エージェントの情報伝達行為や知識・信念の更新の論理に関する調査研究

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1. はじめに

1．1．研究の背景

合理的なエージェントとは、知識、信念の一貫性を保持し、特定の目的に適した判断を自律的に行える計算機システム[1]であり、一般的なプログラムとは、以下の点で異なるとされている。[2]

・環境への反応
・自律性
・ゴール指向
・永続性

あるいは、別の特徴として、以下が挙げられている。[1]

・自律的
・柔軟な動作が可能（環境に反応的、目的指向、社会的）
・少なくとも 1 つのスレッドを持つ。

このようなエージェントを実現するための一般的な構成としては、環境からの刺激を受け取る知覚部、望ましい行動を導き出す推論部、環境に向けて行動を起こす作用部から構成される。

図 1-1 は、エージェントの構成の一例（Utility-based agentsの例）である。Utilityを最大化する行動を選択するため、perception、representation、reasoning、learningを行うとされている。[3]

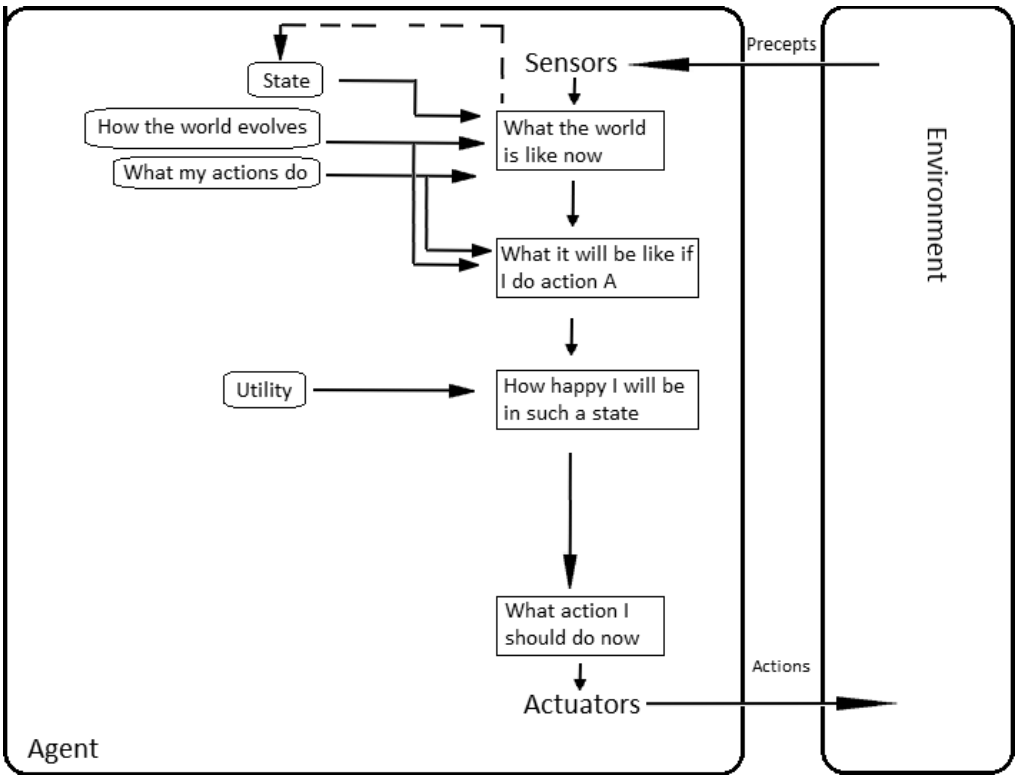


図1-1 エージェントの構成例

「Artificial Intelligence: A Modern Approach」(Russell, Norvig, Peter)

エージェント技術は、人間の作業を支援する自立的判断が可能なソフトウェア（ネットワーク上での分散計算、ソフトウェアのユーザインタフェース）、ロボット（ソフトウェア、ハード）等への実装、言語の発達、個人の行動、社会の意思決定等のシミュレーション等、幅広い分野への応用が想定される。

また、幅広い応用分野が想定されるが故に、エージェント技術の研究は、哲学、数学、工学、経済・金融等関係学問が多岐にわたり、、エージェント／マルチエージェントの研究動向の把握が難しい状況にあることが想定される。

１．２．研究の目的

エージェントの論理の研究において、実際の応用に拡がりがあるのがマルチエージェントのシステムであり、後述するよう、エージェントの論理の研究においても、マルチエージェントの論理に関する研究が活発に行われている状況にある。従って、マルチエージェントの論理について、工学的な応用の見地から、現在どの程度まで知識の表現、状況や行動の判断、グループ等社会性のモデル化が可能であり、また、どの程度実用的かを明らかにするのを目的に、複数のエージェント間における情報の伝達の形式化を含め、エージェントの知識・信念の更新の論理に関する研究成果及び、研究課題の整理・検討を行う。また、本調査を通じて、今後の該当分野における研究課題を明確にする。

2. エージェントに関する論理の概要

２．１．エージェントに関する論理

図2－1に、主に 2000 年初めまでの、本研究の調査対象分野であるエージェントに関する論理の発展を示す。

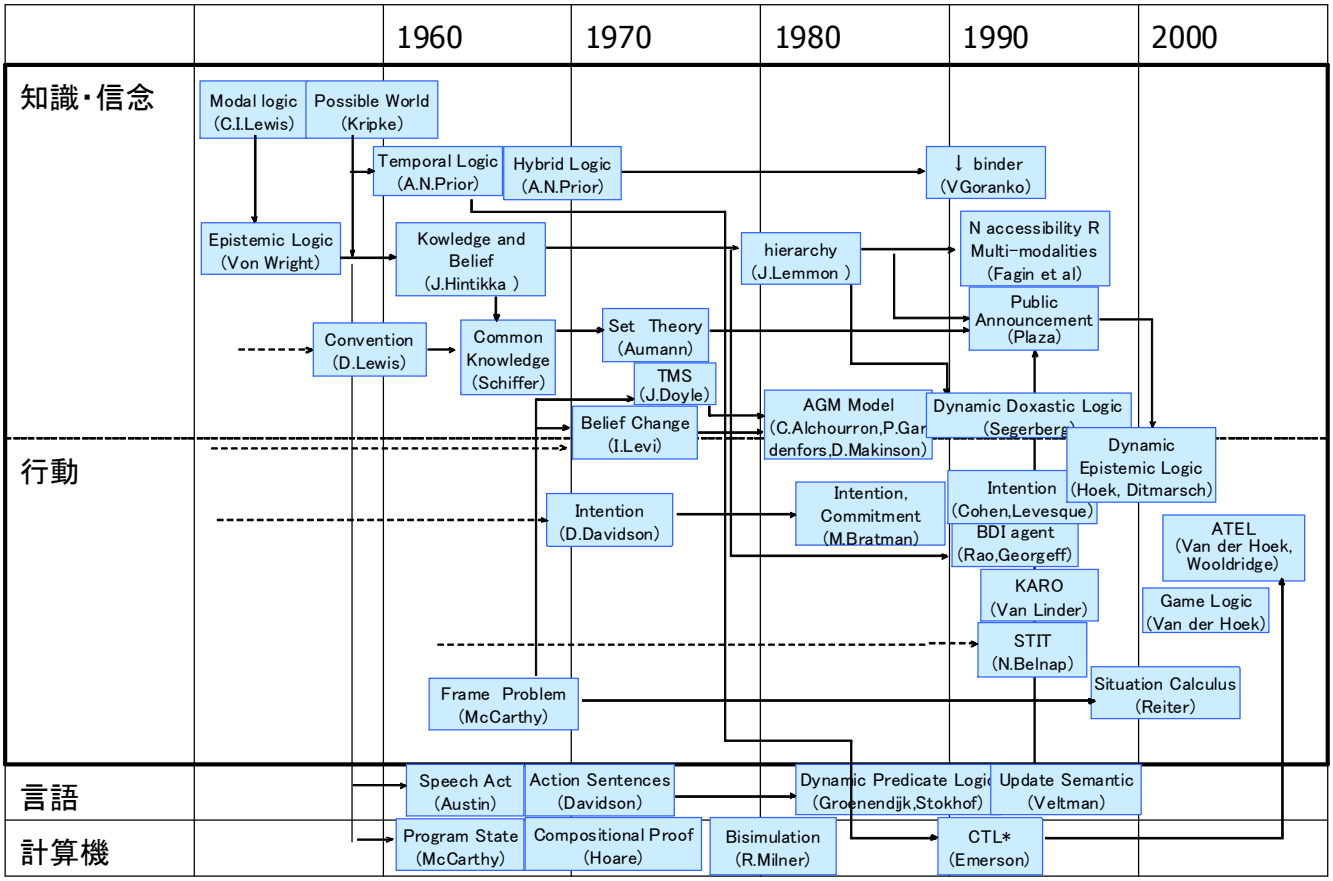


図2－1　エージェントに関する論理

２．２．知識・信念に関する論理

1910 年、C. I. Lewis は、「必ず」と「場合がある」の2つの表現を用いる「様相論理」[6]を形式化した。様相論理の意味論については、 1959 年Saul Kripkeによって与えられた。Kripkeは、可能世界の集合と、可能世界間の2項関係からフレームを構成し、このフレーム上で真偽を論じている。フレーム中の二項関係における順序性、反射性、反射且つ遷移性、反射且つ遷移性且つ対象性等を考慮することで、それぞれ、D,T,S4,S5 といったモデルが、これ以降研究された。後年の 1977 年に、LemmonとScottによって、こられの公理系とフレームの制約条件の関係が整理されている。[8] 様相論理の主要な公理系とフレームの制約条件の関係を表２－１に示す。

表２－１ 様相論理の公理系とフレームの制約条件

公理系の名称	Axiom	フレームの制約条件	関係名
D	□A→◇A	∃u wRu	Serial
T	□A→A	wRw	Reflexive
4	□A→□□A	(wRv&vRu) ⇒ wRu	Transitive
B	A→□◇A	wRv ⇒ vRw	Symmetric
5	◇A→□◇A	(wRv&wRu) ⇒ vRu	Euclidean

構文（Syntax）については、命題論理に以下のルールを追加した公理系が構築されている。

N, Necessitation Rule: p が 定理(theorem)なら、□pも定理

K, Distribution Axiom: □(p→q) → □p → □q

また、様相論理の2つの演算子(modal operator)の解釈を変えることで、様相論理から様々な論理が提案されている。義務論理(Deontic Logic)や、時相論理(Temporal Logic)[12]、知識論理(Doxsastic Logic)が挙げられる。広義には、これらの論理も含め、様相論理として扱われる場合がある。

このように広義に様相論理を捉えた場合、様相論理の１つとして、認識論理(Epistemic Logic)を挙げることができる。個人やグループの「を知っている。」や、「を信じている。」という公理を公理化して扱えないかとする試みであり、1951 年G.H. von Wright によって、今日知られているよう、「知っている」「信じている」という演算子を導入され、主要な形式化が行われた。[13] その後、1960 年にJaakko Hintikkaによって、可能世界を用いた意味論が付与された。[14] 更に、個人のエージェントから見た可能世界間の到達関係と可能世界から構成されるフレームについて、その代数的な特徴（反射、遷移等）を考慮することで様々な公理系が研究され、発展した。その中で知識については、S5、信念については知識で用いたTに代わりDを用いるとするものが多い。また、エージェントが「論理的に完全である(Logical Omniscience)」という仮定が行き過ぎたものとの反省から、エージェントが誤りをおかすことがある点についての研究等も行われた。(例：1975 年 Hintikka [15])

また、様相論理の別の応用例として、1960 年頃Arthur Prior により研究が開始された時相論理(Temporal Logic)[12]がある。時相論理では、未来または過去について、各々様相論理の2つの演算子に対応した「未来／過去において常に」、「未来／過去のある時点において」を表現する2つの演算子を定め、これを用いて時間を含んだ文を表現している。

1960 年代、Priorは更に、時相論理に、ある時点での命題の真偽をあらわすため、noinalsの概念を導入し、時相ハイブリッド論理 （Hybrid Temporal Logic） を提案した。以降、nominalsを用い、様相論理の記述力を増すハイブリッド論理の研究が行われた。1990 年代には、Valentin

Gorankoにより、'↓' バインダの導入が提案されている。[7] '↓'バインダは、変数を現在等現点に結びつけるもので、例えば、「↓y.◇y」は、現状態をyとし、yが到達可能であることを示している。'↓'バインダを用いた論理とともに、これを用いない「弱い」ハイブリッド論理も近年盛んに研究されており、例えば、1999 年に、Areces, Blackburn と Marxが行った様々なクラスについて複雑度を調査した研究等が挙げられる。[24] また、ハイブリッド論理の公理系を扱った研究として、Blackburn と Tzakova[25]等が挙げられる。

1995 年には、Fagin, Halpern, Moses と Vardi[26]らが、様相演算子に各エージェントのインデックスを付与することを研究し、マルチモーダルな様相論理の研究が始まった。これらの研究では、各可能世界のアクセス関係に、各エージェントにおける状態を反映させている。グループにおける様相論理の研究は、1980 年～1990 年代にかけて活発に行われ、認識論理の主な研究対象は、個人の知識からグループの知識に移っていった。現在においても、グループの知識に関する研究は、マルチモーダルの知識論理として活発に行われている。

また、グループの知識に関する研究から、1969 年に David Kellogg Lewisは、会議(Convention)には共通知識(Common Knowledge)が必要であるとし、共通知識を、グループ内のエージェンが、ある事実を知っていることを知っているという作用を無限に繰り返すことで定義した。[6]。 その後、 1972 年代に、Stephen Schiffer[4]は、相互知識の概念を提示している。また、1976 年に、Robert Aumannは、エージェント間のやりとり、社会性、規則等に共通知識が必要であることを指摘し、集合論を用いて共通知識を定義している。[5] 上述のLewisの定義とAumannの定義は等価であることが知られている。

その後、1989 年Plazaは、認識論理(Epistemic Logic)で動的な変化を表す研究に着手している。[27] この研究では、公開告知(Public Announcement)の論理が取り扱われており、'[ ]'という演算子の導入により、例えば$[\phi]\psi$という式て、ϕが公開告知された後には、ψが成り立つという表現が可能である。公開告知の論理の意味論としては、告知が行われる前と後で、可能世界の到達関係が変化するとしており、後の動的な認識論理(Dynamic Epistemic Logic)の発展のもととなった。これまでの、公開告知の論理(PAL)では、以下が成立することが知られている。

・強い完全性と健全性 「$\vdash \alpha$ iff 「$\models \alpha$

・決定性 「$\models \alpha$ であれば、決定的

・表現 PA=S5 ＜ S5C ＜ PAC

1998 年には、Baltag,、Moss、 Soleckiによって、公開告知の論理の公理系(PAL)に、共通知識(Common Knowledge)を加えた、公開告知と共通知識の論理(PAC) が研究された。[28]

1980 年代には、後述の信念更新からヒントを得、van Benthemが、動的な認識論理について研究を開始している。[29] ここでは、事実の変化を表す動的な演算子と、定理の変化を表す動的な演算子を用いている。

２．３．行動に関する論理

行動に関する論理は、主に、言語学、論理学、人工知能、そして哲学等様々な分野において研究されてきた。

言語における行動を扱う論理として、1957 年Austinは、言葉を話す行為を行動として捕らえ、エージェントの行動による状態の変化を研究した。[31] 以降、言語を話す行為についての研究が行われている。一方で、言語と行動の関係として、行動を言語で表現するという研究分野がある。1967 年、Davidson[10]は、今日「event」として知られている行動の表現を研究している。

Vendler (1957) によると、動詞は4つのグループに分類される。[32]

１. States (“know”, “sit”),

２. Activities (“run”, “eat”),

3. Accomplishments (“write a letter”, “build a house”), and
4. Achievements (“reach”, “arrive”).
このうち、2. ～4. が変化を表現するものとされている。

STIT(“sees to it that”)の論理では、命題論理に、新たな演算子を追加する。 [i stit: ϕ]と表記することで、「iはϕとなるよう行動する。」をあらわす。STITの意味論には以下の4要素を含むフレームが用いられる。
・T ある時点をしめす要素からなる集合
・< Tの非反射的な順序関係
・A エージェントの集合
・C 選択関数の集合(あるエージェントのある時点における行動)
また、真偽の付与モデルには、フレームに加え、付値関数が用いられる。
2001 年、Belnapがそれまでの、STITに関する研究をまとめ体系だてた。[30]
人工知能の分野における行動の研究では、1969 年、McCarthy と Hayes が、フレーム問題を提示している。これによると、エージェントの行動選択の際、共通認識があり、行動の影響を前もってすべて把握することは困難であるとされている。[27] フレーム問題に対応するため、デフォルト設定等の考え方がVeltman等により研究された。[28] また、2001 年には、Reiter等によって、 状況計算(situation calculous)によって、部分的な解決が図られている。[29] 状況計算は、行動に関する 1 階論理である。
1963 年、 Donald Davidsonは、エージェントの直接の状態等ではなく、ある目的を達成しようとしている意図の存在を研究した。[10] 1987 年Michael Bratmanは、合理的なエージェント(Rational Agent)の行動選択に大きな役割を果たす意図(Intention)の考えを導入し[33]、後のBDI Logicの基となった。
Bratmanによる意図の導入後、これを論理体系に組み込み形式化する研究が盛んに行われた。著名なものとして、1991 年にCohen と Levesque が発表した、線形時相論理を拡張したものがある。[34] この研究の中で、彼らは、信念や目標、行動を表す演算子を導入した。行動の演算子の例としては、すぐに実行される (HAPPENS α), 実施されたところ (DONE α) 、どのエージェントが該当の行動の動作主体であるか (ACT i a: エージェント i は α の実行者)等が挙げられる。
Rao と Georgeffは、分岐時相論理(Branching-time Temporal Logic)を拡張、形式化したBDI論理を提案している。[35] この研究では、新たに、Belief (BEL), Desire (DES)) と Intention (of the to_be kind, INTEND)と呼ばれる様相演算子を導入し、また同時に、ある行動の成功(succeeded(e)) と失敗(failed(e)) の演算子を導入している。BDI論理の意味論は、各B,D,Iに対する可能世界の到達関係を定義するものである。ここでは、可能世界は、完全な時分岐のCTLツリー構造である。そして、各演算子間の関係が合理的と思われるものを公理として追加している。例えば、あるクラスの式αに対し、 GOAL(α) → BEL(α) 、 INTEND(α) → DES(α)、α = E(ψ)等を追加している。(ここでは、EはCTLの存在を表す量化子)
また、 1996 年以降、Van Linder等により、KARO論理が研究されている。[9] KAROでは、時相論理を基とするBDIとは異なり、動的論理(Dynamic Logic)を基としている。Knowledge (K), Belief (B) 、Action(α :“after performance of α it holds that”)に加え、Desire (D) とエージェントの行動実行能力を示すA演算子を導入した言語で構成されている。更に、補助的な演算子として、以下を追加している。
・O: opportunity ある行動が実行しうる機会がある
・P: practical possibility 実際にある行動を実施できる
・Can: ある結果を導く行動を実行可能(KP)

