Partial and Paraconsistent Approaches to Future Contingents in Tense Logic

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1 Introduction

Tense logic was originally invented by Prior [14] as a modal logic to formalize tensed sentences in natural language. Tense logic is now widely applied to various problems in linguistics, philosophy, computer science, and others. The problem of future contingents is regarded as an important philosophical problem in connection with determinism. *Future contingents* are statements about future events. The problem is to give a philosophically defensible interpretation of future contingent propositions. It has been discussed since the age of Aristotle. There are in fact many approaches to it; see Øhrstrom and Hasle [12] for a comprehensive survey. For considering the problem, some remarks about the ontology of time may be in order here. There are two different philosophical approaches to the ontology of time, i.e., the *A-theory* and the *B-theory*. The A-theory holds that there exist metaphysically privileged times like "present", "past" and "future"; see Craig [6]. The *standard* tense logic has been based on the A-theory since Prior [14]. The B-theory assumes that time has no "flow". Consequently, B-theorists dispense with a tensed language; see Oaklander [11]. Although B-theorists would not regard the problem of future contingents as a problem, we are addressing ourselves to those who share the A-theoretic assumption about time, and who as such are still troubled by Aristotle's problem about future contingents. In this paper,

we consider two approaches to the problem of future contingents based on the A-theoretic view within the framework of tense logic that Prior founded.

We here need to mention two important concepts in investigating the nature of future contingents, namely, *the law of excluded middle* (LEM) and *the principle of bivalence* (PB), and they should be clearly distinguished. (LEM) is the the syntactic thesis of the form $A \vee \neg A$. (PB) is the semantic thesis that every proposition is either true or false. If (PB) holds, then these theses are equivalent. But if it does not hold, then there are two options whether (LEM) holds. Aristotle [5] considered the issue in *De Interpretatione IX*. According to Aristotle, only propositions about the future which are either necessarily true, or necessarily false, or something determined have a determinate truth-value. In other words, Aristotle accepts (LEM), but rejects (PB) for future contingents. Additionally, Aristotle defended *the law of non-contradiction* (LNC): $\neg(A \wedge \neg A)$. Consequently, we need to endorse Aristotle's argument that (PB) leads to *determinism* (fatalism) and seek to avoid the fatalist conclusion. However, Aristotle's approach might be problematic when we see other theories including Prior's Peircean and Ockhamist tense logic based on the concept of branching-time. Lukasiewicz's attempt at formalizing future contingents using a three-valued logic is not successful; see Lukasiewicz [10]. Hintikka believes that Aristotle's approach cannot avoid determinism on the ground that if it is true to say that there will be a sea-battle tomorrow then this is equivalent to saying that tomorrow's sea-battle is unavoidable; also see Frede [8] for a criticism.

2 Possible Approaches

We know several possible approaches to the problem of future contingents. But, if we accept Aristotle's account then there are basically two different approaches to the problem, i.e., *partial approach* and *paraconsistent approach*. Partial approaches use *gaps*, i.e., neither true nor false, and paraconsistent approaches use *glut*, i.e., both true and false. More formally, partial approaches say that the future contingent sentence $\mathrm{F}A$ is neither true nor false at a point in that A is neither true nor false at some later point. Paraconsistent approaches say that $\mathrm{F}A$ is both true and false at a point in that A is both true and false at some later point (or A is true at some later point and is false at some *another* later point). Here, the first paraconsistent interpretation may be rejected if we adopt the idea that proposition is either true or false at a time point. Even if we do not completely agree with Aristotle's idea, these two approaches could be modified in various ways. They can be formally classified by the following four.

1. Partial tense logic
2. Partial semantics
3. Paraconsistent tense logic
4. Paraconsistent semantics

In fact, (1) and (2) belong to partial approaches, and (3) and (4) to paraconsistent approaches, respectively. The difference of (1) and (2) (also (3) and (4)) may be technical in that the former is the object-level construction and the latter is the meta-level construction. Here, we adopt a philosophically neutral position in that we do not stick to any particular logic and semantics. Instead we are interested in *possible approaches* in a logical setting. Thus, we admit both standard tense logic and non-standard semantics.

Partial tense logic is based on some partial logic like three-valued logic. Here, the choice of partial logics is crucial. For example, Akama, Nagata and Yamada [3] gives one approach. Prior's work on three-valued modal logic Q can be also adapted to the approach; see Akama, Nagata and Yamada [4]. In this sense, intuitionistic tense logic can give a basis for the approach. Partial semantics can semantically describe gaps. For instance, Thomason [16] presented a semantics based on *supervaluation*. Partial approaches can naturally interpret future contingents as gaps, and they can be intuitively grasped. They also compatible to Aristotle's interpretation and the interpretation cannot be described in a classical setting. But they must give up some classical laws.

Paraconsistent tense logic is temporal extension of some paraconsistent logic like da Costa's C-systems [7]. Akama, Murai and Kudo [1] sketched the approach based on Priest's DTL in [13]. Temporal extensions of some relevant logic may be also usable. Paraconsistent semantics gives some tensed sentences gluts. One promising method to fulfill the task is to use *subvaluation*. However, no serious work in the line has been done so far. Paraconsistent approaches are novel in the sense that they interpret future contingents as gluts. They can provide a new interpretation, although it may be difficult to show intuitive justification. Like partial approaches, they must also discard some classical laws. In addition, they raise an interesting philosophical problem related to paraconsistency. In paraconsistent approaches, the truth-values are surely "only true", "only false" and "both true and false" and they are distinct. So the first and the second cannot hold together, i.e., future contingents can be seen as *hyper-determinate*. This implies that future contingents are not "hyper-INdeterminate". In this regard, the approaches based on *non-alethic* (i.e., partial and paraconsistent) tense logic or on many-valued (four-valued or fuzzy) semantics may be promising.

3 Conclusions

In this paper, we discussed partial and paraconsistent approaches to the problem of future contingents. Partial approaches, which can be given by partial tense logic or partial semantics, are stem from Prior's work on tense logic and indeterminism. Paraconsistent approaches, which can be formalized by paraconsistent tense logic or paraconsistent semantics, are dual to partial ones. Surprisingly, both approaches can meet the requirements of Aristotle's solution. Aristotle's original thinking is similar to partial approaches, in particular, partial semantics, and they are prominent. In fact, the interpretation of future contingents, namely nether true nor false (gap), has intuitive appeal. But, paraconsistent approaches can also perfectly implement his solution in a slightly different way. At least, they can satisfy (LEM) and reject (PB). If both A and $\neg A$ are true (implying A is both true and false), then (LEM) is also true. If A is both true and false (i.e., glut), then A is not bivalent. However, they cannot be seen as a formalization of Aristotle's own interpretation since he disliked inconsistency.

After fixing the mentioned approaches technically, we could tackle the so-called the *Master Argument*, which should be resolved to avoid determinism, for each approach. For example, Akama, Murai and Miyamoto [2] discussed the Master Argument by formulating three-valued modal tense logic. Extensions of other three approaches could be also applied to the solution of the Master Argument.

We conclude that non-standard (non-classical) approaches to future contingents are still promising, in particular, to discuss Aristotle's interpretation. Note also that some of the ideas in such approaches can be found in Prior's early work. We believe that these approaches can be adapted to other interpretation in the literature.

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