing abductive inference. This pattern also can be transformed into a figure (figure 5.5) which describes the abductive inference in terms of again input, output and domain knowledge. However, the pattern explicates the need for more domain knowledge than Peirce’s pattern does. In addition, there are some conditions related to the rationality of selecting H. If needed, the plausibility of output can be justified on the basis of its being able to better explain the input compared to its alternatives.

![Figure 5.5](image-url)

**FIGURE 5.5 Abductive inference task description at the knowledge level (transformed from Josephson’s justification pattern for abductive inference.)**

‘Why’ questions are important with respect to the ‘principle of rationality’. Even though the principle of rationality has been one of the key aspects in the knowledge level paradigm, it has been taken as a matter of course once the other aspects of the paradigm are realized. Therefore, not many attempts have been made to explicitly model the features that may constrain, or bias goal achievement. We consider this issue as a part of principle of rationality.

In our view, the following constitute some of the points that the answers of ‘why’ questions can be referred to:

- the imposed relation between the output and input (e.g., causally explain),
- focal domain concepts,
- contextual knowledge

Along these lines, we attempt in the next three chapters to elaborate why contextual knowledge is important and should be involved in the task descriptions. We also categorize different types of contextual knowledge and determine the locus of their effects at the task level. None of the existing abduction accounts give the necessary, explicit importance to the notion of context. We therefore attempt to compensate for this absence, by extending the knowledge-level model with contextual knowledge, as illustrated in figure 5.6. The general role of contextual knowledge can be captured by the notion of relevance, which may be seen as a component of rationality. The figure emphasizes that a model or a pattern of abductive inference should include contextual knowledge.
5.7 The abstraction level of abductive inference

There is a main task in each domain. For example, the main task in diagnostic domains is to find the fault causing the surprising observations. This task has its subtasks, and these subtasks, in turn, have their own subtasks. The methods determine how a task is to be decomposed into its subtasks, and in what sequence these will be carried out. It is a well-recognized strategy to decompose a complex information processing task into smaller subprocesses that can more easily be accomplished (see figure 5.7). These subtasks are required to be identified before the actual processing starts. Thus, they must be recognized at the knowledge level.

The question addressed in this context is which subtasks or which subprocesses may be involved in a particular process. For example, as we have seen in the preceding chapter, Peirce decomposed the scientific inquiry process into two subprocesses; hypothesis generation and hypothesis testing. At this level, he matched the inference types with the subprocesses in which they have been used.
Researchers disagree about the abstraction level of abductive inference as a task. For example, Josephson puts abductive inference to the top level in the task tree, that is, abductive inference corresponds to the application task. According to him, abductive inference involves everything from evoking hypothesis to acceptance of a hypothesis as the best explanation. As such, testing of a hypothesis also falls into the scope of abductive inference. On the other hand, for Peirce abduction is a subtask of the main application task, that is, he places it at a lower level than does Josephson. In our view, abductive inference is a subtask of diagnosis or inquiry. It is not a top-level task, as is considered by Josephson. Thus, our approach, thus, in this particular aspect is more similar to Peirce’s. For us, abductive inference is the first step of an inquiry (both a scientific and a diagnostic inquiry) and thus excludes testing. Our view into abductive inference is shown in figure 5.8.

5.7.3 Abductive inference covers only the first stage
In order to emphasize that abductive inference covers only the generation - and partial evaluation- of hypotheses, and that it does not cover confirmation by tests we may modify its logical pattern as follows.
D is a collection of data
H explains D
\(H\) is the best hypothesis for further consideration
It is plausible to test \(H\) first

This pattern has a narrower scope than Josephson’s pattern. It is not complete as it does not sufficiently offer evaluative elements. However, it shows clearly that the abductive inference involves only the first stage of inquiry or diagnosis.