・◇:realizability = $\exists \alpha_1, \ldots \alpha_n P(\alpha_1; \ldots; \alpha_n, \phi)$
・G : goal $\neg \phi \wedge D\phi \wedge \Diamond\phi$
・I : possibly intend ($I(\alpha, \phi) = Can(\alpha, \phi) \wedge KG\phi$)
KAROの意味論としては、K, B, Dのモデルを以下で構成している。

$$M = \langle W, V, R_K, R_B, R_D \rangle$$

・W :状態の集合is a non-empty set of states (or worlds);
・ V :状態毎の真偽値割り当て関数
・ R_K, R_B, R_D:それぞれのアクセス関係
また、行動に関する構造(Structure)は以下で与えられている。

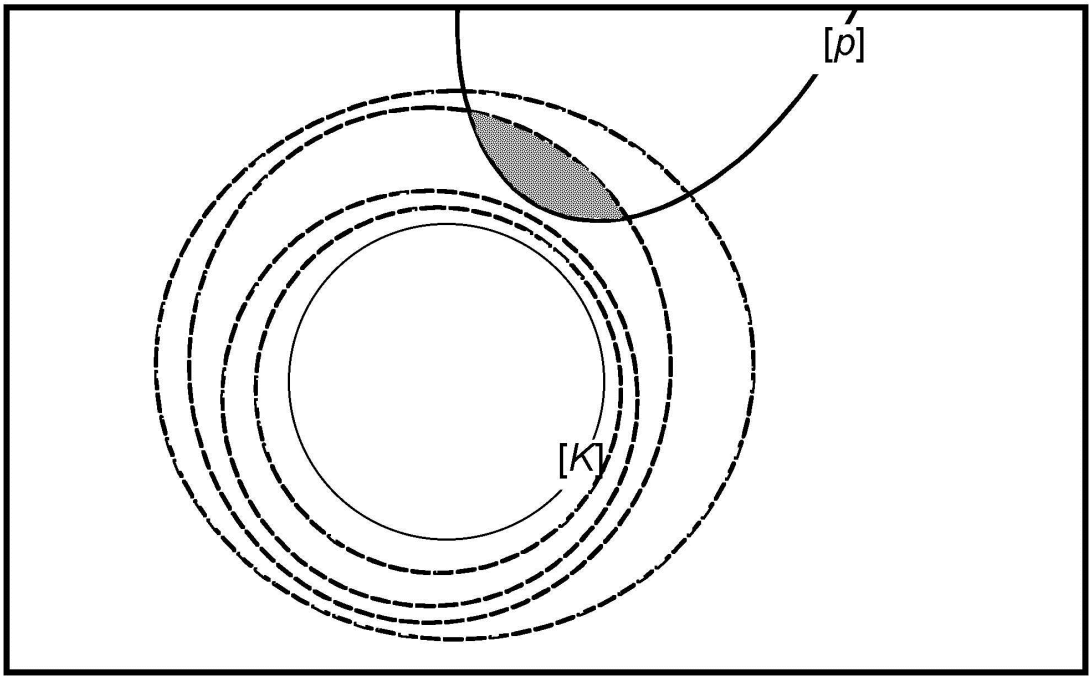
$$\langle \Sigma, \{Ra \mid a \in Ag\}, C, Ag \rangle$$

・Σ: モデルと状態の組の集合
・Ra (a ∈ A): Σ上の到達関係
・C : Σ上の1点においてエージェントが実行できる行動の集合
・Ag : あるエージェントがΣ上の1点においてcommitしている行動の集合
1979 年Jon Doyleは、一貫性を維持したデータベースの更新について分析し、アルゴリズムを提案している。この系(TMS:Truth Maintenance System)は、エージェントの知識状態を表現するためにも用いられることとなった。[11] 1970 年代にIsaac Leviが行った、合理的な知識更新(Belief Change)に必要な要件に関する研究において、知識の更新の形式化が行われた。この研究では、エージェントの知識状態は、エージェントが信じる文の集合として捉えられており、論理的に閉じているとされている。後年、彼はこの理想化について、エージェントが信じるとコミットした文の集合であるとして、現実的な印象との差分を説明している。 エージェントの知識の状態については、これ以降も文の集合として表現するのが一般的である。また、1977 年Leviには更新間の同等性として、Revison ('*')と、Contraction('÷')、Expansion('+')の関係を与えている。[16]

$$\text{Levi identity: } K*p = (K \div \neg p) + p.$$

1985 年に、Carlos Alchourrón, Peter Gärdenfors, と David Makinsonは、後に 3 人の名前にちなんでAGM modelと呼ばれる知識更新のモデルを提案している。[36] ,このモデルの中では、知識の状態の更新を、3種類に分類している。Contractionでは、特定の文pが、知識の集合Kから除去される($K \div p$: pを導出しないよう、Kからpを除いた集合間の共通部分)としており、Expansionでは、 特定の文p が知識の集合 Kに追加され、除去される要素はないとしており(K+p Kとpを含み論理的の閉じた最小の集合)、Revison では、特定の文p が知識の集合 K に追加されると同時に、一貫性を保つために必要な要素の除去が行われるとしている(K*p) 。

知識の更新に関し、知識状態のモデルの別の表現として、可能世界の集合.を用いたものがある。1988 年、Groveは、可能世界の球体モデルを用い、これがPartial Meet Revisionと等価であること示している。[37]



Sphere-based revision of K by p（Grove 1988）

1995 年に、Segerberg は、静的な信念の論理(Doxastic Logic)と、信念の更新の論理(Belief Change)を組み合わせ、動的な信念の論理(DDL : Dynamic Doxastic Logic)を構築した。[18] DDLにおいて、Segerbergは、新たに信念の更新に関係する、以下の3つの演算子を導入している。

[+D]BcA
[*D]BcA
[−D]BcA.

これと信念の論理(Doxastic Logic)の様相演算子(B)により、 信念をDで拡張した後、CはAを信じる（Cの信念の中にAが存在する。）、信念をDで更新した後、CはAを信じる（Cの信念の中にAが存在する。）、信念をDで縮小した後、CはAを信じる（Cの信念の中にAが存在する。）といった表現を可能としている。

また、Segerbergは、後年、DDLの公理化にあたり、完全且つ健全な公理系を挙げている。[19]

1990 年にEmersonは、CTL(Computational Tree Logic)の表現力を高めたCTL*を提案している。[]この影響を受け、CTL上に時相論理を展開した、ATLが研究されるようになった。ATLは、分岐時相論理(Branching-timeTemporal Logic)をゲーム理論に拡張したもので、あるエージェントのグループについて、グループ外のエージェントが何を行っても、特定の状態を成立することができるというエージェントの能力を表現することができる。ATLでは、演算子≪≫が導入され、≪A≫φで、エージェントのグループAは、φを実現させる戦略を持つという事が表現できる。また、ATLの言語では、以下の時相演算子が、Temporal Logicと同様に用いられる。

○(“次に”),

□(“今からずっと”)

U(“until”)

ATLの意味論には、同時ゲームの論理が使用されている。

また、2002 年には、Van der Hoek と Wooldridgeによって、ATL(Alternating-time Temporal Logic)を 認識論(Epistemic Logic)に適用した ATEL(Alternating-time Epistemic Temporal Logic)が提案されている。[38] ATELでは、ATLに加え、以下の認識論理の演算子が追加されている。

K_a:エージェントaは・・・を知っている

E_A:グループAの誰もが知っている

C_A:共通知識 (Common Knowledge)

D_A:分散知識 (Distrbuted Knowledge)

2003 年、van Ditmarsch, van der HoekとKooiは、、エージェントの情報伝達等の行為が、エージェントの認識の状態にどのように影響を与えるかをモデル化した、動的認識論理(DEL : Dynamic Epistemic Logic)を構築した。[39]

３．調査の内容と結果

３．１．調査対象

3.1.1. 調査対象分野

以下キーワード等が含まれる論文や、議題が該当する会議資料等を調査対象とした。

キーワード：エージェント、マルチエージェント（システム）、論理、知識・信念、更新、
コミュニケーション

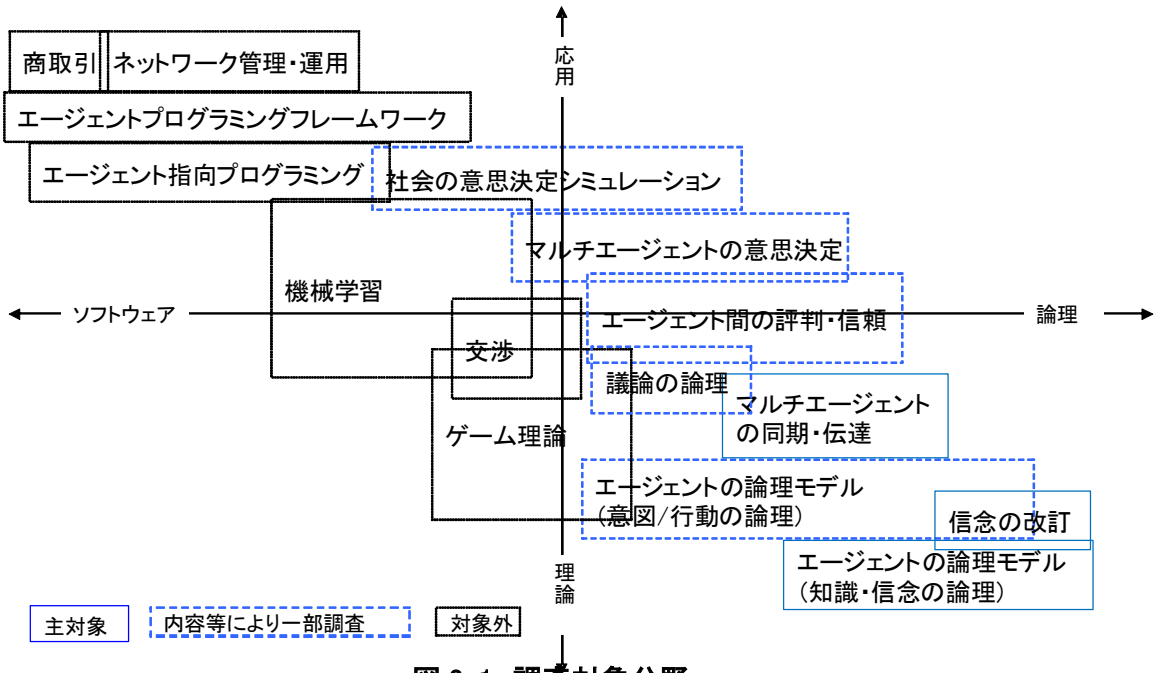


図 3-1　調査対象分野

3．1．2．調査対象

以下の会議や出版物等のなかから、3．1．1．の分野に適合すると考えられる研究を、キーワード、Abstruct、会議等のセッション名等を基に判断し、抽出した。対象期間は、近年の研究動向と今後の課題を探るという研究目的から、過いずれも直近 10 年間とした。

・シンポジウム、ワークショップ
・国際会議（カンファレンス）
・ジャーナル

表3－1　調査対象

分類	会議、雑誌名	開催、発行年
シンポジウム、ワークショップ	CLIMA Workshop(International Workshop on Computational Logic in Multi-Agent Systems)	14th La Coruna, Spain, 2013
		13th Montpellier, France, 2012
		12th Barcelona, Spain,2011
		11th Lisbon, Portugal, 2010
		10th Hamburg, Germany, 2009
		9th Dresden, Germany, 2008
		8th Porto, Portugal, 2007
		7th Hakodate, Japan, 2006
		6th London, UK, 2005
		5th Lisbon, Portugal, 2004
		4th Fort Lauderdale,USA, 2004
	ISMIS(international symposium on methodologies for intelligent systems)	20th Macou, China(2012)
		19th Poland, Warsaw(2011)
		18th Prague, Czech (2009)
		17th Toronto, Canada(2008)
		16th Bari, Italy(2006)
		15th　Saratoga Springs, USA (2005)
		14th　Maebashi City, Japan (2003)

カンファレンス	IJCAI (the International Joint Conference on Artificial Intelligence)	22th IJCAI Barcelona, Spain(2011)
		21th IJCAI: Pasadena, USA (2009)
		20th IJCAI Hyderabad, India (2007)
		19th IJCAI Edinburgh, UK (2005)
		18th IJCAI Acapulco, Mexico (2003
	IEEE/WIC/ACM Intelligent Agent Technology (IAT).	IAT / WI 2012: Macau, China
		IAT / WI 2011: Lyon, France
		IAT / WI 2010: Toronto, Canada
		IAT / WI 2009: Milan, Italy
		IAT / WI 2008: Sydney, Australia
		IAT 2007: Silicon Valley, CA, USA
		IAT 2006: Hong Kong, China
		IAT 2005: Compiegne, France
		IAT 2004: Beijing, China
		IAT 2003: Halifax, Canada
	ECAI(European Conference on Artificial Intelligence)	ECAI-2012 Montpellier, France
		ECAI-2010 Lisbon, Portugal
		ECAI-2008 Patras, Greece
		ECAI-2006 Riva del Garda, Italy
		ECAI-2004 Valencia, Spain
	AAMAS(International Conference on Autonomous Agents and Multiagent Systems)	Saint Paul, Minnesota, USA(AAMAS 2013)
		Valencia, Spain (AAMAS 2012)
		Taipei, Taiwan (AAMAS 2011)
		Toronto, Canada (AAMAS 2010)
		Budapest, Hungary (AAMAS'09)
		Estoril, Portugal (AAMAS'08)
		Honolulu, USA (AAMAS'07)
		Hakodate, Japan (AAMAS'06)
		Utrecht, The Netherlands (AAMAS'05)
		New York, USA (AAMAS'04)
		Melbourne, Australia (AAMAS'03)
	AiML(Advances in Modal Logic)	2012 Copenhagen, Denmark
		2010 Moscow, Russia
		2008 Nancy, France
		2006 Noosa, Australia
		2004 Mancheste, England

ジャーナル	Journal of Autonomous Agents and Multi-Agent Systems	2013 Vol26
		2012 Vol24, 25
		2011 Vol22, 23
		2010 Vol20, 21
		2009 Vol18, 19
		2008 Vol16, 17
		2007 Vol14, 15
		2006 Vol12, 13
		2005 Vol10, 11
		2004 Vol8, 9
	Journal of Logic and Computation	2013 Feb,Apr,Jun
		2012 Feb,Apr,Jun,Aug,Oct,Dec
		2011 Feb,Apr,Jun,Aug,Oct,Dec
		2010 Feb,Apr,Jun,Aug,Oct,Dec
		2009 Feb,Apr,Jun,Aug,Oct,Dec
		2008 Feb,Apr,Jun,Aug,Oct,Dec
		2007 Feb,Apr,Jun,Aug,Oct,Dec
		2006 Feb,Apr,Jun,Aug,Oct,Dec
		2005 Feb,Apr,Jun,Aug,Oct,Dec
		2004 Feb,Apr,Jun,Aug,Oct,Dec
	Journal of Logic, Language and Information(European Association for Logic, Language and Information)	Volume 22, 2013, Jan, Apr
		Volume 21, 2012, Jan, Apr, July, Oct
		Volume 20, 2011 Jan, Apr, July, Oct
		Volume 19, 2010 Jan, Apr, July, Oct
		Volume 18, 2009 Jan, Apr, July, Oct
		Volume 17, 2008 Jan, Apr, July, Oct
		Volume 16, 2007, Jan, Apr, July, Oct
		Volume 15, 2006 Jan, Apr, July, Oct
		Volume 14, 2015 Jan, Apr, July, Oct
		Volume 13, 2004 Jan, Apr, July, Oct
		Volume 12, 2003 Jan, Apr, July, Oct

ジャーナル	Journal of Symbolic Logic	Volume 78, Issue 1 (2013)
		Volume 77, Issue 1-4 (2012)
		Volume 76, Issue 1-4 (2011)
		Volume 75, Issue 1-4 (2010)
		Volume 74, Issue 1-4 (2009)
		Volume 73, Issue 1-4 (2008)
		Volume 72, Issue 1-4 (2007)
		Volume 71, Issue 1-4 (2006)
		Volume 70, Issue 1-4 (2005)
		Volume 69, Issue 1-4 (2004)
	人工知能学会論文誌	Vol 28 (2013)
		Vol 27 (2012)
		Vol 26 (2011)
		Vol 25 (2010)
		Vol 24 (2009)
		Vol 23 (2008)
		Vol 22 (2007)
		Vol 21 (2006)
		Vol 20 (2005)
		Vol 19 (2004)

３． ２． 調査結果

３. ２. １. 研究動向の概要

（1）動向概要の調査

３．１．で対象として抽出した文献のうち、本研究テーマである、エージェントの知識・信念の更新、エージェント間の情報伝達行為によく適合すると考えられるものを、60件程選定し、これを以下の4つの範疇に分類した。

・行動の記述
・行動決定
・知識の表現
・信念更新

更に、この対象について、エージェントの数に着目し、対象とするエージェントが、複数を前提としていない、複数エージェント間を前提としている、グループ・組織等複数エージェントを塊でみているとの3つに分類した。

