Chapter 9

A context-sensitive iterative diagnostic model

9.1 Introduction

This chapter is a transition from a cognitive psychology studies of context, philosophical research on inference (abductive inference in particular), research on diagnostic expertise in medical reasoning, and instructional research towards a view of medical diagnosis in artificial intellig in the above mentioned disciplines. This chapter presents the ideas that we combined from these disciplines into a meaningful whole that provides the ground for developing a diagnostic support system.

This chapter presents the principles of a context-sensitive iterative approach to diagnostic problem solving. Diagnosis has not been considered solely as a classification task as has traditionally been done. It involves a planning task as well. So, diagnosis involves two rather generic tasks, both well-known in AI, namely generating an explanatory classification (i.e., a fault/disorder label), and planning the activity of gathering missing information that is required for solving the diagnostic problem. In a diagnostic process, the latter serves as a subtask of the former one.

In our conceptual model, the main task of diagnosis is accomplished by employing a “generate-and-test” strategy. The generate-and-test method decomposes the diagnosis task into two more easily accomplished subtasks: generation of explanatory hypotheses, and testing of these. This sketchy model, illustrating the relationship between the diagnosis task and the subtasks of generation-of-hypotheses and testing-of-hypotheses, is analogous to the model proposed by Peirce for conceptualization of scientific inquiry (see chapters 4 and 5).

In this chapter we propose a model of diagnosis which illustrates the roles of classification and planning tasks, and the relationship of these tasks to the generate-and-test method. We also show how the generate-and-test method can be conceptualized as an iterative application of the triple of abductive, predictive and inductive inferences.

In our view, the use of contextual knowledge and information comprises a key principle with respect to the issue of improving both the efficiency of the diagnostic process and the quality of the results. The general role of context is to provide a means for focusing attentions on the relevant aspects and features related to a problem. This is particularly important for real world tasks where the domain knowledge is rather rich, the problems are typically ill-structured, and the domain theories are weak. So, we suggest that a knowledge-based system should be contextualized in order to be effective (related to focusing), and to provide solutions with high quality (related to relevance). In our context-sensitive iterative diagnostic approach, which we call ConSID, context plays a central role in triggering the shifts in the focus of attention as well as in capturing the focus of attention.
How does one contextualize knowledge-based systems? Our approach conceptualizes cognitive processes as divided into stages which are captured as subtasks in the knowledge level model of an application problem. Each subtask is accomplished in order to achieve a goal established by the reasoner. Each cognitive or physical task needs to focus only on a portion—the portion relevant for the current goal—of cognitive (i.e., in the mental world) and physical (i.e., in the real-world) resources.

### 9.2 A context-sensitive iterative approach to diagnostic problem solving

This chapter discusses a diagnostic problem solving model, called context-sensitive iterative diagnosis (ConSID), that is particularly appropriate for open and weak domains. ConSID conceptualizes diagnosis as a context sensitive process integrating reasoning and action. The main principles on which the ConSID approach is based can be classified as follows:

1. diagnosis is realized by an iterative application of the abduction-prediction-induction cycle (see figure 9.1).
2. diagnosis is a combination of explanation and planning
3. the problem solving process is goal-driven, and a shift in the focus of attention is triggered by a change in the active goal.
4. the focus of attention is captured in terms of core and contextual entities
5. pattern recognition is an important component of diagnosis at the expert level

![Generate-test method](image)

**FIGURE 9.1 The Generate-test method can be conceptualized as an iterative application of abduction-prediction-induction cycle.**

This approach to diagnosis is context-sensitive in two ways. First, the reasoning line is goal-driven (thus, internal-context driven). Second, it takes into consideration the contextual aspects of the grounded facts (i.e., external context) which allow the focus of attention to be captured in terms of contextual elements in addition to core domain concepts.
9.3 The view of a diagnostic label as an explanation

The hypothesis generation task involves abductive inference where a set of hypothetical explanation of the anomalous observations are tentatively provided.

