Chapter 1
Introduction

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Dedicated to Jair Minoro Abe for his 60th birthday

Abstract Paraconsistent logic is a family of non-classical logics to tolerate inconsistency. Many systems of paraconsistent logics have been developed, and they are now applied to several areas including engineering. Jair Minoro Abe, who is an expert on annotated logics, is one of the important figures in paraconsistent logics. This book collects papers, addressing the importance of paraconsistent logics for several fields.

Keywords Paraconsistent logics · Non-classical logics · Annotated logics · J.M. Abe

1.1 Backgrounds

In the 1980s, I was working on logical foundations for intelligent systems. In particular, I was interested in automated reasoning and knowledge representation in Artificial Intelligence (AI). Unfortunately, some people in related areas believed that logic is of no use for the purpose. However, I believed that logic can serve as mathematical foundations for intelligent systems.

The main tool of logical approaches to AI was undoubtedly *classical logic*. Many researchers studied theorem-proving methods for classical logic, e.g. resolution, and tried to use it as a knowledge representation language. This means that proof theory

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can be applied to inference engine and model theory can be applied knowledge representation language. In the 1970s, logic programming languages like Prolog were developed.

The fact that classical logic was mainly considered in AI is not surprising since it is well-studied in the area of mathematical logic. But, classical logic has some limitations in the study of AI; see Minsky [6]. One of the serious difficulties is that it cannot deal with incomplete and inconsistent information. To overcome it, AI workers invented *non-monotonic logic* for common-sense reasoning.

Naturally, we may explore the use of *non-classical logic* in the study of AI. In the 1980s, this was not a defensible idea for AI. I studied several non-classical logics for AI. I started with modal logics and constructive logics, because these logics are suited to formalize incomplete information. But, I felt that the representation of inconsistent information is also important.

Based on the considerations I learned several paraconsistent logics. Unfortunately, I could not find intriguing applications to AI based on paraconsistent logics. I also found that there were some problems of the use of paraconsistent logics. One major problem is that to develop an automated reasoning method for paraconsistent logic is difficult. In addition, logical basis of paraconsistent logics is complicated. I will give a quick review of paraconsistent logics in Chap. 2.

In logic programming community, the representation of incomplete and inconsistent information in connection with common-sense reasoning is also regarded as an important problem. In 1987, Subramanian proposed an *annotated logic* for qualitative logic programming (cf. [7]) and *paraconsistent logic programming* (cf. [3]). I investigated these papers with great interest.

However, I was dissatisfied with the approach, since it is restrictive from a logical point of view. I believed that annotated logic can be formalized as a formal logical system and the work is intriguing. I tried to study the subject. In fact, it is important to explore foundations and applications of paraconsistent logics, although I was working on other research projects in the period.

In 1991, two important papers on annotated logic have been published; i.e., da Costa et al. [4, 5]. These papers in fact dealt with foundations for annotated logic. For me, the fact was shocking. In 1993, I invited Richard Sylvan in Japan, and he informed that Jair Minoro Abe wrote a dissertation on annotated logic; see Abe [1]. Unfortunately, Abe's dissertation was written in Portuguese. But I could suppose the results from the above two papers. Based on these papers, I stopped foundational work on annotated logic, but seeked a possibility of its applications to computer science.

In 1997, I attended the first World Congress on Paraconsistency held Ghent to present a paper on relevant counterfactuals. From the program, I knew that Abe presented several papers on annotated logic. I attended the session and questioned to him. After the session, I talked with him. It is not surprising that he could speak Japanese. I started the research collaboration with him. In Ghent, I also met Nakamatsu who studied annotated logic from the perspective on logic programming.

Since then, I worked with Abe and Nakamatsu on annotated logics and published many papers. Our goal was to established foundations and applications for annotated logic. We decided to write a monograph on annotated logic. In 2015, we published "Introduction to Annotated Logics" in 2015 by Springer; see Abe et al. [2].