上の分類を、直近5年（2009年から2013年）と、その前の5年（2004年から2008年）に分け、分布を比較した。

なお、対象として選定した研究を下表 3-2 に示す。

表 3-2 分類、キーワード抽出対象文献

分類	No	Year	Author	Title	Jur/Symp
行動記述	7	2004	Bentahar, Jamal; Moulin, Bernard; Meyer, John-JulesCh. & Chaib-draa, Brahim	A Computational Model for Conversation Policies for Agent Communication	CLIMA 5th
	9	2006	T.Yamada	Acts of Commanding and Changing Obligations	CLIMA 7th
	13	2012	de Lima, Tiago	Alternating-time temporal dynamic epistemic logic1	Journal of Logic and Computation
	14	2010	Herzig, Andreas & Lorini, Emiliano	A Dynamic Logic of Agency I: STIT, Capabilities and Powers	Journal of Logic, Language and Information
	21	2012	Knobbout, Max & Dastani, Mehdi	Reasoning under compliance assumptions in normative multiagent systems	AAMAS
	24	2009	Inan? Seylan, Wojciech Jamroga	Description Logic for Coalitions	AAMAS
	27	2005	¥AAgotnes, Thomas & Walicki, Michal	A logic of reasoning, communication and cooperation with syntactic knowledge	AAMAS
	33	2008	Herzig, Andreas & Schwarzentruber, Fran?ois	Properties of logics of individual and group agency	AiML
	36	2012	Dignum, Frank & Dignum, Virginia	A Formal Semantics for Agent (Re)Organization	CLIMA
	38	2012	Wright, Ben; Pontelli, Enrico & Son, TranCao	Implementing Reversible Processes in Multi-agent Action Languages Using Answer Set Planning	CLIMA
	39	2011	Lima, Tiago	Alternating-Time Temporal Announcement Logic	CLIMA
	48	2011	Andreas Herzig, Emiliano Lorini, Fr?d?ric Moisan Nicolas Troquard	A Dynamic Logic of Normative Systems	IJCAI
	50	2011	Xiuyi Fan, Francesca Toni	Assumption-Based Argumentation Dialogues	IJCAI
	53	2007	Thomas ?gotnes, Wiebe van der Hoek, Juan A. Rodr?guez-Aguilar Carles Sierra Michael Wooldridge	On the Logic of Normative Systems	IJCAI
	57	2011	Alechina, Natasha; Logan, Brian; Nga Nguyen, Hoang & Rakib, Abdur	Logic for coalitions with bounded resources	Journal of Logic and Computation

行動決定	1	2012	Pardo, Pere & Sadrzadeh, Mehrnoosh	Planning in the logics of communication and change	AAMAS
	2	2009	Valentin Goranko, Dmitry Shkatov	Tableau-based decision procedure for full coalitional multiagent temporal-epistemic logic of linear time	AAMAS
	5	2006	Luigi Sauro, Jelle Gerbrandy, Wiebe van der Hoek Michael Wooldridge	Reasoning about action and cooperation	AAMAS
	23	2010	Baral, Chitta; Gelfond, Gregory; Son, Tran Cao & Pontelli, Enrico	Using answer set programming to model multi-agent scenarios involving agents' knowledge about other's knowledge	AAMAS
	25	2008	Patrick Kr?mpelmann, Matthias Thimm, Gabriele Kern-Isberner Manuela Ritterskamp	Belief Operations for Motivated BDI Agents	AAMAS
	37	2012	Lam, Ho-Pun; Governatori, Guido; Satoh, Ken & Hosobe, Hiroshi	Distributed Defeasible Speculative Reasoning in Ambient Environment	CLIMA
	40	2010	D?prile, Davide; Giordano, Laura; Gliozzi, Valentina; Martelli, Alberto; Pozzato, GianLuca & Theseider Dupr?, Daniele	Verifying Business Process Compliance by Reasoning about Actions	CLIMA
	41	2010	Ma, Jiefei; Broda, Krysia; Goebel, Randy; Hosobe, Hiroshi; Russo, Alessandra & Satoh, Ken	Speculative Abductive Reasoning for Hierarchical Agent Systems	CLIMA
	42	2004	Riemsdijk, M.Birna; Boer, FrankS. & Meyer, John-JulesCh.	Dynamic Logic for Plan Revision in Intelligent Agents	CLIMA 5th
	63	2009	Bonnefon, Jean-François ; Longin, D. ; Nguyen, Manh-Hung	Relation of Trust and Social Emotions: A Logical Approach	WI-IAT
信念更新	3	2008	Aucher, Guillaume	Internal Models and Private Multi-agent Belief Revision	AAMAS
	8	2006	Hagiwara, Shingo; Kobayashi, Mikito & Tojo, Satoshi	Belief Updating by Communication Channel	CLIMA 7th
	12	2012	Aucher, Guillaume	Private announcement and belief expansion: an internal perspective	Journal of Logic and Computation
	16	2006	Cantwell, John	A Formal Model of Multi-Agent Belief-Interaction	Journal of Logic, Language and Information

信念更新	18	2009	M.Kobayashi, S.Tojo	Agent Communication for Dynamic Belief Update	人工知能学会論文誌24巻(2009)
	29	2004	Perrussel, Laurent & Thevenin, Jean-Marc	A Logical Approach for Describing (Dis)Belief Change and Message Processing	AAMAS
	35	2004	Hans van Ditmarsch, Wiebe van der Hoek & Kooi, Barteld	Public Announcements and Belief Expansion	AiML
	43	2006	Fusaoka, Akira; Nakamura, Katsunori & Sato, Mitsunari	On a Linear Framework for Belief Dynamics in Multi-agent Environments	CLIMA 7th
	44	2012	Maurizio Lenzerini, Domenico Fabio Savo	Updating inconsistent Description Logic knowledge bases	ECAI
	45	2010	Patricia Everaere, Sébastien Konieczny, Pierre Marquis	The Epistemic View of Belief Merging: Can We Track the Truth?	ECAI
	46	2008	Pavlos Peppas, Anastasios Michael Fotinopoulos, Stella Seremetaki	Conflicts between Relevance-Sensitive and Iterated Belief Revision	ECAI
	47	2004	Richard Booth, Samir Chopra, Thomas Meyer, Aditya Ghose	A unifying semantics for belief change	ECAI
	49	2011	C?lia da Costa Pereira, Andrea G. B. Tettamanzi, Serena Villata	Changing One's Mind: Erase or Rewind?	IJCAI
	51	2011	Zhiqiang Zhuang, Maurice Pagnucco	Transitively Relational Partial Meet Horn Contraction	IJCAI
	54	2005	Salem Benferhat, Sylvain Lagrue & Papini, Odile	Revision of Partially Ordered Information:Axiomatization, Semantics and Iteration	IJCAI
	55	2009	Benferhat, Salem; Dubois, Didier; Prade, Henri & Williams, Mary-Anne	A General Framework for Revising Belief Bases Using Qualitative Jeffrey's Rule	ISMIS
	56	2012	Enqvist, Sebastian	Modelling epistemic actions in interrogative belief revision	Journal of Logic and Computation
	61	2011	Andreas, Holger	A Structuralist Theory of Belief Revision	Journal of Logic, Language and Information
	62	2005	Walliser, Bernard; Zwirn, Denis & Zwirn, Herv?	Abductive Logics in a Belief Revision Framework	Journal of Logic, Language and Information
知識表現	4	2008	Thomas Agotnes, Hans van Ditmarsch	Coalitions and Announcements	AAMAS
	6	2006	Lutz, Carsten	Complexity and succinctness of public announcement logic	AAMAS

知識表現	10	2011	Jeremy Seligman, Fenrong Liu & Girard, Patrick	Logic in the Community	ICLA
	11	2011	Wi?ch, Przemys?aw; Rybinski, Henryk & Ry?ko, Dominik	DDLD-Based Reasoning for MAS	ISMIS
	15	2010	Hoshi, Tomohiro	Merging DEL and ETL	Journal of Logic, Language and Information
	17	1998	Alexandru Baltag, Lawrence S. Moss & Solecki, Slawomir	The Logic of Public Announcements,Common Knowledge, and Private Suspicions	Proceedings of the 7th Conference on TARK VII
	19	2012	van Ditmarsch, Hans; French, Tim & Vel¥'{a}zquez-Quesada, Fernando R.	Action models for knowledge and awareness	AAMAS
	20	2012	van der Hoek, Wiebe; Iliev, Petar & Wooldridge, Michael	A logic of revelation and concealment	AAMAS
	22	2011	van Ditmarsch, Hans; van der Hoek, Wiebe & Kooi, Barteld	Reasoning about local properties in modal logic	AAMAS
	26	2007	Lomuscio, Alessio & Wo?na, Bo?ena	A Temporal Epistemic Logic with a Reset Operation	AAMAS
	28	2005	van Ditmarsch, H. P.; van der Hoek, W. & Kooi, B. P.	Dynamic epistemic logic with assignment	AAMAS
	30	2012	Patrick Girard, Jeremy Seligman & Liu, Fenrong	General Dynamic Dynamic Logic	AiML
	31	2010	Marta B?lkov?, Ondrej Majer, Michal Peli? & Restall, Greg	Relevant Agents	AiML
	32	2008	French, Tim & van Ditmarsch, Hans	Undecidability for arbitrary public announcement logic	AiML
	34	2008	Jens Hansen, Thomas Bolander & Bra?ner, Torben	Many-valued hybrid logic	AiML
	52	2007	Chitta Baral, Jicheng Zhao	Non-monotonic TemporalLogics for Goal Speci?cation	IJCAI
	58	2011	Renne, Bryan	Public communication in justification logic	Journal of Logic and Computation
	59	2011	Van Ditmarsch, Hans; Herzig, Andreas & De Lima, Tiago	From Situation Calculus to Dynamic Epistemic Logic	Journal of Logic and Computation
	60	2012	Bochman, Alexander & Gabbay, DovM.	Sequential Dynamic Logic	Journal of Logic, Language and Information

知識表現	64	2009	Ditmarsch, Hans van French, T.	Awareness and Forgetting of Facts and Agents	WI-IAT

(2)調査結果

知識関連の論理においては、知識の更新からについて、知識と行動を扱える動的な知識表現による代替表現の試みや、単一エージェントの論理を複数エージェント更には、グループで1つとして扱う論理等の発表が目立つ。

行動に関する論理においては、行動決定において他エージェントの知識状態を考慮する等、知識表現の取り込みが見られる。

このように、従来の知識の分野の論理から行動の取り込み、従来の行動決定の論理の分野から知識表現の取り込みがあり、両範疇の接近が見られる。また、複数のエージェント間、更にはグループ・組織として複数エージェントを束ねてみるといった研究に対象が移っている。

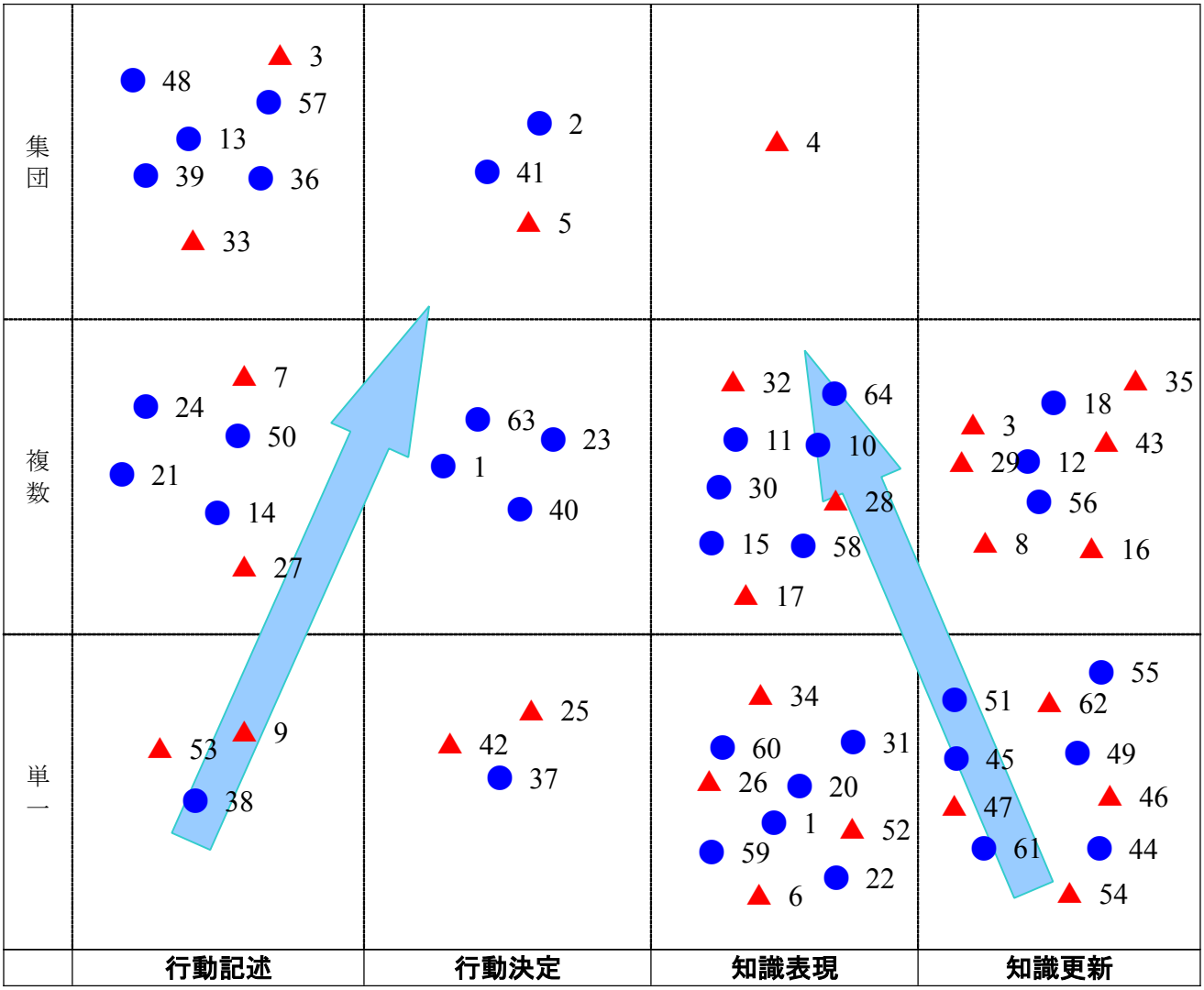
なお、下の図においては以下の凡例を使用している。

●印:直近5年間での発表

▲印:その前5年間での発表

●/▲印右隣の数字:(1)の対象リスト(表 3-2)中の番号(「No.」カラム)

図 3-2 エージェントの知識、行動に関する研究例



３．２．２．頻出キーワード

（1）頻出キーワードの調査

３．２．１．で使用した研究リスト中の各研究について、キーワードを収集した。なお、4つ以上のキーワードが設定されている場合は、研究内容に近接であると考えられるもの3つに絞込みを行った上で実施している。

（2）調査の結果

表 3-3、3-4 に、抽出された頻出キーワードを示す。

知識表現・信念更新に関する研究では、知識に加え、行動を合わせて扱う動的な、Dynamic Epistemic Logic, Public Announcement, Awareness,等の語や、信念更新のマルチエージェントへの対応を示唆する、AGM, Internal,、Communication Channel, グループ・集団の知識を示す Common Knowledge,等の語が、比較的多く現れるキーワードとして挙げられる。

また、行動決定・記述に関する研究では、集団の行動決定を示す、 Coalition Logic, Norms, Alternating-time Temporal Logicといった語, マルチエージェントの実装を示唆するAnswer Set Programming,, 知識と行動の交差を示す Dialogue, Epistemic、Announcement,といった語 不確かな環境における行動決定等を対象とする Speculative,等が、頻出キーワードとして挙げられる。

表 3-3
知識表現・更新に関する論文キーワード

DEL (Dynamic Epistemic Logic)	6
AGM	5
PAL (Public Announcement Logic)	5
internal	3
awareness	2
common knowledge	2
communication channel	2
Description Logic	2
epistemic	2
iterated	2
merge	2
non-monotonic	2
abduction	1
action	1
assignment	1
belief expansion	1
belief merge	1
change	1
CL (Coalition Logic)	1
conplexity	1
Default Logic	1
Distributed Default Logic	1
Dynamic Logic	1
ETL	1
frame problem	1
Horn fragment	1
Hybrid Logic	1
inconsistent	1
interaction	1
interrogative	1
Jeffrey's Rule	1
Justification Logic	1
KQML	1
linear algebra	1
local	1
many valued	1
message processing	1
mind	1
ordering	1
partially orderd information	1
PDL, (Propositional Dynamic Logic)	1

表 3-4
行動決定・記述に関する論文のキーワード

ASP (Answer Set Programming)	4
CL (Coalition Logic)	4
norms	4
ATL	3
Dynamic Logic	4
LTL	3
announce	2
coalition	2
dialogue	2
epistemic	2
speculative	2
3PAL	1
Assumption Based Argumentation	1
BDI;	1
common knowledge	1
communication	1
compliance	1
CTL	1
Description Logic	1
group	1
hierarchical	1
incomplete information	1
nondeterministic	1
organization	1
other agents	1
PDL,	1
Resource-Bounded	1
reversible	1
STIT	1
trust	1

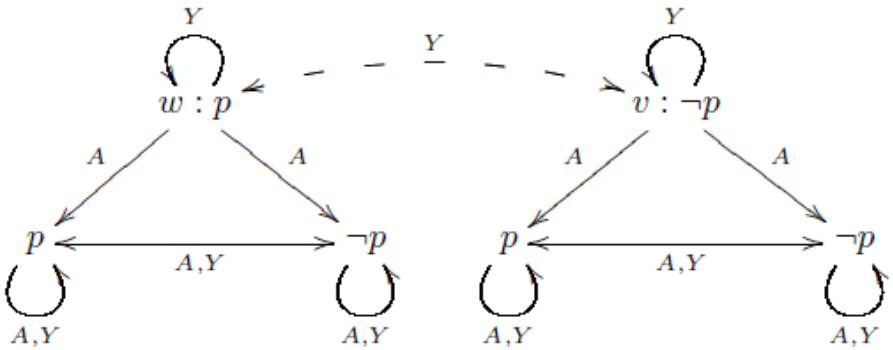
possible world semantics	1
prioritised	1
Relevant Logic	1
reset	1
rewind	1
sequential	1
Situation Calculus	1
Temporal Logic	1
Temporal Epistemic Logic	1
uncertain	1
undecidability	1