As we mentioned before, an explanation, according to common understanding, has two components: explanandum and explanan. In our view, a third factor which deserves to be counted as a component is the explanatory relationship linking explanan to explanandum. According to the ConSID approach, a diagnostic explanation should

- explain the anomalous findings,
- explain them in terms of the desired explanatory relationship, i.e, the relationship, which is specified in advance, for linking explanans and explanandum
- agree with the contextual features pertinent to the situation. This condition ensures that the explanans (the fault) is consistent with the contextual factors of the faulty situation. For example, in the medical domain the risk factors comprises a part of contextual features. This type of contextual information does not directly explain the observations, but it does, in a way, imply the fault.

In medical diagnostic tasks, the explanans, that is the explanatory hypothesis, is a diagnosis label, a disease. In this domain, an explanandum is a set of findings such as complaints, measurements and signs. An explanatory hypothesis (explanans) in this domain is linked to the findings it explains (explanandum) by causal, associational and structural relations.

9.4 Iterative application of abduction-prediction-induction cycle

A diagnostic label is established by employing a strategy consisting of the generation of tentative explanatory hypotheses and the testing of these hypotheses on the basis of evidence which is incrementally gathered by performing actions in the physical world.

So, diagnosis is realized by a generate-and-test method which decomposes this task into two main subtasks, the first of which is the abductive generation of hypothetical diagnoses, and the other is the testing of these hypotheses by collectively employing predictive and inductive reasoning lines. This implies an iterative process because the hypotheses are generated with scarce information and through an abductive process which produces fallible results. As such, the hypotheses may fail to explain the newly gathered evidence. Consequently, a new hypotheses generation process may need to be invoked. This means a new cycle of hypotheses generation and of testing.

This model is similar to the model of scientific inquiry which consists of a sequential application of abductive, deductive and inductive inferences proposed by Peirce. However, an important difference is that we propose an iterative and cyclic application of this triple. We argue also that inductive inference is not corrective, but needs another abductive step which is corrective. In our view, the corrective step in the whole diagnostic process is the abductive step. However, an abductive step is not able to verify a generated hypothesis by itself. The abductive step includes, however, a justification of why a particular hypothesis is generated.
9.5 Internal context utilization

Internal context elements include the goal of the reasoner, the reasoner’s current hypotheses, the hypotheses which were previously considered and rejected (after testing), and the strategy she chooses for testing hypotheses (e.g., confirmation or elimination of a hypothesis). The goal of the reasoner is related to her background, interests, motivations, as also proposed by [Leake 93] who points to importance of the goals of the reasoner in everyday-life explanations.

9.5.1 The shift of focus is goal-driven

Reasoning can be viewed as intentionally constrained information processing. The underlying mechanism for this constraint is goal dependent. In our system, the active goals of the problem solver determine the immediate task to be accomplished. A task, in turn is realized by a method that invokes either cognitive or physical actions. So, the reasoning line can be conceptualized as a chain of goal, task, and method sequences. For each goal there may exist several subgoals that the problem solver should, in turn, adopt. These subgoals are related to each other. For example, complex goals are decomposed into smaller, more easily and quickly achievable ones. For a specific task, not all goal sequences can be valid. For example, the testing of a hypothesis may not precede the generation of that hypothesis. The valid goal sequences for a diagnostic task can be sketched as in figure 9.2, where g-determine-anomalies and g-explain-anomalies are the immediate subgoals of g-establish-diagnose, and the achievement of g-determine-anomalies precedes the achievement of g-explain-anomalies.

![Figure 9.2 Valid goal sequences in a diagnostic problem solving](image)

The question to be addressed now is to put forth how the relevance and focus can be realized. At each point in reasoning, only a small portion of the huge knowledge base is relevant, and only that relevant part should be brought to the working memory. If we are able to pinpoint this relevant portion then we can focus on that portion. So, the notions of focus
and relevance are rather interlinked. As our interests and needs change, what was relevant before the change may be irrelevant, while new aspects may become relevant. So, if we want to model the mechanism underlying a trigger of shift of focus, we have to be able to locate the points where and when a shift is required.

In our model, the points where the focus shifts correspond to the points where the goal of the system changes. That is, we adopt a goal-driven shift of focus.