The last point we wish to deal with involves another modification regarding the pattern of abduction. In our account, the condition that the hypothesis explains data is not sufficient. There may be data/information that the hypothesis does not explain, but should be consistent with. These we refer to as contextual elements which either explain the hypotheses or together with hypotheses explain \(D\). So, the form of the abductive pattern becomes more complete when augmented with contextual considerations, \(Cxt\):

\[
\begin{align*}
D & \text{ is data available so far} \\
H & \text{ explains } D \text{ together with } Cxt \\
H & \text{ coheres with } Cxt \\
\text{H is the best hypothesis for further scrutiny} \\
\text{It is plausible to test } H \text{ first}
\end{align*}
\]

Notice that \(Cxt\) includes various contextual information of which some parts predisposing or triggering the onset of the diagnostic entity (i.e., hypothesis), and some other parts taking part in the appearances of the manifestations, \(D\).

On the other hand, the overarching task, e.g., inquiry or diagnosis, can be formulated as follows:

\[
\begin{align*}
D & \text{ is a collection of data} \\
H & \text{ explains } D \text{ together with } Cxt \\
H & \text{ coheres with } Cxt \\
\text{H explains } D \text{ better than its alternatives} \\
H & \text{ is probably true.}
\end{align*}
\]

Notice that the scope of this formula is larger than that of the above (abductive) formula since the last one includes testing.

### 5.8 Summary

Peirce’s late abductive pattern seems to be an attempt to integrate some evaluative elements into the logical form of abductive inference. However, the pattern does not provide sufficient basis for a plausibility evaluation. Josephson’s abductive pattern is more adequate in this respect. It is an improvement on Peirce’s, nevertheless it is not sufficient for a thorough evaluation. For example, it does not give any hint as to why all possible hypotheses are not generated. There must be an evaluative filter that hinders formulation of an infinite number of possible hypotheses. His pattern obviously disregards non-explanatory elements. As can easily be seen from the premises, only the data to be explained is included in the premises. However there may be very many hypotheses capa-
ble of explaining the observations. We suggest the use of contextual knowledge as a means for filtering out some implausible hypotheses. Contextual knowledge can play an important role as a focusing mechanism providing for relevance criteria. This is explained in more detail in the following chapters.

In the broad framework of scientific inquiry, Peirce relied on induction in order to confirm plausible conclusions of abductive inference. Since he failed to account for the justification of abductive inference, he dumps the entire justification on induction. This is why he argued for the self-correctiveness of the inquiry method based only on the justification of inductive verification. However, in scientific inquiry, as well as in diagnosis, justification of the conclusion does not prove the method which has drawn these conclusions. The method as a whole should also be justified. Therefore abductive inference also needs to be justified.

Justification of abduction involves justification of the plausibility of its conclusion, which we see also as justification of the reasoner’s rationality. That is, justification of believing why the conclusion is plausible. Evaluation of the plausibility of the conclusion is distributed through the process of abductive reasoning. In an abductive process, first a number of hypotheses are evoked, in other words, activated or formulated. Then these are elaborated by using deep knowledge which makes possible to refutation of some implausible ones. The hypotheses are then ranked according to some criteria. So, there are several subprocesses which may be evaluated as to their rationally. For example, we suggest the use of contextual information, usually easily available in the situation, for formulation of plausible hypotheses. This needs to be reflected in the pattern of abductive inference. For example, this would lead to a modification in the second statement of Josephson’s pattern as in the following:

H explains D in context $C_{\text{current}}$ (would, if true, explain D)

In our view, evaluation of an explanatory hypothesis takes two forms:

- evaluation of the rationality of the reasoner
  1. the explanatory hypothesis should meet the goal, i.e., the type of hypothesis must be imposed by the goal. For example, should it be a ‘causal’ or ‘structural’ explanation?
  2. the candidate hypothesis must explain the so far available surprising facts,
  3. the candidate hypothesis should agree with contextual information.
  4. the candidate hypothesis should not conflict with the past experiences
- evaluation of the conclusion: the conclusion is evaluated by testing it on the basis of new evidence. This refers to confirmation or rejection of the hypothesis.

In the next chapter, we start investigating the notion of context. We propose that context is important for ensuring the relevance of the generated hypotheses. Context is also important for developing efficient computational methods for realizing abductive inference. In particular, in relation to psychological aspects of abductive inference, context constitutes a bridge between abductive inference and the notion of intuition which has been stated to originate from episodic experiences.