４．個別の研究課題について

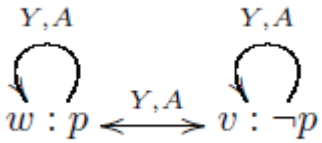
４．１．信念の更新の論理のマルチエージェントへの拡張

2006 年Cantwell Johnは、あるグループに対する告知による信念の更新(Belief Revision)の意味論として、各エージェントの内面的な可能世界を提案し、AGMの選択関数をこれに取り入れている。[40]

AGMの信念更新(Belieff Revision)は、単一のエージェントを対象としており、2008 年、Aucher, Guillaumeは、これをMulti Agent System に適用する研究を行っている。[41] この中で、マルチエージェントに認識論理(Episteimc Logic)を適用する際、その意味論について、AGMのモデルのように、単一のエージェントの内面的な可能世界（各現世界）の共通部分を持たない集合の和集合として表現している。



内面的な認識モデル(Epistemic Model) { (M_1, w),(M_2, w) }



Bisimular Model

図 4-1 内面的な認識モデル（Cantwell）

そして、この内面的な可能世界の文法面について、AGMの信念更新の 8 つの公理が成立するとしている。

＊:Revision Operator (K*A は知識ベースKのAによる更新を示す。)

(K*1) K*A 論理的帰結に対し閉じている。

(K*2) A は K*Aに含まれる。

(K*3) K*A は、 K ∪ {A}の部分集合

(K*4) ¬A がKに含まれないなら、 K ∪ {A} は K*Aの部分集合

(K*5) K*A が一貫性を持たないなら、 K かAは一貫性を持たない。
(K*6) A と B が論理的に等しいのであれば、 K*A と K*Bも等しい。
(K*7) K*(A & B) は K*A ∪ {B} の部分集合
(K*8) ¬B が K*Aに含まれないのであれば、 K*A ∪ B は K*(A & B)の部分集合

Aucher, Guillaumeは、2012 年、上記内面モデルの考え方を、認識論理(Epistemic Logic)に適用し、BMSフレーム(Baltag, Moss and Solecki[28])において、特定グループへの告知による信念の更新(Belief Expansion)を表現している。[42]

また、2006 年、Fusaoka Akira; Nakamura Katsunori と Sato Mitsunariは、エージェントの信念の更新を線形代数として取り扱う方法について、従来の研究から、マルチエージェントを扱うものに拡張した。[43] 認識の状態 (Epistemic States)はベクトルで、情報は演算子として、また信念の状態(Belief States)は、テンソルとして表現できることを示し('*u*'を状態とする時、情報'A'が伝わった後の状態は、'A*u*'で表される。)、マルチエージェントシステム(MAS)にみられる、他者の知識状態に関する知識等を表現するために、マルチエージェントの場合の信念を、テンソルの内積で表現している。

４．２．エージェントグループの能力の記述の拡張

あるエージェントのグループが、集団行動による目的の状態を達成する能力を表現する言語として、CL (Coalition Logic) や、ATL (Alternating-time Temporal Logic) が、2000 年以降研究されている。近年、これらの課題を克服しようとする研究が、比較的多く見られる。

200 年、van der Hoek と M. Wooldridgは、ATL(Alternating-timeTemporal Logic)と認識論理(Epistemic Logic) を組み合わせ、エージェントの行動能力を表現できるATEL (Alternating-time Temporal Logic)を提案している。[44] これを受け、Wojciech Jamroga, Thomas Ågotnesは、2006 年、不確かな情報におけるエージェントの行動決定に関する論理の意味論として、状態の集合においてある式が成立するとする研究を行っている。[45] Jamroga等は、以下のように、通常の単一世界ではなく、起こりうる世界の集合の全ての要素において、ある状態が真となるという意味論を考えることで、不完全な情報において、エージェントがある状態を成立させるための統一的な戦略を持っていることを表現している。

$M, Q \models p$
ここで、Qは状態の集合

2007 年、Jamroga WojciechとBulling Nilsは、ATLに、あるの起こりやすさを表現する演算子を追加し、例えば以下の式で、「ωによって定義される合理的な戦略の集合を考えたとき、ϕが成り立つと考えるのが、最も確からしい。」ということを表現できるような演算子を追加し、これを、例えば、Nash均衡やパレート最適の戦略に従う場合の起こりやすさの表現を試みている。[46]

$(\text{set-pl}\ \omega)\text{Pl}\phi$

2010 年、Herzig Andreas と Lorini Emilianoは、CL (Coalition Logic) やATLを基とした研究とは異なり、PDL (Propositional Dynamic Logic) を拡張することで、エージェントの集団の能力を表現することができる論理 (DLA: Dynamic Logic of Agency) の構築を試みている。DLAの言語は以下から構成される。[47]

$\phi ::= p \mid \bot \mid \neg\phi \mid \phi \vee \phi \mid \langle i:a\rangle\phi \mid \Box\phi$

ここで、<i:a>はエージェントiが行動aを実行する、□φは、「あるグループのエージェント全ての行動の結果、φが成立する。」を意味する。DLAの文法として、グループCの各エージェントが1つずつある行動を同時に実施する合同行為（joint action）を定義している。

$$\delta_C \equiv \langle \delta_i \rangle_{i \in C}$$

また、DLAのフレームは、以下であらわされている。

$$F = \langle W, R, \sim \rangle$$

ここで、Wは、可能世界の集合、Rは、エージェントと行動の組合わせと、状態の遷移関係を結びつける関係（$R_{<i:a>}(w)$）、～は、可能世界における等値関係を表す。

CLやATLでは、各エージェントの行動に名称を付与し、目的とする状態に単一の演算子で直接結ぶつけていたため、「エージェントが目的の状態を保障するある行動を知っている。」という表現と。「エージェントが目的の状態を保障すると知っているような、ある行動がある。」という表現を区別できない問題があった。DLAでは、これをPDLを拡張し、履歴上必然の演算子（□）から構成することで、識別可能としている。

同様に、ATLやCLが、エージェントの行動により、実際どのようにある目的の状態が達成されるのかを表現できない問題に対処するため、2011 年、Limaは、CAL(Coalition Announcement Logic）を拡張し、Annoumcement 以外の環境に影響を与える物理的な行動も扱えるようにした、ATAL（Alternating-time Temporal Annoumcement Logic）を研究している。[48]

≪G≫φ：Gは、次の段階で、φが成立するようにすることができる。

なお、ATALでは、時相の演算子（Temporal Operator）が追加されており、≪G, ψ≫φで、「グループGは、ψが成立するよう行動することで、次にφを真とすることができる.。」を表現できる。Lamaは、更に 2012 年、Annoumcement以外の物理的な行動について研究し、その完全性と健全性を証明している。[49]

一方、CL（Coalition Logic）は、2002 年、M.Paulyにより研究が開始された。[50] CLでは、'[C]φ'で、あるエージェントのグループCが、φを成立させることができることをあらわしている。

従来ののCLと他の様相論理のマージが命題論理を対象としていたのに対し、2009 年、İnanç Seylan,とWojciech Jamrogaは、CLとDescription LogicのALCを掛け合わせた論理（CLALC）によって、一階述語論理に対するエージェントの能力を記述できるようにした。[52]

また、Natasha等は、2011 年、現実世界におけるエージェントの行動決定には、時間やお金等リソースの制約があるとし、RBCL（Resource Bounded Coalition Logic）を研究している。[53] 本研究で扱われているRBCLの言語は以下である。

$p \mid \neg\phi \mid \phi \wedge \psi \mid [C^b]\phi$

$p \in Prop, C \subseteq A, b \in N^r$で、Propは命題論理の集合、Aはエージェントの集合、Nはエージェントを表現ししている。$[C^b]\phi$で、エージェントのグループCは、リソースの制約bのもとで、φを実現できることを表現している。単一の行動の場合のRBCLのフレームは以下で構成されている。

$(A, R, \Sigma = \cup i \in A \Sigma i, S, T, o, Res)$

A ：エージェントの集合

R ：リソースの集合

Σ :エージェントの行動の集合
S :状態の集合
T :状態とエージェントの組み合わせと、その状態でエージェントがとれる行動を結びつける関係の集合（S × A → ℘(Σ i)）
O :状態と協調行動の結果から発生する状態を返す関数
Res :行動に必要なリソースの関係の集合（Σ → Nr）

そして、行動のモデルを、以下として、公理化を行っている。

M = (F, V)
F は上記フレーム、Vは、状態において真となる命題を表す付値関数

なお、Seylan,とJamrogaは、更に、RBCLを複数回の行動についても適用している。

４．３．エージェントの協調行動と規則

規則（Norms）は、エージェントの協調行動を制御する効果的な方法であるとの認識から、1990 年代後半から研究されるようになり、義務論理（Deontic Logic）を用いたMulti Agent System における規則がある場合のエージェントの行動決定論理等が行われている。

規則については、義務論理（Deontic Logic）の観点からも研究されており、2003 年、K. Segerbergは、義務論理（Deontic Logic）に動的な要素を取り入れたDynaimc Deontic Logicを発表している。[57]

以下の様相演算子を追加して構成されている。

[H]ϕ: 履歴上常にϕ
[D]ϕ: it is deontically necessary that ϕ.
[F]ϕ: it will always be the case that ϕ.
[P]ϕ: it always was the case that ϕ.

Dynamic Deontic Logicの意味は、以下で定義されている。

(h, g) |= ϕ

また、行動αについて、'|α|'で、行動αの解釈であるイベントを示すとき、「エージェントiは、αを履歴hにおいて実施する。」は、以下で記述できる。

iff ∃h , h , e,p(p ∈ e∧e = |α|∧h ≈ h ＜ i, e, p＞h)

行動との関係において、Dynamic Deontic Logicでは、更に行動を制約する演算子を2つ導入している。

obi(α): エージェントiにとって、行動αが実行された状態にする事が義務付けられている
fbi(α): エージェントiにとって、行動αが実行された状態にする事が禁止されている。

この演算子における充足可能性は以下で定義されている。

(h, g) |= obi(α) iff ∀g ∈ cont0(h)(¬(i does α in g) ⇒ ∀f ∈ norm(hg) (i does α in f))
(h, g) |= fbi(α) iff ∀g ∈ cont0(h)(∀f ∈ norm(hg) ¬(i does α in f))

ここで、cont(h)は、履歴hの最後の時点以降に続き履歴を示す。

また、norm(h)は、cont(h)のうち、規則(Norm)に適合しているものを示す。

このSegerbergの論理を拡張する形で、締め切りのある義務として規則を捉えた研究を 2006 年、Robert Demolombe, Philippe Bretier, Vincent Louisが行っている。[58] この研究の中で、締め切りの概念は、以下の演算子objを用いて表現されている。

obi(α ＜ d): エージェントiについて、現時点から、最初にdが成立するまでの間に、行動αが実施された状態することが義務付けられている。

また、演算子objが成立するのは以下で定義されている。

$$obi(\alpha < d) \overset{def}{=} [H](\text{until } done_i(\alpha) \vee d)[D](\text{before } d)done_i(\alpha)$$

また、2013 年に、Koen V. Hindriks, M. Birna van Riemsdijkが、義務の達成には締め切りが必要であるとの考えから、締め切りのある規則について、Real-timeで締め切りが変化する場合の論理の研究を行っている。[61]

義務論理を基とした研究以外では、2007 年、Thomas Ågotnes, Wiebe van der Hoek, Juan A. Rodríguez-Aguilar Carles Sierra Michael Wooldridgeは、分岐時相論理のCTL (Computation Tree Logic) を基に、規則のあるシステムにおける時相論理（NTL: Normative Temporal Logic) の研究を行った。[59] NTLでは、分岐時相論理の経路の量化子A(“on all paths. . . ”) と E (“on some path. . . ”) は、それぞれ、インデックスのついた義務様相演算子O_η と P_η で置き換えられている。$O_\eta \phi$は、「規則のある系においてφは義務となっている」、$P_\eta \phi$は、「規則のある系において、φは許されている」を、それぞれ表す。また、時相論理の一般的な演算子〇、◇、□、Uとともに用いられる。

NTLの言語は、以下で表現される。

$$\phi ::= \top \mid p \mid \neg\phi \mid \phi \vee \phi \mid P_\eta \bigcirc \phi \mid P_\eta(\phi \ U \ \phi) \mid O_\eta \ \phi \mid O_\eta(\phi \ U \ \phi)$$

意味は、

$$K, s \models_I \phi$$

について、エージェントiは、状態sについて、解釈iのもと、φが導かれるとしている。義務論理と、NTLの違いは、時相が表れるかによって区別される。「φであることが義務である($O\phi$)」は、NTLでは、「常に義務である ($O_\eta \Box \phi$)」または 「次に義務となる ($O_\eta \bigcirc \phi$)で表される。

2011 年、Andreas Herzig, Emiliano Lorini, Frédéric Moisan Nicolas Troquardhは、PDL (Propositional Dynamic Logic) に、割り当て (Propositional Assignment) の考え方を導入したPDL-PAに、演算子を追加することで、規則を表現できるとした研究を展開している。[60] PDL-PAの基本的な考え方は、エージェントは、ある命題変数pを真とする行動をとりうる(+p)または、偽とする行動をとりうる(-p)とするものである。Ai(α) と Pi(α)という特定の命題変数を用いる（ここで、iはエージェントを表し、αは割り当てを表す。）ことで、Ai(α) は、「i は、αとすることができる。」、 Pi(α) は、「i はαとすることを許されている。」ということが表現可能となる。PDL-PAは、高階の述語論理に関するエージェントの能力等を記述できるとしている。

義務論理以外の観点からの研究としては、他に、2012 年、Knobbout, Max & Dastani, Mehdi は、エージェントが規則に従う能力を、ATL (Alternating-time Temporal Logic) を拡張し、表現することを研究している。[51]

４．４．動的な認識論理の拡張

2000 年以降、DEL (Dynamic Epistemic Logic) 等、認識論理 (Epistemic Logic) を行動等の影響を考慮し、動的な状態を扱えるよう拡張する研究が多く見られる。

2004 年、Hans van Ditmarsch, Wiebe van der Hoek & Kooi, Barteldは、DELと従来の信念更新の関係について調査している。[62] Public Announcement が、信念更新のうち、信念の拡大 (Belieff Expansion) に等しいことを示している。ただし、これは、彼等が定義するところの positive knowledge （その言語を $'L^0_{pos'}$ で表現している。）の場合に限るとし、最終的に以下の等式を導いている。

$$L^0_{pos}, K^0_{(M|\neg\phi,w)}(a) = Cn(K^0_{(M,w)}(a) \cup \{\neg\phi\})$$

2005 年、H. P van Ditmarsch、W van der Hoek と B.P. Kooi は、DELに割り当ての考え方を導

入することで、知識の変化と事実の変化を統一的に扱えるよう、DELを拡張している。[65] 割り当てについては、エージェントのグループ全体がその事実の変化に気付いていることを意味する公的な割り当て（Public Assignment）と、事実が変わったのみで、エージェントはこれに気付いていない原始的な割り当て（Atomic Assignment）とを区別して用いている。

2009 年、Ditmarsch,、French、Fernandoは、エージェントの気付きと忘れを認識論理に取り入れる研究を行っている。[63] 同様に、彼等は 2012 年、知識と気付きの関係をモデル化した認識論理を展開している。[64] ここでは、まず気付きを、気付き関数を使用した認識に関するモデルで定義している。

認識モデル $M = (S,R,A, V)$

・S ： 状態（可能世界）

・R ： 二項関係 N → P(S×S) エージェントiの添え字で表される到達関係

・A ： 気付き関数 N → S → P(P) エージェントiが状態sで気付く命題の集合を返す

・V ： pの付値関数 P → P(S)

更に、気付きを考慮した行動に関するモデルを以下で定義している。

行動モデル M = (S, R,A, pre, post)

・S ：行動の集合

・R : エージェントiにおける行動間の到達関係 N → P(S×S)

・A : 気付き変化関数 エージェントiが行動sの後に、気付く(+),気付かなくなる(−)
{+,−} → N → S → P(P)

・pre : S → L 行動sの実行の事前条件関数;

・post : S → P → L 行動sの後、pの真偽が変わることを表す事後条件関数

そして、行動モデルの論理の言語を定義した後、意味論を以下で定義している。意味論は、通常の ⊤, atoms, negationと conjunction に加え、以下を追加定義している。

$(M, s) \models K^{S}_{i}\ \phi$ iff $\forall(s, t) \in R_i$ and $\forall(M', t') \leftrightarrow^{Ai(s)(} M, t)$,
$(M', t') \models \phi$

$(M, s) \models A_i\ \phi$ iff $v(\phi) \subseteq A_i(s)$

$(M, s) \models [M, s]\phi$ iff $(M, s) \models pre(s) \Rightarrow (M \otimes M, (s, s)) \models \phi$

５．まとめ

本調査研究では、マルチエージェントにおける信念の更新や、エージェント間の情報伝達に関する論理の研究について、近年１０年に、主要な国際会議や論文誌で発表されている研究成果を調査した。その結果、本研究のテーマに密接に関係のあると思われる文献を選び、研究分野の分類や、キーワードの集計を行った。知識関連の論理においては、知識に加え、行動や事実を扱える動的な知識表現による知識の変化を表す試みや、単一エージェントの論理を複数エージェント等に展開する試みが見られた。また、行動に関する論理においては、行動決定において他エージェントの知識状態を考慮する等知識表現の取り込みが見られた。また、キーワードの観点からは、行動を合わせて扱う動的な知識論理、信念更新のマルチエージェントへの対応、エージェントのグループ・集団の共通知識、エージェントのグループの目標達成能力に関する論理，マルチエージェントの実装、知識状態を考慮した行動の論理、不確かな環境における行動決定等が、研究対象としてあがっていることが伺いしれた。