This view parallels an emphasis placed by Barrows on the link between the ‘process’ and the ‘content’ with regard to the issue of finding the best way of teaching medical expertise to medicine students (see section 2.5). The link between a goal-task-method plane to a domain knowledge plane happens through tasks in our system. A task specifies the epistemological needs by referring to the domain knowledge.

So, in order to model focus shift in a diagnostic task, we should identify the possible goal changes in this domain, and correspondingly the points where new tasks (or subtasks) are invoked. Thus, the tasks comprise possible loci where a shift in focus of attention may be natural at the knowledge level.

In the views of the knowledge acquisition and reusability communities (e.g., [Chandrasekaran 92; Breuker 94]) a goal is attached to a task whose accomplishment entails achievement of that goal. In our approach, each task imposes a perspective, as is shown in figure 8.3, which determines the type of hypotheses that will be generated and the aspects that can be relevant for the problem.

The reasoner sets up new goals dynamically, either via subgoaling, which means to continue in the same reasoning line, or by interrupting the current task and generating a new goal. The former alternative happens if everything goes as the reasoner predicted and expected, and the latter when expectations are failed, that is, when the reasoner is on the wrong track (e.g., wrong hypothesis is pursued).

9.5.2 Generated hypotheses provide further focus

Once some hypotheses are formulated, these guide how the problem solving behavior of the diagnostician proceeds. The currently considered hypotheses determine the types of checks and measurements to be employed. The set of hypotheses determines the strategy for information acquisition. For example, if one of the hypotheses is far more promising than the others, it becomes a candidate for confirmation. After the strategy is decided, the hypothesis again serves as a focusing mechanism, since information is gathered that presumably contributes to the confirmation of that particular hypothesis.

9.6 External context utilization

9.6.1 Contextual domain knowledge

An expert, after solving a problem, learns an episode where the involved fault process is explained. A fault process is the understanding of how a particular fault has occurred in the situation. The fault processes that occur in the discourse of the considered diagnostic domain need to be analysed and transformed into fault models at the knowledge level. It
is these fault models which the reasoning process uses towards the goal of finding the underlying fault, from a set of anomalous observations. A knowledge level model, therefore, should be able to appropriately represent the fault models. So, the task of determining the types of knowledge to be included in the knowledge base cannot be isolated from the task of modeling the fault processes.

The relationship between the conceptualization of fault models and the diagnostic reasoning process is a reflection of the link between the ‘content’ and the ‘process’.

Context is a special type of knowledge which is a necessary component in order to understand the faults in a real-world setting. Therefore, before determining the knowledge types at the knowledge level, a contextualized model of fault processes in the domain should be constructed.

Figure 9.3 illustrates our general model of a fault-finding process. This model differs from most traditional ones as it integrates contextual aspects thoroughly into the model. It elicits the interactions between two main types of contextual knowledge, and the incidence of a fault and the way the fault manifests itself. The enabling context and the outcome modifying context play two important roles during the fault process - and during the explanation process as well. An explanation consists of a chain starting from enabling conditions, including the fault, and ending with the manifestations (i.e., the car does not start) of the fault. The collection of all manifestations is the outcome. If we divide the life-span of the fault process into ‘before’ and ‘after’ the occurrence of the fault, we may roughly highlight two roles of contextual factors played respectively by enabling and outcome-modifying contexts. The former is effective in the first stage, and the latter in the second stage of the fault’s life span (see figure 9.3).

FIGURE 9.3 Enabling context factors ‘enable’ the faults, and ‘outcome modifying context’ influences the outcome. The problem is explained in terms of enabling conditions, the fault, manifestations, and outcome modifying context. It is these explanations that the reasoner stores in its memory. An outcome consists of a set of manifestations. Only the manifestations of outcome-3 and outcome-4 are illustrated in the figure. Manifestations within the dark region are the ones available in the new case at the moment. The ones written with italics are common to both outcome-3 and outcome-4.
The influences of the former on the fault happens temporally ‘before’ the fault arises. The latter influences the way the fault manifests itself in terms of findings, i.e., the outcome (see figure 9.8).

