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研究課題名（和文）部分構造論理とその情報科学への応用

研究課題名（英文）Substructural logics and their applications to computer science

研究代表者

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研究成果の概要（和文）：部分構造論理を含む非古典論理のセマンティクスおよび証明システムを構築し、非古典論理の理論基盤を整備するとともに情報科学への新たな応用を提案した。時間論理およびパラCONSISTENT論理に対する証明システムおよびセマンティクスを構築するとともに、それらのソフトウェア科学および人工知能への新たな応用を提案した。時間論理に関する研究では、ソフトウェア検証手法の一つであるモデル検査に関する基礎を与えた。パラCONSISTENT論理に関する研究では、Web オントロジー言語の基礎を与えるためのいくつかの拡張論理を提案し、それらの基本的性質を明らかにした。

研究成果の概要（英文）：The aim of this study is to construct proof systems and semantics for substructural logics, and to propose computer science applications of these proof systems and semantics. In this study, we construct some proof systems and semantics for some temporal and paraconsistent substructural logics, and propose some new applications (such as software model checking and Web ontology languages) of the proposed proof systems and semantics. We have obtained some theoretical results (such as completeness and decidability results) on the proposed proof systems and semantics.

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1. 研究開始当初の背景  
情報科学への応用上、従来の部分構造論理は表現力に乏しく、さらなる拡張が望まれている。例えば、並行・分散計算機環境の形式化のためには、マルチエージェント環境を記述したり、種々の時間概念および空間概念を記

述したり、計算資源および知識・情報を適切に表現したりすることが求められる。そのため、本研究では従来の部分構造論理を拡張することから取り組む。拡張論理に対する無矛盾性を保障するとともに、決定可能性や計算複雑さを分析する際の有用な方法論を提供

する。

## 2. 研究の目的

本研究の目的は、部分構造論理を含む非古典論理のセマンティクスおよび証明システムを構築し、非古典論理の理論基盤を整備するとともに情報科学への応用に役立てることである。

## 3. 研究の方法

本研究では、まず拡張パラコンシステント論理および拡張時間論理に対する各種証明システムおよび意味論を構築した。そしてそれらシステムと意味論の基本的性質であるカット除去定理、(強)正規化定理および完全性定理を証明した。以上のような理論的結果を利用することにより、ソフトウェアモデル検査、オントロジー記述言語、並行・分散システム、プログラミング言語、等の論理的形式化を実現する。

## 4. 研究成果

時間論理およびパラコンシステント論理に対する証明システムおよびセマンティクスを構築するとともに、それらの情報科学への応用を模索した。時間論理に関する研究では、ソフトウェア検証手法の一つであるモデル検査に関する基礎を与えた。パラコンシステント論理に関する研究では、Web オントロジー言語の基礎を与えるためのいくつかの拡張論理を提案し、それらの基本的性質を明らかにした。

### (1) 時間論理に関する成果：

従来の線形時間論理を、マルチエージェント間のインタラクションを扱うことができるように拡張した。そのような拡張の1つに対して、モデル検査アルゴリズムの存在(決定可能性)を証明した。また、従来の線形時間論理を、多次元空間を表現可能なように拡張し、完全性定理およびカット除去定理を証明した。従来の線形時間論理の時間軸の範囲を有限に制限した時間論理を提案し、完全性定理、決定可能性、およびカット除去定理を証明した。

### (2) パラコンシステント論理に関する成果：

パラコンシステント論理と記述論理の両方の拡張となる、いくつかのパラコンシステント記述論理のセマンティクスを比較した。これらセマンティクスのいくつかは、Web オントロジー言語の基礎として使用されているものである。ここでは、それらセマンティクスの基本的な部分は本質的に同等であることを証明した。証明は、従来の埋め込み定理を修正・拡張することにより行われた。また、それら基本的なパラコンシステント記述論理に対して補間定理を証明した。

## 5. 主な発表論文等

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## 6. 研究組織

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