更に、本調査研究では、これらの傾向に従い、以下の課題について個別の動向等を抽出した。また、これらの課題に関する研究動向から、今後の研究課題等を整理した。

・信念の更新の論理におけるマルチエージェントへの拡張の試み

本試みでは、各エージェントの世界観を、内面的な可能世界として表現することで、従来の信念更新論理が成立することや、線形代数を用いた状態変化のマルチエージェントへの拡張等の研究が見られた。

・エージェントのグループの能力の記述に関する論理の拡張の試み

比較的新しい行動の論理である、CL（Coalition Logic） や、ATL（Alternating-time Temporal Logic） について、その表現力を高め、現実の世界をより合った表現を可能とする研究が幾つか抽出された。

・マルチエージェントの協調行動を達成する規則に関する研究

協調行動を効果的に実現する手段として、規則を含んだ系の研究が、義務の論路（Deontic Logic） や、その他の論理を拡張する形で行われていることが判った。

・動的な認識論理の展開

認識論理（Epistemic Logic）について、気付きの概念を取り入れたり、割り当てを用いて事実も表現する等、知識の動的な変化に着目する傾向が見られた。

なお、その他にも、動的な認識論理（Dynamic Epistemic Logic）の実装に ASP '(Answer Set Programming) を用いた研究や、分散知識表現に関する研究等マルチエージェントを意識した研究が多く見られたが、今回の個別動向では除外している。

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Ａ．全抽出文献リスト

Author	Title	Jur/Symp	Volume	Number	Pages	Year	abstract	key word
Pardo, Pere & Sadrzadeh, Mehrnoosh	Planning in the logics of communication and change	AAMAS			1231--1232	2012	We adapt backward planning to Logics of Communication and Change (LCC), that model how do actions, announcements and sensing change facts and agents' beliefs. An LCC planner takes into account the epistemic effects of planned actions upon other agents, if their beliefs are relevant to her goals. Our results include: a characterization of frame axioms as theorems in *-free LCC, and soundness and completeness results for deterministic planning and strong planning in the non-deterministic case.	communication, dynamic epistemic logic, planning, MAS, Action
Valentin Goranko, Dmitry Shkatov	Tableau-based decision procedure for full coalitional multiagent temporal-epistemic logic of linear time	AAMAS				2009	We develop a tableau-based decision procedure for the full coalitional multiagent temporal-epistemic logic of linear time CMATEL(CD+LT). It extends LTL with operators of common and distributed knowledge for all coalitions of agents. The tableau procedure runs in exponential time, matching the lower bound obtained by Halpern and Vardi for a fragment of our logic, thus providing a complexity-optimal decision procedure for CMATEL(CD+LT).	Logics for multi-agent systems, decision procedures, tableaux
Aucher, Guillaume	Internal Models and Private Multi-agent Belief Revision	AAMAS				2008	We generalize AGM belief revision theory to the multi-agent case. To do so, we first generalize the semantics of the single- agent case, based on the notion of interpretation, to the multi-agent case. Then we show that, thanks to the shape of our new semantics, all the results of the AGM framework transfer. Afterwards we investigate some postulates that are specific to our multi-agent setting.	Belief revision, Epistemic logic, Multi-agent systems, AGM
Thomas Agotnes, Hans van Ditmarsch	Coalitions and Announcements	AAMAS				2008	Two currently active strands of research on logics for multi-agent systems are dynamic epistemic logic, focusing on the epistemic consequences of actions, and logics of coalitional ability, focusing on what coalitions of agents can achieve by cooperating strategically. In this paper we make a ?rst attempt to bridge these topics by considering the question: "what can a coalition achieve by public announcements?". We propose, ?rst, an extension of public announcement logic with constructs of the form hGi?, where G is a set of agents, with the intuitive meaning that G can jointly make an announcement such that?will be true afterwards. Second, we consider a setting where all agents can make (truthful) announcements at the same time, and propose a logic with a construct h[G]i?, meaning that G can jointly make an announcement such that no matter what the other agents announce, ? will be true. The latter logic is closely related to Marc Pauly' s Coalition Logic.	Dynamic epistemic logic, coalition logic, public announcements
Luigi Sauro, Jelle Gerbrandy, Wiebe van der Hoek Michael Wooldridge	Reasoning about action and cooperation	AAMAS				2006	We present a logic for reasoning both about the ability of agents to cooperate to execute complex actions, and how this relates to their ability to reach certain states of affairs. We show how the logic can be obtained in a modularised way, by combining a model for reasoning about actions and their effects with a model that describes what actions an agent can perform. More precisely, we show how one can combine an action logic which resembles Propositional Dynamic Logic with a cooperation logic which resembles Coalition Logic. We give a sound and complete axiomatisation for the logic, illustrate its use by means of an example, and discuss possible future extensions to it.	Agent and multi-agent architectures, Cooperation and coordination among agents, Logics for agent systems, (Multi-)Agent planning, Dynamic Logic, Coalition Logic
Lutz, Carsten	Complexity and succinctness of public announcement logic	AAMAS				2006	There is a recent trend of extending epistemic logic (EL) with dynamic operators that allow to express the evolution of knowledge and induced by knowledge-changing actions. The most basic such extension is public announcement logic (PAL), which is obtained from EL by adding an operator for truthful public announcements. In this paper, we consider the computational complexity of PAL and show that it coincides with that of EL. This holds in the single- and multi-agent case, and also in the presence of common knowledge operators. We also prove that there are properties that can be expressed exponentially more succinct in PAL than in EL. This shows that, despite the known fact that PAL and EL have the same expressive power, there is a benefit in adding the public announcement operator to EL: it exponentially increases the succinctness of formulas without having negative effects on computational complexity.	logics for agent systems, computational complexity, dynamic epistemic logic, public announcement
Bentahar, Jamal; Moulin, Bernard; Meyer, John-JulesCh. & Chaib-draa, Brahim	A Computational Model for Conversation Policies for Agent Communication	CLIMA 5th	3487		178-195	2004	In this paper we propose a formal specification of a persuasion protocol between autonomous agents using an approach based on social commitments and arguments. In order to be flexible, this protocol is defined as a combination of a set of conversation policies. These policies are formalized as a set of dialogue games. The protocol is specified using two types of dialogue games: entry dialogue game and chaining dialogue games. The protocol terminates when exit conditions are satisfied. Using a tableau method, we prove that this protocol always terminates. The paper addresses also the implementation issues of our protocol using logical programming and an agent-oriented platform.	communication
Hagiwara, Shingo; Kobayashi, Mikito & Tojo, Satoshi	Belief Updating by Communication Channel	CLIMA 7th	4371		211-225	2006	In this paper, we introduce the notion of communication channel into a multiagent system. We formalize the system in term of logic with Belief modality, where each possible world includes CTL. We represent the channel by a reserved set of propositional variables. With this, we revise the definition of inform of FIPA; if the channel exists the receiver agent surely learns the information whereas if not the action fails. According to this distinction, the current state in each world would diverge into two different states. We have implemented a prover, that works also as a model builder. Given a formula in a state in a possible world, the system proves whether it holds or not, while if an inform action is initiated the system adds new states with branching paths.	communication channel

Author	Title	Jur/Symp	Volume	Number	Pages	Year	abstract	key word
T.Yamada	Acts of Commanding and Changing Obligations	CLIMA 7th				2006	If we are to take the notion of speech act seriously, we must be able to treat speech acts as acts. In this paper, we will try to model changes brought about by various acts of commanding in terms of a variant of update logic. We will combine a multi-agent variant of the language of monadic deontic logic with a dynamic language to talk about the situations before and after the issuance of commands, and the commands that link those situations. Although the resulting logic inherits various inadequacies from monadic deontic logic, some interesting principles are captured and seen to be valid nonetheless. A complete axiomatization and some interesting valid principles together with concrete examples will be presented, and suggestions for further research will be made.	Deontic logic, Dynamic logic, Update semantics, Eliminative commands, Obligations
Jeremy Seligman, Fenrong Liu & Girard, Patrick	Logic in the Community	ICLA				2011	Communities consist of individuals bounds together by social relationships and roles. Within communities, individuals reason about each other's beliefs, knowledge and preferences. Knowledge, belief, preferences and even the social relationships are constantly changing, and yet our ability to keep track of these changes is an important part of what it means to belong to a community.	Public Announcement, Common Knowledge, Distributed Knowledge, Facebook
Wi?ch, Przemys?aw; Rybinski, Henryk & Ry?ko, Dominik	DDLD-Based Reasoning for MAS	ISMIS	6804		182-191	2011	In this paper, a model for DDL $¥mathfrak{D}$ -based multi-agent system is described. The article extends our previous work, in which a formalism for distributed default reasoning to be performed by a group of agents that share knowledge in the form of a distributed default theory has been presented. The formalism is based on default transformations, which can be used to derive answers to queries in the form of defaults. The distributed reasoning process is described in a setting where agents communicate by passing messages.	multi-agent system; default logic; description logic; distributed reasoning;Distributedn Default Reasoning
Aucher, Guillaume	Private announcement and belief expansion: an internal perspective	Journal of Logic and Computation	22	3	451-479	2012	AGM belief revision theory and the BMS framework of dynamic epistemic logic both deal with the formalization of belief change, the former in a single-agent setting and the latter in a multi-agent setting. In this article, we study the relation between these two formalisms.To be fair,we restrict our attention to the AGM operation of expansion since the original BMS framework does not allow for belief revision. The generalization of the AGM operation of revision to the multi-agent setting is dealt with in the companion paper [Aucher (2010, Logic Journal of the IGPL, 18, 530?558)]. Besides, because AGM theory follows the internal approach, instead of the original BMS framework we define and deal with its internal version. This allows us to show that the AGM operation of expansion can naturally be viewed in the multi-agent setting of the BMS framework as the operation of private announcement, which goes against the claims of [van Ditmarsch, van der Hoek and Kooi (2004, Advances in Modal Logic, 335?346)]. In parallel, we also provide conditions under which seriality of accessibility relations is preserved during an update, in the BMS framework as well as its internal version: it is a preliminary step towards the introduction of revision mechanisms into these frameworks.	Belief revision theory, Dynamic epistemic logic, Internal approach, Private announcement,Seriality preservation
de Lima, Tiago	Alternating-time temporal dynamic epistemic logic1	Journal of Logic and Computation				2012	This article proposes a formalism called alternating-time temporal dynamic epistemic logic (ATDEL). It is somewhat similar to the coalition announcement logic (CAL) proposed by ?gotnes et al. As well as CAL, ATDEL has a coalition operator that enables to express sentences like 'there is an action a for each member of the group of agents G after which ? is true, in spite of what the agents outside the group G do'. One of the differences here, is that such actions a can also have factual effects. They are not restricted only to public announcements, as in CAL. In addition, this operator is coupled with temporal operators similar to those in alternating-time temporal logic. For instance, ATDEL has operators enabling to express sentences like 'the group of agents G is able to enforce that ψ is true until ? becomes true'. Comparisons with several other logics, such as public announcement logic with assignment, group announcement logic and arbitrary public announcement logic are drawn. Since the descriptions of actions in ATDEL is concise, it is advocated that one of its main advantages is the possibility to have reasonable-sized multi-agent systems specifications. Moreover, a sound and complete axiomatization, model checking and satisfiability checking algorithms as well as some complexity bounds are provided. Satisfiability checking in ATDEL with finite sets of actions is shown to be decidable.	alternating-time temporal dynamic epistemic logic (ATDEL); Coalition Announcement Logic
Herzig, Andreas & Lorini, Emiliano	A Dynamic Logic of Agency I: STIT, Capabilities and Powers	Journal of Logic, Language and Information	19		89-121	2010	The aim of this paper, is to provide a logical framework for reasoning about actions, agency, and powers of agents and coalitions in game-like multi-agent systems. First we define our basic Dynamic Logic of Agency (DLA). Differently from other logics of individual and coalitional capability such as Alternating-time Temporal Logic (ATL) and Coalition Logic, in DLA cooperation modalities for expressing powers of agents and coalitions are not primitive, but are defined from more basic dynamic logic operators of action and (historic) necessity. We show that STIT logic can be reconstructed in DLA . We then extend DLA with epistemic operators, which allows us to distinguish capability and power. We finally characterize the conditions under which agents are aware of their capabilities and powers.	Logic of agency; STIT; Coalition logic; Game theory, Dynamic Logic; MAS
Hoshi, Tomohiro	Merging DEL and ETL	Journal of Logic, Language and Information	19		413-430	2010	This paper surveys the interface between the two major logical trends that describe agents' intelligent interaction over time: dynamic epistemic logic (DEL) and epistemic temporal logic (ETL). The initial attempt to "merge" DEL and ETL was made in van Benthem et al. (Merging frameworks for interaction: DEL and ETL, 2007) and followed up by van Benthem et al. (J Phil Logic 38(5):491?526, 2009) and Hoshi (Epistemic dynamics and protocol information. Ph.D. thesis, Stanford University Stanford, 2009a). The merged framework provides a systematic comparison between these two logical systems and studies new logics of intelligent interaction. This paper presents the main results and the recent developments at the interface between DEL and ETL.	Intelligent interaction; Reasoning about knowledge; Dynamic epistemic logic (DEL); Epistemic temporal logic (ETL)

Author	Title	Jur/Symp	Volume	Number	Pages	Year	abstract	key word
Cantwell, John	A Formal Model of Multi-Agent Belief-Interaction	Journal of Logic, Language and Information	15	4	303-329	2006	A semantics is presented for belief revision in the face of common announcements to a group of agents that have beliefs about each other' s beliefs. The semantics is based on the idea that possible worlds can be viewed as having an internal-structure, representing the belief independent features of the world, and the respective belief states of the agents in a modular fashion. Modularity guarantees that changing one aspect of the world (a belief independent feature or a belief state) has no effect on any other aspect of the world. This allows us to employ an AGM-style selection function to represent revision. The semantics is given a complete axiomatisation (identical to the axiomatisation found by Gerbrandy and Groeneveld for a semantics based on non-wellfounded set theory) for the special case of expansion.	common announcements; dynamic logic; epistemic logic; common knowledge; belief revision
Alexandru Baltag, Lawrence S. Moss & Solecki, Slawomir	The Logic of Public Announcements,Common Knowledge, and Private Suspicions	Proceedings of the 7th Conference on Theoretical Aspects of Rationality and Knowledge (TARK VII)				1998	This paper presents a logical system in which various group-level epistemic actions are incorporated into the object language. That is, we consider the standard modeling of knowledge among a set of agents by multi-modal Kripke structures. One might want to consider actions that take place, such as announcements to groups privately, announcements with suspicious outsiders, etc. In our system, such actions correspond to additional modalities in the object language. That is, we do not add machinery on top of models (as in, e.g., Fagin et al (1995), but we reify aspects of the machinery in the logical language. Special cases of our logic have been considered in Plaza (1989), Gerbrandy (1999), and Gerbrandy and Groeneveld (1997). The latter group of papers introduce a language in which one can faithfully represent all of the reasoning in examples such as the Muddy Children scenario. In that paper we find operators for updating worlds via announcements to groups of agents who are isolated from all others. We advance this by considering many more actions, and by using a more general semantics. Our logic contains the infinitary operators used in the standard modeling of common knowledge. We present a sound and complete logical system for the logic, and we study its expressive power.	Public announcement, Common Knowledge
M.Kobayashi, S.Tojo	Agent Communication for Dynamic Belief Update	人工知能学会論文誌24巻(2009)	24			2009	Thus far, various formalizations of rational / logical agent model have been proposed. In this paper, we include the notion of communication channel and belief modality into update logic, and introduce Belief Update Logic (BUL). First, we discuss that how we can reformalize the inform action of FIPA-ACL into communication channel, which represents a connection between agents. Thus, our agents can send a message only when they believe, and also there actually is, a channel between him / her and a receiver. Then, we present a static belief logic (BL) and show its soundness and completeness. Next, we develop the logic to BUL, which can update Kripke model by the inform action; in which we show that in the updated model the belief operator also satisfies K45. Thereafter, we show that every sentence in BUL can be translated into BL; thus, we can contend that BUL is also sound and complete. Furthermore, we discuss the features of CUL, including the case of inconsistent information, as well as channel transmission. Finally, we summarize our contribution and discuss some future issues.	Belief update logic, Belief update, Agent communication, Communication channel
van Ditmarsch, Hans; French, Tim & Vel¥'{a}zquez-Quesada, Fernando R.	Action models for knowledge and awareness	AAMAS			1091--1098	2012	We consider semantic structures and logics that differentiate between being uncertain about a proposition, being un-aware of a proposition, becoming aware of a proposition and getting to know the truth value of a proposition. We give a unified setting to model all this variety of static and dynamic aspects of awareness and knowledge, without any constraints on the modal properties of knowledge (or belief --- such as introspection) or on the interaction between awareness and knowledge (such as awareness introspection). Our primitive epistemic operator is called speculative knowledge. This is different from the better known implicit knowledge, now definable, which plays a more restricted role. Some dynamic semantic primitives that are elegantly definable in our setting are the actions of 'becoming aware of a propositional variable', 'implicit knowledge', 'addressing a novel issue in an announcement', and also more complex ways in which an agent can become aware of a novel issue by way of increasing the complexity of the epistemic model.	awareness, dynamics, epistemic logic, modal logic, Uncertainity
van der Hoek, Wiebe; Iliev, Petar & Wooldridge, Michael	A logic of revelation and concealment	AAMAS			1115--1122	2012	The last decade has been witness to a rapid growth of interest in logics intended to support reasoning about the interactions between knowledge and action. Typically, logics combining dynamic and epistemic components contain ontic actions (which change the state of the world, e.g., switching a light on) or epistemic actions (which affect the information possessed by agents, e.g., making an announcement). We introduce a new logic for reasoning about the interaction between knowledge and action, in which each agent in a system is assumed to perceive some subset of the overall set of Boolean variables in the system; these variables give rise to epistemic indistinguishability relations, in that two states are considered indistinguishable to an agent if all the variables visible to that agent have the same value in both states. In the dynamic component of the logic, we introduce actions r(p, i) and c(p, i): the effect of r(p, i) is to reveal variable p to agent i; the effect of c(p, i) is to conceal p from i. By using these dynamic operators, we can represent and reason about how the knowledge of agents changes when parts of their environment are concealed from them, or by revealing parts of their environment to them. Our main technical result is a sound and complete axiomatisation for our logic.	dynamic epistemic logic, epistemic logic, interpreted systems, knowledge and change, modal logic