A correspondence exists between this model and the way we consider the use of context in the reasoning process involved in finding the fault from observed anomalies of the object (e.g., a car, a patient, or an electronic board) under consideration. Figure 9.4 illustrates how this model of the fault process is reflected by our knowledge level model of context.

**FIGURE 9.4 Context effects on the explanation process.** The figure illustrates that various types of contextual elements play different roles. The goal determines the types of hypotheses that are relevant for the current task. As such, it constraints the search in the hypothesis space. Parts of target-related context (the enabling context) further narrows the set of hypotheses that have been found relevant for the current goal. The other part of the target-related context influences the way a fault manifests itself. That is, it constraints the outcome. So, in general, the various contextual elements narrow down the various parts of the domain knowledge that are used for the diagnostic reasoning process.

### 9.6.2 The role of external context in capturing the focus of attention

As we noted before, while internal context elements do have inter-process influences, the influences by external context elements can be investigated in the frame of separate processes, that is, local to processes. According to our methodology for modeling context, as formulated in chapter 6, we study external context in the following sequence: First, locate the subprocesses where context effects can be investigated at the levels from which we can refer to our context ontology (as defined in chapter 8). Second, analyze the nature of the interaction between the context element and the subprocesses they are utilized in. Finally, identify which type of context element in the ontology that is utilized in each subprocess.
9.7 Loci of context effects in diagnosis

Accounts of context have usually referred to context effects either on input, output, or on the memory (i.e., knowledge base). Figure 9.5 illustrates how a process can be visualized in terms of input, output, and memory. Note, for example, that classical contextual accounts of perception consider either a restriction on selection of input signals, or a limitation in the storage of the output of the pattern recognizer. On the other hand, in language, context effects have been studied in connection with the selection of word-meaning from memory.

![FIGURE 9.5](image.png)

FIGURE 9.5 Context may interact with input, output, or memory.

In diagnostic problem solving, there are several loci where context has apparent influences. We identify three main loci for context assistance corresponding to three different stages in a diagnostic process. On the basis of our approach to the logic of diagnostic inquiry we propose context influences in hypothesis generation, information-gathering strategy selection, and making a plan for gathering information (see figure 9.6).

![FIGURE 9.6](image.png)

FIGURE 9.6 Stages of diagnosis which render effects of the external-context

Based on the nature of the subprocesses, we can recognize the types of contextual elements that underlie the context assistance in each subprocess, in a specific domain. In each subprocess, different types of context elements are found to be functional. In the next chapter we elucidate the types of external context elements which influence each of these loci, in our example domain, namely medicine.

9.7.3 Context assistance in hypotheses generation

In the ConSID approach, the experiences, and the ability to find similarities between a current problem and the previous experiences, are the basis for formulating good hypotheses. As Hatano and Inagaki [Hatano 92] assert, “the construction of models by abduction is nearly impossible when one does not possess a usable old model. People tend to be at a loss when they cannot think of any model that can explain the observed unexpected
According to them, it is hardly possible that we can formulate hypotheses which explain the surprising facts “unless we possess a familiar prototype” that we can take as the starting point. The notion of ‘familiarity’ can also be found in Peirce’s writings. He relates this notion to a human’s ‘abductive talent’ or instinct.

We will now elaborate on the relationship between context utilization and hypothesis formulation by recalling previous episodes. An episode consists of a combination of a set of contextual and core cues. Some of the contextual cues are interactively encoded with core concepts and explanations, and some others are independent. Contextual elements from both groups are used in associating past experiences to the new one.

We now analyse the nature of the relationship between the hypothesis formation process and the contextual information that assists this process. This endeavor will shed light on the matter of how context assists hypothesis formulation. This issue is rather important with regard to the efficiency of abductive inference, since its efficiency is proportional with the number of evoked hypotheses, and since we predict that contextual information should have a constraining effect on the formulation of hypotheses. The smaller the number of activated hypotheses, the more effective the abductive inference will be, under the condition that the hypotheses set includes the best hypotheses. So, context should not constrain the activation for any price: the hypothesis set should cover the most relevant hypotheses.