To celebrate Abe's sixty birthday, I decided to edit a book for him. The project is important because he is one of the important figures in the area of paraconsistent logic in that he explored many applications of paraconsistent logics for engineering. I am happy to present this book to honor him and show progresses of paraconsistent logics.

Jair Minoro Abe was born in São Paulo, Brazil on October 6, 1955. He received bachelor and master degrees at Institute of Mathematics and Statics of University of São Paulo in 1978 and 1983, and doctor degree at Faculty of Philosophy, Letters and Human Sciences from University of São Paulo in 1992. He is now Full Professor of Paulista University. His research topics include non-classical logics and Artificial Intelligence. He is working on foundations and applications of paraconsistent logics, in particular, annotated logic. I will describe Abe's life and research in Chap. 12.

1.2 About This Book

The title of this book "Towards Paraconsistent Engineering" clearly describes Abe's research projects. Now, we summarize the contents of this book. Most papers are concerned with paraconsistent logics, and some papers addressed the usefulness of non-classical logics (Fig. 1.1).

Chapter 2 by S. Akama and N.C.A da Costa discusses the reason why paraconsistent logics are very useful to engineering. In fact, the use of paraconsistent logics

Fig. 1.1 Jair Minoro Abe

is a starting point of Abe's work. The ideas and history of paraconsistent logics are reviewed. The chapter is also useful for readers to read papers in this book.

Chapter 3 by N.C.A da Costa and D. Krause is concerned with an application of a paraconsistent logic to quantum physics. The paper reviews the authors' previous papers on the concept of complementarity introduced by Bohr. Logical foundations for quantum mechanics have been worked out so far. The paper reveals that the authors' paraconsistent logic can serve as the basis for the important problem in quantum mechanics.

Chapter 4 by J.-Y. Beziau proposes two three-valued paraconsistent logics, which are 'genuine' in the sense that they obey neither $p, \neg p \vdash q$ nor $\vdash \neg(p \wedge \neg p)$. Beziau investigates their properties and relations to other paraconsistent logics. His work is seen as a new approach to three-valued paraconsistent logics.

Chapter 5 by S. Akama surveys *annotated logics* which have been developed as paraconsistent and paracomplete logics by Abe and others. The paper presents the formal and practical aspects of annotated logics and suggests their further applications for paraconsistent engineering.

Chapter 6 by J.I. da Silva Filho et al. discusses an application of the annotated logic called *PAL2v* based on two truth-values for *Paraconsistent Artificial Neural Network* (PANet), showing an algorithmic structure for handling actual problems. The paper is one of the interesting engineering applications of paraconsistent logic.

Chapter 7 by K. Nakamatsu and S. Akama is concerned with *annotated logic programming*. Indeed the starting point of annotated logics is paraconsistent logic programming, but the subject has been later expanded in various ways. Annotated logic programming can be considered as a tool for many applications. In this paper, they present several approaches to annotated logic programming.

Chapter 8 by Y. Kudo et al. reviews *rough set theory* in connection with modal logic. Rough set theory can serve as a basis for granularity computing and can be applied to deal with many problems in intelligent systems. It is well known that there are some connections between rough set theory and modal logic.

Chapter 9 by T. Murai et al. investigates paraconsistency and paracompleteness in Chellas's conditional logic using Scott-Montague semantics. It is possible to express inconsistency and incompleteness in conditional logic, and they provide several formal results.

Chapter 10 by F.A. Doria and C.A. Cosenza presents a logical approach to the so-called *efficient market* which means that stock prices fully reflect all available information in the market. They introduce the concept of almost efficient market and study its formal properties.

Chapter 11 by J.-M. Alliot et al. is about a logic called the *Molecular Interaction Logic* to represent temporal reasoning in biological systems. The logic can semantically characterize *Molecular Interaction Maps* (MIM) and formalize various reasoning on MIM.

Chapter 12 by S. Akama summarizes Abe's work on paraconsistent logics and their applications to engineering, and surveys some of his projects shortly. The paper clarifies his ideas on paraconsistent engineering.

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