Author	Title	Jur/Symp	Volume	Number	Pages	Year	abstract	key word
Knobbout, Max & Dastani, Mehdi	Reasoning under compliance assumptions in normative multiagent systems	AAMAS			331—340	2012	The use of norms in multiagent systems has proven to be a successful approach in order to coordinate and regulate the behaviour of participating agents. In such normative systems it is generally assumed that agents can obey or disobey norms. In this paper, we develop a logical framework for normative systems that allows reasoning about agents' abilities under a multitude of norm compliance assumptions. In particular, we investigate different types of norm compliance and propose an extension of Alternating Temporal Logic (ATL) to reason about the abilities of (coalitions of) agents under different types of norm compliance assumptions. For this extension we show that the problem of model-checking remains close to the domain of standard ATL. Finally, we show that some norms can limit an agent's autonomy in the sense that an agent cannot control the violation of these norms. We present and discuss various classes of the so-called self-supporting norms, i.e., norms for which individual agents have control over their violations.	logic, normative systems, organizations, verification, ATL, MAS
van Ditmarsch, Hans; van der Hoek, Wiebe & Kooi, Barteld	Reasoning about local properties in modal logic	AAMAS			711—718	2011	In modal logic, when adding a syntactic property to an axiomatisation, this property will semantically become true in all models, in all situations, under all circumstances. For instance, adding a property like Kap → Kbp (agent b knows at least what agent a knows) to an axiomatisation of some epistemic logic has as an effect that such a property becomes globally true, i.e., it will hold in all states, at all time points (in a temporal setting), after every action (in a dynamic setting) and after any communication (in an update setting), and every agent will know that it holds, it will even be common knowledge. We propose a way to express that a property like the above only needs to hold locally: it may hold in the actual state, but not in all states, and not all agents may know that it holds. We can achieve this by adding relational atoms to the language that represent (implicitly) quantification over all formulas, as in ∀p(Kap → Kbp). We show how this can be done for a rich class of modal logics and a variety of syntactic properties.	canonicity, correspondence theory, epistemic logic, local properties, modal logic
Morris, Alexis; Ross, William & Ulieru, Mihaela	Modelling culture in multi-agent organizations	AAMAS			65--79	2011	We introduce a novel way to model and visualize culture in multi-agent organizations exploring the multi-dimensionality of culture and cultural modelling from a complex systems and multi-agent systems standpoint. The need for performing such modelling and simulation is evident since in-vivo organizational experiments are costly, not easily generalizable, and may not be feasible in critical situations. The proposed model enables one to point to strategies for organizational transformation/evolution by i) developing a unique approach to culture modelling from a holistic and systems-theoretic perspective according to seven dimensions, and ii) simulating cultural interactions as a multi-agent system that achieves an equilibrium of beliefs. Incipient results with a simple model reveal the dynamics of emergent culture of an agent organization having distinct roles and influences that develop as new individuals are added to the system.	complex systems, culture modelling, multi-agent systems, simulation
Baral, Chitta; Gelfond, Gregory; Son, Tran Cao & Pontelli, Enrico	Using answer set programming to model multi-agent scenarios involving agents' knowledge about other's knowledge	AAMAS			259—266	2010	One of the most challenging aspects of reasoning, planning, and acting in a multi-agent domain is reasoning about what the agents know about the knowledge of their fellows, and to take it into account when planning and acting. In the past this has been done using modal and dynamic epistemic logics. In this paper we explore the use of answer set programming (ASP), and reasoning about action techniques for this purpose. These approaches present a number of theoretical and practical advantages. From the theoretical perspective, ASP's property of non-monotonicity (and several other features) allow us to express causality in an elegant fashion. From the practical perspective, recent implementations of ASP solvers have become very efficient, outperforming several other systems in recent SAT competitions. Finally, the use of ASP and reasoning about action techniques allows for the adaptation of a large body of research developed for single-agent to multi-agent domains. We begin our discussion by showing how ASP can be used to find Kripke models of a modal theory. We then illustrate how both the muddy children, and the sum-and-product problems can be represented and solved using these concepts. We describe and implement a new kind of action, which we call ask-and-truthfully-answer and show how this action brings forth a new dimension to the muddy children problem.	answer set programming, reasoning about actions, MAS
Inan? Seylan, Wojciech Jamroga	Description Logic for Coalitions	AAMAS				2009	Coalition Logic (CL) is one of the most important formalisms for specification and verification of game-like multi-agent systems. Several extensions of the logic have been studied in the literature. These extensions are usually fusions (independent joins) of CL with other modal logics (e.g., temporal, epistemic, dynamic, etc.), and they are generally propositional. In this paper, we propose a game description logic called CLALC which is based on a product of Coalition Logic with the description logic ALC. The new logic allows one to reason about agents' ability to influence firstorder structures. We show that the satisfiability problem for CLALC is decidable; we prove this by giving a goal-directed decision procedure for the problem.	Strategic logics, description logics, satisfiability, tableaux, Coalition Logic

Author	Title	Jur/Symp	Volume	Number	Pages	Year	abstract	key word
Patrick Kr?mpelmann, Matthias Thimm, Gabriele Kern-Isberner Manuela Ritterskamp	Belief Operations for Motivated BDI Agents	AAMAS				2008	The beliefs of an agent re?ecting her subjective view of the world constitute one of the main components of a BDI agent. In order to incorporate new information coming from other agents, or to adjust to changes in the environment, the agent has to carry out belief change operations while taking metalogical information on time and reliabilities into account. In this paper, we describe a framework for belief operations within a BDI agent, sketching the interactions of beliefs with desires and intentions, respectively. Furthermore, we illustrate how motivations and know-how come into play in our agent model of this framework. We focus on the presentation of a complex setting for belief change that makes use of techniques both from merging and update, and provides a BDI agent with advanced reasoning capabilities. Extended logic programs under the answer set semantics will serve as the basic knowledge representation formalism.	Multiagent System, BDI, Belief Revision, Motivation
Lomuscio, Alessio & Wo?na, Bo?ena	A Temporal Epistemic Logic with a Reset Operation	AAMAS				2007	We present an axiomatisation for an extension of a temporal epistemic logic with an epistemic "reset" operator de?ned on the intersection between epistemic and temporal relations. Additionally we show the logic has the ?nite model property, hence it is decidable.	Epistemic logic, axiomatisation, decidability
¥AAgotnes, Thomas & Walicki, Michal	A logic of reasoning, communication and cooperation with syntactic knowledge	AAMAS			1135--1136	2005	We present a general logic of explicit knowledge represented as finite sets of logical formulae which can evolve by non-deterministic reasoning and communication. It is partly based on Alternating-time Temporal Logic, which allows the expression of properties of cooperation. Properties of an agent's reasoning mechanism such as the agent knows modus ponens″ can be expressed. Instead of a common closure condition such as ″if the agent knows both p and p → q he must also know q″	ATL, epistemic logic, syntactic knowledge representation
van Ditmarsch, H. P.; van der Hoek, W. & Kooi, B. P.	Dynamic epistemic logic with assignment	AAMAS			141—148	2005	We add assignment operators to languages for epistemic actions, so that change of knowledge and change of facts can be combined in specifications of multi-agent system dynamics. We make a distinction between 'public assignment' and 'atomic assignment'. Public assignment means that the entire group of agents is aware of the factual change. This operation combines well with public announcement. We propose semantics for the logic of public announcements and public assignments, and we give a relevant valid principle. Atomic assignment means that only facts are changed, so that it can be expressed independently in the language how agents are aware of this factual change. Atomic assignment and 'test' (the truth of a formula) are the two basic constructs in a logic of epistemic actions. We propose semantics for this logic of epistemic actions and atomic assignment. The logic of public announcements and public assignments is a special case of this logic. Examples include card games where cards change hands.	agent communication, assignment, dynamic epistemic logic
Perrussel, Laurent & Thevenin, Jean-Marc	A Logical Approach for Describing (Dis)Belief Change and Message Processing	AAMAS			614—621	2004	This paper focuses on the features of two KQML performatives, namely tell and untell, in the context of nonprioritized belief change. Tell allows agents to send beliefs while untell allows agents to send explicit disbeliefs. In a multi agent system, agents have to change their belief when they receive new information from other agents. They may revise or contract their belief state accordingly. The revision action consists of inserting a new belief in a beliefs set while the contraction action consists of managing a set of disbeliefs. Whenever incoming information entails inconsistencies in an agent?s belief state, the agent must either drop some beliefs or refuse the incoming statement. For this, agents consider a preference relation over other agents embedded in the multi agent system and may reject new information based on their belief state and their preference relation. In this article, we survey a logic-based framework for handling messages and (dis)beliefs change. In this context, we formally describe the consequences of tell and untell performatives.	KQML, Belief Revision
Patrick Girard, Jeremy Seligman & Liu, Fenrong	General Dynamic Dynamic Logic	AiML				2012	Dynamic epistemic logic (DEL) extends purely modal epistemic logic (S5) by adding dynamic operators that change the model structure. Propositional dynamic logic (PDL) extends basic modal logic with programs that allow the definition of complex modalities. We provide a common generalisation: a logic that is `dynamic' in both senses, and one that is not limited to S5 as its modal base. It also incorporates, and significantly generalises, all the features of existing extensions of DEL such as BMS [3] and LCC [21]. Our dynamic operators work in two steps. First, they provide a multiplicity of transformations of the original model, one for each `action' in a purely syntactic `action structure' (in the style of BMS). Second, they specify how to combine these multiple copies to produce a new model. In each step, we use the generality of PDL to specify the transformations. The main technical contribution of the paper is to provide an axiomatisation of this `general dynamic dynamic logic' (GDDL). This is done by providing a computable translation of GDDL formulas to equivalent PDL formulas, thus reducing the logic to PDL, which is decidable. The proof involves switching between representing programs as terms and as automata. We also show that both BMS and LCC are special cases of GDDL, and that there are interesting applications that require the additional generality of GDDL, namely the modelling of private belief update. More recent extensions and variations of BMS and LCC are also discussed. Keywords: Dynamic logic, BMS, LCC	Dynamic logic, BMS, LCC, PDL, belief change

Author	Title	Jur/Symp	Volume	Number	Pages	Year	abstract	key word
Marta B?lkov?, Ondrej Majer, Michal Peli? & Restall, Greg	Relevant Agents	AiML			22–38	2010	In [4], Majer and Peli s proposed a relevant logic for epistemic agents, providing a novel extension of the relevant logic R with a distinctive epistemic modality K, which is at the one and the same time factive (K' ! ' is a theorem) and an existential normal modal operator (K(' _) ! (K' _ K) is also a theorem). The intended interpretation is that K' holds (relative to a situation s) if there is a resource available at s, confirming '. In this article we expand the class of models to the broader class of `general epistemic frames'. With this generalisation we provide a sound and complete axiomatisation for the logic of general relevant epistemic frames. We also show, that each of the modal axioms characterises some natural subclasses of general frames.	Modal Logic, Epistemic Logic, Relevant Logic, Substructural Logic, Frame Semantics
French, Tim & van Ditmarsch, Hans	Undecidability for arbitrary public announcement logic	AiML			23–42	2008	Arbitrary public announcement logic (AP AL) is an extension of multi–agent epistemic logic that allows agents' knowledge states to be updated by the public announcement of (possibly arbitrary) epistemic formulae. It has been shown to be more expressive than epistemic logic, and a sound and complete axiomatization has been given. Here we address the question of decidability. We present a proof that the satis?ability problem for arbitrary public announcement logic (AP AL) is co–RE complete, via a tiling argument.	Epistemic Logic, Public Announcement Logic, Decidability;MAS
Herzig, Andreas & Schwarzentruber, Fran?ois	Properties of logics of individual and group agency	AiML			133–149	2008	We provide proof–theoretic results about deliberative STIT logic. First we present STIT logic for individual agents without time, where the problem of satisfiability has recently been shown to be NEXPTIMEcomplete in the general case. Then we study STIT logic for groups of agents. We prove that satisfiability of STIT formulas involving groups of agents is undecidable by reducing the problem of satisfiability of a formula of the product logic S5 n to group STIT satisfiability problem. We also prove that group STIT is not finitely axiomatizable.	logics of agency, deliberative STIT, joint action, decidability, axiomatizability, complexity
Jens Hansen, Thomas Bolander & Bra?ner, Torben	Many–valued hybrid logic	AiML			111–132	2008	In this paper we define a many–valued semantics for hybrid logic and we give a sound and complete tableau system which is prooftheoretically well–behaved, in particular, it gives rise to a decision procedure for the logic. This shows that many–valued hybrid logics is a natural enterprise and opens up the way for future applications.	Modal logic, hybrid logic, many–valued logic, tableau systems.
Hans van Ditmarsch, Wiebe van der Hoek & Kooi, Barteld	Public Announcements and Belief Expansion	AiML	5			2004	In this paper we study the relation between two ap proaches to information change: Dynamic Epistemic Logic and Belief Revision. One of the main differences between these approaches is that higher–order information plays an important role in the field of Dynamic Epistemic Logic, whereas it does not feature in Belief Revision. In this paper we study to which extent public announcements (a particular kind of information change studied in Dynamic Epis temic Logic) can be viewed as a belief expansion (a particular kind of information change studied in Belief Revision).	Dynamic Epistemic Logic, Belief Revision
Dignum, Frank & Dignum, Virginia	A Formal Semantics for Agent (Re)Organization	CLIMA	7486		61–76	2012	Agent organizations can be seen as a set of entities regulated by mechanisms of social order and created by more or less autonomous actors to achieve common goals. Just like agents, organizations should also be able to adapt themselves to changing environments. In order to develop a theory on how this reorganization should be performed we need a formal framework in which organizations, organizational performance and the reorganization itself can be described. In this paper, we present a formal description of reorganization actions in LAO (Logic for Agent Organization). We show how this formalization can support the preservation of some nice properties of organizations while it can also be used to reason about which reorganization is needed to achieve some basic organizational properties.	Agent organizations, LAO (Logic for Agent Organization)
Lam, Ho–Pun; Governatori, Guido; Satoh, Ken & Hosobe, Hiroshi	Distributed Defeasible Speculative Reasoning in Ambient Environment	CLIMA	7486		43–60	2012	Speculative Computation is an effective means for solving problems with incomplete information in an open and distributed environment, such as peer–to–peer environment. It allows such a system to compute tentative (and possibly final) solutions using default knowledge about the current environment, or the agent's perception, even if the communications between peers are delayed or broken. However, previous work in speculative reasoning assumed that agents are hierarchically structured, which may not be the case in reality. We propose a more generalmulti–agent dynamic epistemic logic. Agents in the framework have equivalent functionalities and can collaborate with each other to achieve their common goals. We characterize the framework using the argumentation semantics of defeasible logic, which provides support of speculative reasoning in the presence of conflicting information. We provide an operational model for the framework and present a prototype implementation of the model.	hierarchically structure, dynamic epistemic logic,speculative reasoning, the argumentation semantics, defeasible logic
Wright, Ben; Pontelli, Enrico & Son, TranCao	Implementing Reversible Processes in Multi–agent Action Languages Using Answer Set Planning	CLIMA	7486		163–180	2012	This paper presents an implementation of the action language ? in answer set programming. The novelty of this language comes from the use of processes to execute delayed effects for actions. In addition, the ability to reverse, or cancel, the processes is available. A simple example is introduced to show when reversing actions are useable – even by other agents in the domain. These processes are the base foundation for future implementation of commitments in planning for multi–agent domains.	Knowledge Representation; Action Languages; Multi–agent systems; Answer Set Programming, Planning