![Figure 9.7 External context role in hypothesis formulation](image)

**FIGURE 9.7** External context role in hypothesis formulation
We summarize our claim of the nature of the interaction between the context and activation process as a chart, illustrated in figure 9.7.

Evoking is based on how distinct the current case is and how similar it is to the past experiences. Increased distinctiveness and a constrained similarity judgement collectively facilitate ‘association by resemblance’ [Peirce 58]. The underlying context effects in hypothesis formation are the following:

- context comprises a reference point for judgment of similarity between ‘core’ cues presented in the new experience and the past experiences
- context increases the distinctiveness of the available information
- a good association can be accounted for by the notions of similarity and distinctiveness
- a good association entails enhanced recall
- enhanced recall implies good recognition as well, in the sense that, the likelihood that the recalled episodes’ is similar to the current situation/case, with regard to the hypothesis, is high.
- a hypothesis dictated by a similar past episode may be more likely to explain the surprising facts. The idea is that the hypotheses formulated by retrieving a similar episode is plausible in the current situation since it has once been verified to be true in similar situations.

According to Dreyfus and Dreyfus [Dreyfus 86] “... when a similar pattern is seen, the memory is triggered and the diagnosis comes to mind” (p 31). They explain the mental process of an expert by “experience-based holistic recognition of similarity produces deep situational understanding” (p 32). In our account, what makes an experience whole is its encoding of contextual elements, which fill the gaps between core cues. Consideration of an experience as a “whole” opens the possibility for an ‘overall similarity’ judgment. It is exactly the adjective ‘overall’ which makes the similarity notion practically useful.

**Context as a reference point for similarity.** Internal context, by imposing a perspective, determines which of the available cues are salient for the current purpose. That is, a goal modifies the relevance of pieces of available information. This is a top-down imposition of perspective. McGuire and McGuire [McGuire 81] investigated how classification is dependent on context. They showed that adjectives individuals used in order to describe themselves depend on the context in which they imagined themselves. For example, a tall, male, contact-lens wearing basketball player described himself as tall relative to his classmates, as a contact-lens wearer relative to his teammates, as a basketball player relative to other athletes, and as male relative to his family. Even if he, all the time knew about his tallness, contact-lens-wearerness, and maleness, he found only one of these relevant in each different context. Being a family member or a basket player provided a reference point for comparing himself with others. This implies that he judged his similarity to and distinctiveness from others in the context of a certain goal.

On the other hand, external context also creates a somewhat similar effect. However, this will be more bottom-up and implicit in the sense that sometimes a single external context element and other times a collection of such elements may imply a certain reference
point. To give an example from medicine, the contextual information of ‘drug abusing’ and ‘unemployment’ (thus, possibly bad nutrition) may collectively be associated to immunosuppression, which may constitute a reference point for the search for hypotheses, even if it is not explicitly expressed. However the combination of drug abuse and unemployment, at least for medical experts who experienced the relationship of these two factors with diseases related to immunosuppression, will constitute a bias in their search of the hypothesis space.

**Distinctiveness:** To be distinct means to be distinguishable, which in turn, means to be more easily accessible and recognizable. If something is not common, that is, if it has properties that make it different from similar concepts, it can easily be picked out among many others in the same set. For example, rare symptoms immediately trigger particular disease hypotheses, while common ones such as fever, or sweating can be associated with many diseases.

Distinctiveness can be increased by contextual information in two ways, both increasing the strength of the total association:

1. **By quantitatively** increasing the total information
2. **By qualitatively** modifying the salience of core cues. For example “the eyes are filled with tears” is a rather salient symptom in *spring time*, since allergic conditions arise then. In winter time, however it is not that obvious whether it may indicate something special.

A highly distinct phenomenon would have similarity with a small number of other phenomena, while less distinct ones may share a lot with very many others.

In our context terminology, both independent and interactive type of contexts can increase distinctiveness of an episode. However, in the same way as the similarity between contextual information in learning and remembering time illustrates a positive effect, the reverse, that is, variance in contextual information in learning and remembering time may also have a detrimental effect. Therefore, we select carefully which independent context element to include in the system.

Saying that something is similar to another thing does not mean much unless one states in what respect they are similar. As claimed by cognitive psychologists, similarity requires a “frame of reference” [Medin 93]. The most accepted method for measuring similarity is based on matching aspects or features. According to Medin et al., “The only way to make similarity nonarbitrary is to constraint the predicates that apply or enter into computation of similarity” (p 255). By providing a reference point for a similarity assessment, context supports a constrained search in memory. The search is constrained since the similarity is assessed in a certain context, not arbitrarily and extensively. This ensures a ‘relevant’ and focused similarity assessment.

The hypotheses evoked in such a way are elaborated in the following recognition stage, which consists of both elaboration and selection phases.
9.7.4 Context in testing a hypothesis

The process that follows hypothesis generation shows differences in language understanding and in scientific inquiry or diagnosis. Testing in the latter group happens in the real world. In scientific inquiry, controlled experiments are done, and in diagnosis some measurements and examinations are performed. Conversely, in language understanding, a selected meaning is tested against the rest of the text that follows. Nevertheless, there is something common to all tasks: they include a process of making predictions about the consequences of to-be-tested hypotheses, and a process of assessing whether the expectations are fulfilled in the case.

9.7.4.1 Selection of the strategy for gathering information

The question taken up in this section is ‘how to use the set of formulated hypotheses further’. The matter of what to do with this set of hypotheses is dependent on what intention the reasoner has.

Each evoked hypothesis has a certain confidence value. However, it is not sure that these values are correct, especially because such plausible reasoning is made on the basis of partial information. More certainty needs more information; this is gained with the process following hypothesis selection. Even the most confident hypotheses can be rendered implausible in the light of new information. This is why abductive inference is fallible.

Diagnostic reasoning employs various strategies for gathering information. The strategy to be employed is selected dynamically, according to the nature of the activated hypothesis set. There are mainly three strategies in diagnostic reasoning:

- confirming a hypothesis,
- eliminating a hypothesis, and
- differentiating between hypotheses.

Based on the relationships between hypotheses in the set, with respect to the criteria we just mentioned, one of these strategies is applied. Selection of the strategy reflects the priority criteria. These priority criteria may be based on utility and policy considerations. For example, what happens if a life-threatening, but possibly less likely hypothesis is not considered. Or, what do we gain or lose from considering the less likely hypothesis first. The policy adopted is dependent on the location where the diagnosis happens. For example, concerns of the medical expert will be different in an ambulance, in a war zone, and in a well-established hospital.

Of the above listed three strategies, the first one is generally used when one of the hypotheses in the set is much more plausible than all the others. The second can be used if a less plausible but highly life-threatening hypothesis exists in the set. The last one is employed when none of the hypotheses is distinguished with respect to being either very plausible or highly life-threatening. So, the selection of a strategy for gathering information is dependent on,

1. the characteristic of each hypothesis with respect to its plausibility
2. the relative plausibility and urgency
From our context perspective, the relations between the hypotheses in the hypotheses set serve as a context for strategy selection. Policy and utility concerns also constitute a context for strategy selection.

9.7.4.2 **Contextual role in prediction**

Peirce’s pragmatical principle requires that a hypothesis (or its *meaning* in his view) should be able to be tested. That is, its ‘practical conditions’ should be testable. Implications of the pragmatical principle are rather demanding; first and foremost these practical conditionals must be finite and determinable. However, determining all the ramifications of a concept is neither possible, nor necessary. Contrary to Peirce’s view, we do not view the prediction of consequences as simply deduction. There must be some mechanisms in order to determine the practical conditions, and only the conditions that are essentially needed for refuting or confirming a hypothesis. These conditions constitute a small portion of all possible consequences. What makes the role of context significant is that, in each context, only some of these conditions are usually relevant. Furthermore, sometimes a practical condition follows from the hypothetical concept only together with another concept. For example, the outcome of a disease presents itself in various ways across different patient contexts. The way a disease develops after its onset depends on other factors related to the situation of the patient; outcome is context dependent. For example, if the physician made the tentative diagnosis of endocarditis, then she expects low blood pressure as a consequence. But if the patient is suffering from chronic high-blood-pressure then the physician will not expect a low value, and a high blood pressure value will not reduce her suspicion of endocarditis. Such context which we have called “outcome modifying context” in preceding sections, modifies the outcome of the disease. So, in weak domains (which diagnostic domains are) we cannot deduce from a hypothesis its true consequences. The deduction of consequences should be a contextualized process, and this we call prediction instead of deduction in order to differentiate it from traditional deduction. So, Peirce’s ‘deduction’ of consequences of a hypothesis is not as straightforward as he implies.