Author	Title	Jur/Symp	Volume	Number	Pages	Year	abstract	key word
Lima, Tiago	Alternating-Time Temporal Announcement Logic	CLIMA	6814		105-121	2011	We propose a formalism that we call Alternating-time Temporal Announcement Logic (ATAL). It can be seen as an extension of the Coalition Announcement Logic (CAL) proposed by ?gotnes et al. As well as CAL, ATAL has modal operators enabling to express sentences like 'there is an action α by group of agents G after which consequence ϕ is true, in spite of what the other agents do'. One of the differences here, is that such action α can also be a physical action, and not only public announcements, as in CAL. Based on the latter kind of operator, ATAL also presents operators similar to those in Alternating-time Temporal Logic, which enable to express agents abilities. For instance, ATAL has operators enabling to express sentences like 'the group of agents G is able to enforce that ϕ is true from the next step on until ψ becomes true'. We also provide a sound and complete axiomatization for ATAL and draw comparisons with several other logics, such as Public Announcement Logic with Assignment, Arbitrary Public Announcement Logic, Coalition Logic and Alternating-time Temporal Logic.	Logics for coalitional ability; Epistemic Logic; Dynamic Epistemic Logic; Coalition Logic; Alternating-time Temporal Logic
D?prile, Davide; Giordano, Laura; Gliozzi, Valentina; Martelli, Alberto; Pozzato, GianLuca & Theseider Dupr?, Daniele	Verifying Business Process Compliance by Reasoning about Actions	CLIMA	6245		99-116	2010	In this paper we address the problem of verifying business process compliance with norms. To this end, we employ reasoning about actions in a temporal action theory. The action theory is defined through a combination of Answer Set Programming and Dynamic Linear Time Temporal Logic (DLTL). The temporal action theory allows us to formalize a business process as a temporal domain description, possibly including temporal constraints. Obligations in norms are captured by the notion of commitment, which is borrowed from the social approach to agent communication. Norms are represented using (possibly) non monotonic causal laws which (possibly) enforce new obligations. In this context, verifying compliance amounts to verify that no execution of the business process leaves some commitment unfulfilled. Compliance verification can be performed by Bounded Model Checking.	Answer Set Programming, Dynamic Linear Time Temporal Logic (DLTL), temporal domain description, Social Simulattion
Ma, Jiefei; Broda, Krysia; Goebel, Randy; Hosobe, Hiroshi; Russo, Alessandra & Satoh, Ken	Speculative Abductive Reasoning for Hierarchical Agent Systems	CLIMA	6245		49-64	2010	Answer sharing is a key element in multi-agent systems as it allows agents to collaborate towards achieving a global goal. However exogenous knowledge of the world can influence each agent's local computation, and communication channels may introduce delays, creating multiple partial answers at different times. Agent's answers may, therefore, be incomplete and revisable, giving rise to the concept of speculative reasoning, which provides a framework for managing multiple revisable answers within the context of multi-agent systems. This paper extends existing work on speculative reasoning by introducing a new abductive framework to hierarchical speculative reasoning. This allows speculative reasoning in the presence of both negation and constraints, enables agents to receive conditional answers and to continue their local reasoning using default answers, thus increasing the parallelism of agents collaboration. The paper describes the framework and its operational model, illustrates the main features with an example and states soundness and completeness results.	Answer sharing, multi-agent systems,, partial information
Riemsdijk, M.Birna; Boer, FrankS. & Meyer, John-JulesCh.	Dynamic Logic for Plan Revision in Intelligent Agents	CLIMA 5th	3487		16-32	2004	In this paper, we present a dynamic logic for a propositional version of the agent programming language 3APL. A 3APL agent has beliefs and a plan. The execution of a plan changes an agent's beliefs. Plans can be revised during execution. Due to these plan revision capabilities of 3APL agents, plans cannot be analyzed by structural induction as in for example standard propositional dynamic logic. We propose a dynamic logic that is tailored to handle the plan revision aspect of 3APL. For this logic, we give a sound and complete axiomatization.	3PAK,Dynamic Logic, Plan Revision
Fusaoka, Akira; Nakamura, Katsunori & Sato, Mitsunari	On a Linear Framework for Belief Dynamics in Multi-agent Environments	CLIMA 7th	4371		41-59	2006	In this paper, we discuss the dynamics of multi-agent belief change in the framework of linear algebra. We regard an epistemic state of each agent as an element in the vector space spanned by the basis of possible worlds, so that belief change corresponds to a linear transformation on this vector space. The compound belief states of multi-agents are treated by using the product tensor of the vector for each agent. In this formulation, the reasoning in the process of belief change can be reduced to the matrix and tensor calculation.	MAS, linear algebra
Maurizio Lenzerini, Domenico Fabio Savo	Updating inconsistent Description Logic knowledge bases	ECAI	242			2012	Finding an appropriate semantics for task of updating an inconsistent knowledge base is a challenging problem. In this paper, we consider knowledge bases expressed in Description Logics, and focus on ABox inconsistencies, i.e., the case where the TBox is consistent, but the whole knowledge base is not. Our first contribution is the definition of a new semantics for updating an inconsistent Description Logic knowledge base with both the insertion and the deletions of a set of ABox assertions. We then concentrate on the DL-Lite family of Description Logics, and present algorithms for updating a possibly inconsistent knowledge base expressed in the most expressive logic of such family. We show that, by virtue of both the characteristics of our semantics, and the limited expressive power of DL-Lite, both insertions and deletions can be done in polynomial time with respect of the size of the ABox.	Description Logic; TBox; ABox; Inconsistent Knowledge; Update

Author	Title	Jur/Symp	Volume	Number	Pages	Year	abstract	key word
Patricia Everaere, Sébastien Konieczny, Pierre Marquis	The Epistemic View of Belief Merging: Can We Track the Truth?	ECAI	215			2010	Belief merging is often described as the process of defining a base which best represents the beliefs of a group of agents (a profile of belief bases). The resulting base can be viewed as a synthesis of the input profile. In this paper another view of what belief merging aims at is considered: the epistemic view. Under this view the purpose of belief merging is to best approximate the true state of the world. We point out a generalization of Condorcet's Jury Theorem from the belief merging perspective. Roughly, we show that if the beliefs of sufficiently many reliable agents are merged then in the limit the true state of the world is identified. We introduce a new postulate suited to the truth tracking issue. We identify some merging operators from the literature which satisfy it and other operators which do not.	Belief Merging; Truth Tracking
Pavlos Peppas, Anastasios Michael Fotinopoulos, Stella Seremetaki	Conflicts between Relevance-Sensitive and Iterated Belief Revision	ECAI	178			2008	The original AGM paradigm focuses only on one-step belief revision and leaves open the problem of revising a belief state with whole sequences of evidence. Darwiche and Pearl later addressed this problem by introducing extra (intuitive) postulates as a supplement to the AGM ones. A second shortcoming of the AGM paradigm, seemingly unrelated to iterated revision, is that it is too liberal in its treatment of the notion of relevance. Once again this problem was addressed with the introduction of an extra (also very intuitive) postulate by Parikh. The main result of this paper is that Parikh postulate for relevance-sensitive belief revision is inconsistent with each of the Darwiche and Pearl postulates for iterated belief revision.	AGM; Belieff Revision; Iterated;
Richard Booth, Samir Chopra, Thomas Meyer, Aditya Ghose	A unifying semantics for belief change	ECAI				2004	Many belief change formalisms employ plausibility orderings over the set of possible worlds to determine how the beliefs of an agent ought to be modified after the receipt of a new epistemic input. While most such possible world semantics rely on a single ordering, we look at using an extra ordering to aid in guiding the process of belief change. We show that this provides a unifying semantics for a wide variety of belief change operators. By varying the conditions placed on the second ordering, different families of known belief change operators can be captured, including AGM belief contraction and revision, the severe withdrawal of Rott and Pagnucco, the systematic withdrawal of Meyer et. al, and the linear liberation and sigma liberation of Booth et al. This approach also identifies novel classes of belief change operators that are worth further investigation.	Belief Revision, Possible Worlds Semantics, AGM contraction, withdrawal, liberation, AGM revision
Andreas Herzig, Emiliano Lorini, Fr?d?ric Moisan Nicolas Troquard	A Dynamic Logic of Normative Systems	IJCAI	1		228	2011	We propose a logical framework to represent and reason about agent interactions in normative systems. Our starting point is a dynamic logic of propositional assignments whose satisfiability problem is PSPACE-complete. We show that it embeds Coalition Logic of Propositional Control CL-PC and that various notions of ability and capability can be captured in it. We illustrate it on a water resource management case study. Finally, we show how the logic can be easily extended in order to represent constitutive rules which are also an essential component of the modelling of social reality.	Dynamic Logic, Coalition Logic, Normative System, Agent Interaction
C?lia da Costa Pereira, Andrea G. B. Tettamanzi, Serena Villata	Changing One's Mind: Erase or Rewind?	IJCAI	1			2011	We address the issue, in cognitive agents, of possible loss of previous information, which later might turn out to be correct when new information becomes available. To this aim, we propose a framework for changing the agent's mind without erasing forever previous information, thus allowing its recovery in case the change turns out to be wrong. In this new framework, a piece of information is represented as an argument which can be more or less accepted depending on the trustworthiness of the agent who proposes it. We adopt possibility theory to represent uncertainty about the information, and to model the fact that information sources can be only partially trusted. The originality of the proposed framework lies in the following two points: (i) argument reinstatement is mirrored in belief reinstatement in order to avoid the loss of previous information; (ii) new incoming information is represented under the form of arguments and it is associated with a plausibility degree depending on the trustworthiness of the information source.	plausibility degree, Change One's Mind, previous information
Xiuyi Fan, Francesca Toni	Assumption-Based Argumentation Dialogues	IJCAI	1			2011	We propose a formal model for argumentationbased dialogues between agents, using assumptionbased argumentation (ABA). The model is given in terms of ABA-specific utterances, trees drawn from dialogues and legal-move and outcome functions. We prove a formal connection between these dialogues and argumentation semantics. We illustrate persuasion as an application of the dialogue model.	ABA(Assumption Based Argumentation), Dialogues
Zhiqiang Zhuang, Maurice Pagnucco	Transitively Relational Partial Meet Horn Contraction	IJCAI	2			2011	Following the recent trend of studying the theory of belief revision under the Horn fragment of propo- sitional logic this paper develops a fully charac- terised Horn contraction which is analogous to the traditional transitively relational partial meet contraction [Alchourron et al., 1985]. This Horn con- traction extends the partial meet Horn contraction studied in [Delgrande and Wassermann, 2010] so that it is guided by a transitive relation that models the ordering of plausibility over sets of beliefs.	Belief Revision, Horm Contraction, Partial Meet Contraction
Chitta Baral, Jicheng Zhao	Non-monotonic TemporalLogics for Goal Specification	IJCAI				2007	One of the main ways to specify goals of agents is to use temporal logics. Most existing temporal logics are monotonic. However, in representing goals of agents, we often require that goals be changed non-monotonically. For example, the initial goal of the agent may be to be always in states where p is true. The agent may later realize that under certain conditions (exceptions) it is ok to be in states where p is not true. In this paper, we propose a simple extension of LTL, which we call N-LTL, that allows non-monotonic specification of goals. We study properties of N-LTL. We also consider a translation from N-LTL to logic programs and study the relationship between N-LTL and logic programs.	Temporal Logic, Agent Goal, Non-monotonic

Author	Title	Jur/Symp	Volume	Number	Pages	Year	abstract	key word
Thomas ?gotnes, Wiebe van der Hoek, Juan A. Rodr?guez-Aguilar Carles Sierra Michael Wooldridge	On the Logic of Normative Systems	IJCAI				2007	We introduce Normative Temporal Logic (NTL), a logic for reasoning about normative systems. NTL is a generalisation of the well-known branchingtime temporal logic CTL, in which the path quanti?ers A ("on all paths. . . ") and E ("on some path. . . ") are replaced by the indexed deontic operators Oη and Pη, where for example Oη ? means "? is obligatory in the context of normative system η". After de?ning the logic, we give a sound and complete axiomatisation, and discuss the logic's relationship to standard deontic logics. We present a symbolic representation language for models and normative systems, and identify four different model checking problems, corresponding to whether or not a model is represented symbolically or explicitly, and whether or not we are given an interpretation for the normative systems named in formulae to be checked. We show that the complexity of model checking varies from P-complete up to EXPTIME-hard for these variations.	Normative Temporal Logic
Salem Benferhat, Sylvain Lagrue & Papini, Odile	Revision of Partially Ordered Information:Axiomatization, Semantics and Iteration	IJCAI				2005	This paper deals with iterated revision of partially ordered information. The rst part of this paper concerns the Katsuno-Mendelzon's postulates: we rst point out that these postulates are not fully satisfactory since only a class of partially ordered information can be revised. We then propose a suitable de nition of faithful assignment, followed by a new set of postulates and a representation theorem. The second part of this paper investigates ad- ditionalpostulates dedicatedto iteratedrevisionoperators of partially ordered information. Three ex- tensions of well-known iterated belief revision operations for dealing with partially ordered information are brie y presented.	Belief Revision, Partially Orderd Information
Benferhat, Salem; Dubois, Didier; Prade, Henri & Williams, Mary-Anne	A General Framework for Revising Belief Bases Using Qualitative Jeffrey's Rule	ISMIS	5722		612-621	2009	Intelligent agents require methods to revise their epistemic state as they acquire new information. Jeffrey's rule, which extends conditioning to uncertain inputs, is currently used for revising probabilistic epistemic states when new information is uncertain. This paper analyses the expressive power of two possibilistic counterparts of Jeffrey's rule for modeling belief revision in intelligent agents. We show that this rule can be used to recover most of the existing approaches proposed in knowledge base revision, such as adjustment, natural belief revision, drastic belief revision, revision of an epistemic by another epistemic state. In addition, we also show that that some recent forms of revision, namely improvement operators, can also be recovered in our framework.	Jeffrey's Rule, Probabilistic Epistemic State, Uncertain Information, Belief Revision
Enqvist, Sebastian	Modelling epistemic actions in interrogative belief revision	Journal of Logic and Computation	22	6	1335-1365	2012	Interrogative belief revision is a relatively recent framework for belief revision theory, in which the epistemic state of an agent includes a representation of that agent's research agenda, i.e. the set of questions the agent wants to have answers to. This added structure opens new possibilites for various types of epistemic change that cannot be distinguished in traditional belief revision. In this article I use the so-called 'action model' approach known from the literature on dynamic epistemic logic to provide a unified framework in which we can reason about these various types of epistemic changes. I show how to model some natural examples of epistemic changes involving change of the research agenda in this framework. The action models give rise to a dynamic logic which is proven to be decidable.	Dynamic Epistemic Logic, Belief Revision; Action Model; interrogative
Alechina, Natasha; Logan, Brian; Nga Nguyen, Hoang & Rakib, Abdur	Logic for coalitions with bounded resources	Journal of Logic and Computation	21	6	907-937	2011	Recent work on Alternating-Time Temporal Logic and Coalition Logic has allowed the expression of many interesting properties of coalitions and strategies. However, there is no natural way of expressing resource requirements in these logics. In this article, we present a Resource-Bounded Coalition Logic (RBCL) that has explicit representation of resource bounds in the language. We give a complete and sound axiomatization of RBCL, a procedure for deciding satisfiability of RBCL formulas, and a model-checking algorithm.	Alternating-Time Temporal Logic(ATTL); Coalition Logic(CL);Resource-Bounded Coalition Logic (RBCL)
Renne, Bryan	Public communication in justification logic	Journal of Logic and Computation	21	6	1005-1034	2011	Justification Logic is a framework for reasoning about evidence and justification in multi-agent systems. Most accounts of Justification Logic are essentially static, in that the (justified) beliefs of agents are immutable. In this article, we add public communication, a dynamic operation of belief change studied in the area of Dynamic Epistemic Logic, to the language of Justification Logic. Introducing notions of bisimulation for the languages of Justification Logic with and without public communication, we catalogue the expressive relationships that exist between almost all of the well-known static fragments of Justification Logic and then determine whether the addition of public communication affects the various expressive relationships existing between these fragments.	Justification Logic; MAS; Public Announcement
Van Ditmarsch, Hans; Herzig, Andreas & De Lima, Tiago	From Situation Calculus to Dynamic Epistemic Logic	Journal of Logic and Computation	21	2	179-204	2011	We start from Reiter's solution to the frame problem in terms of successor state axioms and Scherl and Levesque's extension to knowledge, as formulated by Lakemeyer and Levesque in their logic ES.While it was believed up to now that quantification over actions is a characteristic feature of Reiter's solution, we here show that for a reasonably large subset of Reiter's basic action theories one can do without.We do so by recasting restricted basic action theories in a propositional modal logic, viz. dynamic epistemic logic with public announcements and public assignments.	Situation calculus; Epistemic logic; Dynamic logic

Author	Title	Jur/Symp	Volume	Number	Pages	Year	abstract	key word
van Ditmarsch, H. P.; Ruan, J. & Verbrugge, R.	Sum and Product in Dynamic Epistemic Logic	Journal of Logic and Computation	18	4	563–588	2008	The Sum-and-Product riddle was first published in the reference H. Freudenthal (1969, Nieuw Archief voor Wiskunde 3, 152) [6]. We provide an overview on the history of the dissemination of this riddle through the academic and puzzle-math community. This includes some references to precursors of the riddle, that were previously (as far as we know) unknown.We then model the Sum-and-Product riddle in a modal logic called public announcement logic. This logic contains operators for knowledge, but also operators for the informational consequences of public announcements. The logic is interpreted on multi-agent Kripke models. The information in the riddle can be represented in the traditional way by number pairs, so that Sum knows their sum and Product their product, but also as an interpreted system, so that Sum and Product at least know their local state. We show that the different representations are isomorphic. We also provide characteristic formulas of the initial epistemic state of the riddle. We analyse one of the announcements towards the solution of the riddle as a so-called unsuccessful update: a formula that becomes false because it is announced.The riddle is then implemented and its solution verified in the epistemic model checker DEMO. This can be done, we think, surprisingly elegantly. The results are compared with other work in epistemic model checking and the complexity is experimentally investigated for several representations and parameter settings.	Modal logic, puzzle math, dynamic epistemic logic, characteristic formula, model checking
Bochman, Alexander & Gabbay, DovM.	Sequential Dynamic Logic	Journal of Logic, Language and Information	21		279–298	2012	We introduce a substructural propositional calculus of Sequential Dynamic Logic that subsumes a propositional part of dynamic predicate logic, and is shown to be expressively equivalent to propositional dynamic logic. Completeness of the calculus with respect to the intended relational semantics is established.	Dynamic logic; Substructural logics; Dynamic predicate logic; Sequent calculus
Andreas, Holger	A Structuralist Theory of Belief Revision	Journal of Logic, Language and Information	20		205–232	2011	The present paper aims at a synthesis of belief revision theory with the Sneed formalism known as the structuralist theory of science. This synthesis is brought about by a dynamisation of classical structuralism, with an abductive inference rule and base generated revisions in the style of Rott (2001). The formalism of prioritised default logic (PDL) serves as the medium of the synthesis. Why seek to integrate the Sneed formalism into belief revision theory? With the hybrid system of the present investigation, a substantial simplification of the ranking information that is necessary to define revisions and contractions uniquely is achieved. This system is, furthermore, expressive enough to capture complex and non-trivial scientific examples. It is thus closely related to a novel research area within belief revision theory which addresses the dynamics of scientific knowledge.	Abduction; Belief bases; Belief revision; Default logic; Defeasible reasoning; Epistemic ranking; Structuralist theory of science
Walliser, Bernard; Zwirn, Denis & Zwirn, Herv?	Abductive Logics in a Belief Revision Framework	Journal of Logic, Language and Information	14	1	87–117	2005	Abduction was first introduced in the epistemological context of scientific discovery. It was more recently analyzed in artificial intelligence, especially with respect to diagnosis analysis or ordinary reasoning. These two fields share a common view of abduction as a general process of hypotheses formation. More precisely, abduction is conceived as a kind of reverse explanation where a hypothesis H can be abduced from events E if H is a "good explanation" of E. The paper surveys four known schemes for abduction that can be used in both fields. Its first contribution is a taxonomy of these schemes according to a common semantic framework based on belief revision. Its second contribution is to produce, for each non-trivial scheme, a representation theorem linking its semantic framework to a set of postulates. Its third contribution is to present semantic and axiomatic arguments in favor of one of these schemes, "ordered abduction," which has never been vindicated in the literature.	Abduction; belief revision; explanation; non-monotonic reasoning
Bonnefon, Jean-François ; Longin, D. ; Nguyen, Manh-Hung	Relation of Trust and Social Emotions: A Logical Approach	WI-IAT	2			2009	Trust and social emotions such as gratitude and anger have natural relations and they both play a key role in research of interaction systems in the context of ambient intelligence and affective computing nowadays. This paper presents a logical approach to formalize both the relations between trust and anger for one hand, and between distrust and gratitude for another hand. Our formal framework is a multimodal logic that combines a logic of belief and choice, a logic of linear time, and a logic of norms. We also provide the behavioral validation for these relations.	Modal logic;cognitive structure of emotions;trust
Ditmarsch, Hans van French, T.	Awareness and Forgetting of Facts and Agents	WI-IAT	2			2009	We propose various logical semantics for change of awareness. The setting is that of multiple agents that may become aware of facts or other agents, or forget about them. We model these dynamics by quantifying over propositional variables and agent variables, in a multi-agent epistemic language with awareness operators, employing a notion of bisimulation with a clause for `same awareness'. The quantification is over all different ways in which an agent can become aware (or forget).	knowledge; multi-agent systems