9.7.4.3 **Context and information gathering - planning**

Suppose that the tentative hypothesis for the cause of a car’s problem is ‘engine does not start’. In order to confirm this certain checks should be done. However, if ‘engine does not start’ is not the only plausible hypothesis, a strategy to discriminate between ‘engine does not fire’ and ‘jammed carburettor valve’ is adopted. The information required in order to distinguish between these hypotheses will possibly be different from what is needed in order to confirm ‘engine does not fire’. So, the information gathering strategy constitutes a context for the planning of information gathering activities. This context determines the relevant information required to be gathered. The second type of context captures the preconditions related to the applicability of various actions that gather the required piece of information. These preconditions may be of various kinds. Some are related to the target, others to the environmental conditions. In the preceding chapters we have referred to the former type of context, as target-related context, and the latter type as environment-related context. The environment related context includes the physical resources required by the actions, such as instruments, and medicals.
We may say that the contextual factors, more specifically external-context related context factors capture requirements related to the resources needed for either cognitive or physical activities of the reasoner. In the explanation task the resources are of epistemological type, while the planning task is facilitated by considering the physical resources.

9.7.5 Evaluative power of contextual knowledge

As we have mentioned in relation to abductive inference, evaluation of the reasoner’s reasoning is important for efficiency and relevance aspects of abductive reasoning. We emphasized also that evaluation of the hypothesis alone is not sufficient. Evaluation and generation should be integrated, as has also been proposed by [Josephson 94] and [Leake 92].

The question we try to answer in this section is a somewhat more abstract form of the question ‘how is it that only a limited number of diseases comes to the mind of a medical expert, based on rather scarce information which could, in fact, be related to many diseases’. There must be an implicit evaluation mechanism which eliminates some hypotheses from being activated in the first place.

We integrate evaluation into generation, or in other words, we apply a distributed evaluation by way of utilizing contextual knowledge. In this approach, a kind of implicit evaluation in diagnostic reasoning is made when formulating/evoking hypotheses. By using contextual criteria we prevent all possible hypotheses from being evoked. This happens because hypotheses are evoked in a particular context. That is, the hypothesis activation is conditioned on coherence with the context. One implication of this is that hypotheses are attempted to explain the surprising facts, but only under the condition that they also agree with the contextual facts and considerations. As these contextual concerns are taken into consideration as early as in the phase of evoking hypotheses, the hypotheses evoked can be assumed to have gone through an evaluative filter. The reasoner does not even access the hypotheses which are at odds with the contextual factors.

The activated hypotheses are subsequently evaluated and assigned a plausibility value. The evaluation in this step, takes common sense knowledge into consideration. The plausibility value of each hypothesis reflects also its plausibility as to contextual knowledge. Some implausible hypotheses are eliminated in this phase. For example, the activated hypothesis ‘pregnancy’ may turn out implausible in deeper investigation if the patient is ‘male’.

In the strategy selection stage we consider the hypotheses in the hypothesis pool all together. The activated hypothesis pool is a component of internal context in our model. This gives the possibility to compare alternative hypotheses. On the basis of some strategy-selection criteria, we select a strategy to continue with. The strategy-selection criteria is shaped by utility/policy considerations. An example criteria is that if there is a hypothesis calling for emergent interference then the “eliminate hypothesis” strategy is adopted. If there is a hypothesis that seems to have a much higher plausibility value than that of all other alternatives, then prefer to “confirm” it. Otherwise select the “hypothesis discrimination” strategy. In this work we consider only the first two, both involving a selection of a hypothesis for testing. Testing is the last step of evaluation. There hypotheses may be eliminated or confirmed.
9.8 Why does agreement with context imply plausibility

The basic fact is that some enabling conditions may gradually make some changes in the object under diagnostic consideration, which, in turn, enables the occurrence of a fault. The fault itself will subsequently make some changes on the object which will present itself in the form of symptoms and signs, i.e., the outcome (see figure 9.8).

It is tempting to build a connection between this process and the reasoning process where a diagnostician formulates fault hypotheses. The strength of the relation between the enabling context and the fault may vary across faults. Enabling context may be, for some fault types, a necessary condition for the incidence of the fault, and in some other cases it may only slightly increase the likelihood of the fault, compared to absence of these contextual factors. Therefore, when we know that the enabling conditions of a phenomenon do exist we may expect the phenomena itself to also be true. Similarly, if we knew that some consequences that follow from a phenomena are, then true we may, through association, think that the phenomena itself is also true. So, both consequences and the enabling conditions of a phenomenon are the familiarity sources that lead us to the guess of a phenomenon.

Peirce asserted that the best hypothesis must render surprising facts likely and must be likely in itself..

We argue in this section that the likelihood of a fault in general is different from its likelihood in particular contexts.

Based on Peirce’s statements, it would not be irrational to say that a “good” hypothesis must be likely in itself and must be likely to explain the surprising facts. We think that a hypothesis is plausible when we think it seems likely for explaining the facts. There are two questions that immediately arises:

- what does it mean that a fault “renders the surprising observations likely”?
- what does it mean that a fault “is likely in itself”?

In our interpretation, the first part of the statement “H explains D in the context C_{current}” (which has been elaborated in section 5.8), namely “H explains D” has a close relation with the first question while the second part, “under context C” to the second question above.

![FIGURE 9.8 The effects of enabling and outcome modifying context on a fault](image-url)
What does it mean that a fault “renders the surprising observations likely”? What should a diagnostician take into consideration in order for this condition be satisfied? The answer may be that the hypothesis formulation process should formulate hypotheses that have causal associations with the surprising facts.

However, this is not that straightforward, because there exists no knowledge that simply conveys that something like “in case of fault A this and that consequence follow”, which when applied gives a perfect result in determining whether fault A is the correct diagnosis. In other words, the relationship between a fault and its outcome is not one that always brings you to the same outcome from a certain fault. There are ‘outcome modifying context’ factors that shape the outcome.

The triplet of enabling-condition, fault and outcome may be seen as a local knowledge network where invoking some portions leads to invoking other parts. When a piece of critical information on the local network is provided, the partial picture becomes complete and the whole network becomes apparent. We may conceptualize the process of developing a fault as a chain connecting the nodes of ‘enabling-conditions’, ‘fault’ and ‘outcome’ (see figure 9.9).

![Diagram](image-url)

**FIGURE 9.9** Enabling context limits the number of activated hypotheses.

An interpretation of hypothesis formulation is that the diagnostician is given parts of the information describing the outcome and is required to find the ‘fault’ node. This is the classic approach which has commonly been adopted in computational models of diagnosis. An alternative is that the expert may also be given parts of the enabling conditions as well. Then, finding the node in the middle, namely the fault will be easier as the number of possible fault nodes connecting both the given enabling conditions and the outcome may dramatically be reduced. This can be considered as the part of the mechanism underlying, in Peirce’s word, a “skilled guess”.

As Arthur C. Doyle writes,

“From a drop of water,” said the writer, “a logician could infer the possibility of an Atlantic or a Niagara without having seen or heard of one or the
other. So all life is a great chain, the nature of which is known whenever we are shown a single link of it. (italics are ours)

9.9 Summary

This chapter presents a context-sensitive iterative approach to diagnosis. This approach considers the reasoning of an expert as a pattern recognition process, where the formulation of diagnostic hypotheses relies on experience. The use of experience as a shortcut requires the ability to identify the similarity of the new problem with previously experienced problems. This indicates that context plays a significant role in this similarity assessment.