Author	Title	Jur/Symp	Volume	Number	Pages	Year	abstract	key word
Koen V. Hindriks, M. Birna van Riemsdijk	A Real-Time Semantics for Norms with Deadlines	AAMAS				2013	Norms have been proposed as a way to regulate multi-agent systems. In order to operationalize norms, several computational frameworks have been proposed for programming norm-governed agent organizations. It has been argued that in such systems it is essential that norms, in particular those giving rise to achievement obligations, have deadlines. In this paper we propose a novel semantic framework that takes into account and formalizes real-time aspects of such norms with deadlines. The framework introduced provides a semantics for norms with real-time deadlines that is a conservative extension of more traditional transition systems semantics that has been used for specifying multi-agent systems. Our framework thus provides a natural extension for formalizing multi-agent systems with norms that have real-time deadlines. We address several important aspects of semantics of norms with deadlines such as deadline termination and, in particular, investigate the issue of deadline shifting that arises naturally in a real-time setting as a result of interactions between norms. A new normative model is presented for handling such interactions. We present several formal results showing that our semantics corresponds with basic intuitions that any operational semantics for norms with (real-time) deadlines should satisfy, and that it is well-de?ned.	Real-Time Semantics; Norms; Deadlines; MAS
Murat ?Sensoy, Achille Fokoue, Jeff Z. Pan Timothy J. Norman Yuqing Tang Nir Oren & Sycara, Katia	Reasoning about Uncertain Information and Conflict Resolution through Trust Revision	AAMAS				2013	In information driven MAS, information consumers collect information about their environment from various sources such as sensors. However, there is no guarantee that a source will provide the requested information truthfully and correctly. Even if information is provided only by trustworthy sources, it can contain con- ?icts that hamper its usability. In this paper, we propose to exploit such con?icts to revise trust in information. This requires a reasoning mechanism that can accommodate domain constraints, uncertainty, and trust. Our formalism —SDL-Lite— is an extension of a tractable subset of Description Logics with Dempster-Shafer theory of evidence. SDL-Lite allows reasoning about uncertain information and enables con?ict detection. Then, we propose methods for con?ict resolution through trust revision and analyse them through simulations. We show that the proposed methods allow reasonably accurate estimations of trust in information in realistic settings.	Information Fusion, Trust, Uncertainty, Description Logics; MAS
Bulling, Nils & Hindriks, Koen V.	Taming the complexity of linear time BDI logics	AAMAS			275—282	2011	Reasoning about the mental states of agents is important in various settings, and has been recognized as vital for teamwork. But the complexity of some of the more well-known agent logics that facilitate reasoning about mental states prohibits the use of these logics in practice. An alternative is to investigate fragments of these logics that have a lower complexity but are still expressive enough for reasoning about the mental states of (other) agents. We explore this alternative and take as our starting point the linear time variant of BDI logic (BDILTL). We summarize some of the relevant known complexity results for e.g. LTL, KD45n, and BDILTL itself. We present a tableau-based method for establishing complexity bounds, and provide a map of the complexity of (various fragments of) BDILTL. Finally, we identify a few fragments that may be usefully applied for reasoning about mental states.	complexity, linear time BDI logic, reasoning about mental states, satisfiability
Ghorbani, Amineh; Dignum, Virginia & Dijkema, Gerard	An analysis and design framework for agent-based social simulation	AAMAS			96--112	2011	Agent-based modeling is one of the popular tools for analyzing complex social systems. To model such systems, social attributes such as culture, law and institutions need to implemented as part of the context of a MAS, independently of individual agents. In this paper, we present MAIA; a framework for modeling agent-based systems based on the Institutional Analysis and Development Framework (IAD). The IAD is a well established comprehensive framework which addresses many social attributes. To make this framework applicable to agent-based software implementation, we inspire from some of the detailed definitions in the OperA methodology. The framework covers the different types of structures affecting agents at the operational level; physical, collective and constitutional. Moreover, this framework includes the conceptualization and design of evaluation. An agent-based methodology has also been developed from the MAIA framework which consists of two layers. A conceptualization layer for analyzing and decomposing the system and a detailed design layer which leads to the implementation of social models. MAIA allows the balance of global institutional requirements with the autonomy of individual agents thus enabling system evolution and reflecting more of reality in artificial societies.	IAD, agent-basedmodeling, methodology, social simulation
Wu, Jun; Wang, Chongjun & Xie, Junyuan	A framework for coalitional normative systems	AAMAS			259—266	2011	We propose coalitional normative system (Cns), which can selectively restrict the joint behavior of a coalition, in this paper. We extend the semantics of Atl and propose Coordinated Atl (Co-Atl) to support the formalizing of Cns. We soundly and completely characterize the limitation of the normative power of a coalition by identifying two fragments of Co-Atl language corresponding to two types of system properties that are unchangeable by restricting the joint behavior of such a coalition. Then, we prove that the effectiveness checking, feasibility and synthesis problems of Cns are Ptime-complete, Np-complete and Fnp-complete, respectively. Moreover, we define two concepts of optimality for Cns, that is, minimality and compactness, and prove that both minimality checking and compactness checking are Conp-complete while the problem of checking whether a coalition is a minimal controllable coalition is Dp-complete. The relation between Ns and Cns is discussed, and it turns out that Nss intrinsically consists of a proper subset of Cnss and some basic problems related to Cns are no more complex than that of Ns.	complexity, logic, model checking, normative systems, ATL

Author	Title	Jur/Symp	Volume	Number	Pages	Year	abstract	key word
Grossi, Davide	On the logic of argumentation theory	AAMAS			409—416	2010	The paper applies modal logic to formalize fragments of argumentation theory. Such formalization allows to import, for free, a wealth of new notions (e.g., argument equivalence), new techniques (e.g., calculi, model-checking games, bisimulation games), and results (e.g., completeness of calculi, adequacy of games, complexity of model-checking) from logic to argumentation.	argumentation theory, modal logic, Logic of Linear Time, Common Knowledge, Distributed Knowledge
Khan, Shakil M. & Lesp{¥'e}rance, Yves	A logical framework for prioritized goal change	AAMAS			283—290	2010	Most previous logical accounts of goals do not deal with prioritized goals and goal dynamics properly. Many are restricted to achievement goals. In this paper, we develop a logical account of goal change that addresses these deficiencies. In our account, we do not drop lower priority goals permanently when they become inconsistent with other goals and the agent's knowledge; rather, we make such goals inactive. We ensure that the agent's chosen goals/intentions are consistent with each other and the agent's knowledge. When the world changes, the agent recomputes her chosen goals and some inactive goals may become active again. This ensures that our agent maximizes her utility. We prove that the proposed account has desirable properties. We also discuss previous work on postulates for goal revision.	goal change, intention, logic of agency, prioritized goals
Lavindra de Silva, Sebastian Sardina, Lin Padgham	First Principles Planning in BDI Systems?	AAMAS				2009	BDI (Belief, Desire, Intention) agent systems are very powerful,but they lack the ability to incorporate planning. There has been some previous work to incorporate planning within such systems. However, this has either focussed on producing low-level plan sequences, losing much of the domain knowledge inherent in BDI systems, or has been limited to HTN (Hierarchical Task Network) planning, which cannot ?nd plans other than those speci?ed by the programmer. In this work, we incorporate classical planning into a BDI agent, but in a way that respects and makes use of the procedural domain knowledge available, by producing abstract plans that can be executed using such knowledge. In doing so, we recognize an intrinsic tension between striving for abstract plans and, at the same time, ensuring that unnecessary actions, unrelated to the speci?c goal to be achieved, are avoided. We explore this tension, by ?rst characterizing the set of "ideal" abstract plans that are non-redundant while maximally abstract, and then developing a more limited but feasible account in which an abstract plan is "specialized" into a new abstract plan that is non-redundant and preserves abstraction as much as possible. We describe an algorithm to compute such a plan specialization, as well as algorithms for the production of a valid high level plan, by deriving abstract planning operators from the BDI program	BDI, abstract plan
Jamroga, Wojciech	A Temporal Logic for Markov Chains	AAMAS				2008	Most models of agents and multi-agent systems include information about possible states of the system (that de?nes relations between states and their external characteristics), and information about relationships between states. Qualitative models of this kind assign no numerical measures to these relationships. At the same time, quantitative models assume that the relationships are measurable, and provide numerical information about the degrees of relations. In this paper, we explore the analogies between some qualitative and quantitative models of agents/processes, especially those between transition systems and Markovian models. Typical analysis of Markovian models of processes refers only to the expected utility that can be obtained by the process. On the other hand, modal logic o?ers a systematic method of describing phenomena by combining various modal operators. Here, we try to exploit linguistic features, o?ered by propositional modal logic, for analysis of Markov chains and Markov decision processes. To this end, we propose Markov temporal logic ? a multi-valued logic that extends the branching time logic ctl*.	Temporal logic, Markov chains, Markov decision processes, CTL
Thomas Agotnes, Wiebe van der Hoek, Michael Wooldridge	Quantifying Over Coalitions in Epistemic Logic	AAMAS				2008	Some natural epistemic properties which may arise in applications can only be expressed in standard epistemic logic by formulae which are exponentially long in the number of agents in the system. An example is the property "at least m agents know that at most n agents know ?". We present Epistemic Logic with Quanti?cation over Coalitions (ELQC), where the standard common knowledge operator has been replaced allowing expressions of the form hPiC ? and [P]C ? where P is a coalition predicate, meaning that there is a coalition satisfying P which have common knowledge of ? and that all coalitions satisfying P have common knowledge of ?, respectively; and similarly for distributed knowledge and everybody-knows. While the language is no more expressive than standard epistemic logic, it is exponentially more succinct. We give a sound and complete axiomatisation for ELQC, and characterise the complexity of its model checking problem	epistemic logic, expressivity, succinctness, model checking, complexity, coalition
Wojciech Jamroga, Thomas ?gotnes	What agents can achieve under incomplete information	AAMAS				2006	We propose a non-standard semantics for Alternating-time Temporal Logic (ATL) with incomplete information, for which no commonly accepted semantics has been proposed yet. In our semantics, formulae are still interpreted with respect to ATL structures, but are interpreted in sets of states rather than in single states. We also propose a new epistemic operator for constructive" knowledge and we show that the new language is strictly more expressive than existing solutions while retaining the same model checking complexity."	Alternating-time Temporal Logic (ATL),Incomplete Information, Expressive

Author	Title	Jur/Symp	Volume	Number	Pages	Year	abstract	key word
Bentahar, Jamal; Moulin, Bernard; Meyer, John-Jules Ch. & Chaib-draa, Brahim	A Logical Model for Commitment and Argument Network for Agent Communication	AAMAS			792—799	2004	In this paper we present a semantics for our approach based on social commitments (SCs) and arguments for conversational agents. More precisely, we propose a logical model based on CTL* and on dynamic logic (DL). Called Commitment and Argument Network, our formal framework based on this approach uses three basic elements: SCs, actions that agents apply to these SCs and arguments that agents use to support their actions. The advantage of this logical model is to bring together all these elements and the relations existing between them within the same framework. Our semantics makes it possible to represent the dynamics of agent communication. It also allows us to establish the important link between SCs as a deontic concept and arguments. CTL* enables us to express the temporal characteristics of SCs and arguments. DL enables us to capture the actions that agents are committed to achieve.	CTL*, Dynamic Logic, Social Commitment, Argument
Blackburn, Patrick & J?rgensen, Klaus Frovin	Indexical Hybrid Tense Logic	AiML				2012	In this paper we explore the logic of now, yesterday, today and tomorrow by combining the semantic approach to indexicality pioneered by Hans Kamp [9] and re ned by David Kaplan [10] with hybrid tense logic. We rst introduce a special now nominal (our @now corresponds to Kamp's original now operator N) and prove completeness results for both logical and contextual validity. We then add propositional constants to handle yesterday, today and tomorrow; our system correctly treats sentences like ¥Niels will die yesterday as contextually unsatis able. Building on our completeness results for now we prove completeness for the richer language again for both logical and contextual validity.″	Hybrid logic, two-dimensional logic, nominals, indexicals, now
James Hales, Tim French & Davies, Rowan	Refinement Quantified Logics of Knowledge and Belief For Multiple Agents	AiML				2012	Given the ¥possible worlds interpretation of modal logic a re nement of a Kripke model is another Kripke model in which an agent has ruled out some possible worlds to be consistent with some new information. The re nements of a nite Kripke model have been shown to correspond to the results of applying arbitrary action models to the Kripke model [10]. Re nement modal logics add quanti ers over such re nements to existing modal logics. Work by van Ditmarsch French and Pinchinat [11] gave an axiomatisation for the re nement modal logic over the class of unrestricted Kripke models for a single agent. Recent work by Hales French and Davies [13] extended these results restricting the quanti cation to the class of doxastic and epistemic mod- els for a single agent. Here we extend these results further to the classes of doxastic and epistemic models for multiple agents. The generalisation to multiple agents for doxastic and epistemic models is not straightforward and requires novel techniques particularly for the epistemic case. We provide sound and complete axiomatisations for the considered logics and a provably correct translations to their underlying modal logics corollaries of which are expressivity and decidability results.″	Modal logic, Epistemic logic, Doxastic logic, Bisimulation quantifier,Refinement quantifier, Temporal epistemic logic, Multi-agent system, Action models
Wesley Holliday, Tomohiro Hoshi & Icard, Thomas	A Uniform Logic of Information Dynamics	AiML				2012	Unlike standard modal logics, many dynamic epistemic logics are not closed under uniform substitution. A distinction therefore arises between the logic and its substitu- tion core, the set of formulas all of whose substitution instances are valid. The classic example of a non-uniform dynamic epistemic logic is Public Announcement Logic (PAL), and a well-known open problem is to axiomatize the substitution core of PAL. In this paper we solve this problem for PAL over the class of all relational models with in nitely many agents, PAL-K!, as well as standard extensions thereof, e.g., PAL-T!, PAL-S4!, and PAL-S5!. We introduce a new Uniform Public Announcement Logic (UPAL), prove completeness of a deductive system with respect to UPAL semantics, and show that this system axiomatizes the substitution core of PAL.	dynamic epistemic logic, Public Announcement Logic, schematic validity, substitution core, uniform substitution
Hans van Ditmarsch, Tim French & Pinchinat, Sophie	Future Event Logic – Axioms and Complexity	AiML			77-99	2010	In this paper we present a sound and complete axiomatization of future event logic. Future event logic is a logic that generalizes a number of dynamic epistemic logics, by using a new operator . that acts as a quanti er over the set of all re nements of a given model. (A re nement is like a bisimulation except that from the three relational requirements only `atoms' and `back' need to be satis ed.) Thus the logic combines the simplicity of modal logic with some powers of monadic second order quanti cation. We prove the axiomatization is sound and complete and discuss some extensions to the result.	Bisimulation Quanti er, Modal Logic, Temporal Epistemic Logic, Multi-Agent System
Shapirovsky, Ilya	Simulation of Two Dimensions in Unimodal Logics	AiML			371-391	2010	In this paper, we prove undecidability and the lack of nite model property for a certain class of unimodal logics. To do this, we adapt the technique from [7], where products of transitive modal logics were investigated, for the unimodal case. As a particular corollary, we present an undecidable unimodal fragment of Halpern and Shoham's Interval Temporal Logic.	products of modal logics, undecidable modal logics, logics without the nite model property, locally one-component frames, Halpern and Shoham's Interval Temporal Logic
Wansing, Heinrich	Tableaux for multi-agent deliberativestit logic	AiML	6			2006	We present a sound and complete tableau calculus for the multi-agent logic of deliberatively seeing to it that (dstit), Ldm. The agents in this setting are assumed to be independent of each other. Until now only an axiomatic proof system for Ldm has been available. Moreover, in order to underline the usefulness of stit logics, we suggest the introduction of dstit modalities into B(elief)D(esire)I(ntention) logics or the introduction of belief, desire, and intention modalities into deliberative-stit logic.	modal logic of agency, deliberative-stit logic, independence of agents, branching time structures, tableaux, BDI logics, belief, desire,intention,DSTIT

Author	Title	Jur/Symp	Volume	Number	Pages	Year	abstract	key word
M¨uller, Thomas	On the Formal Structure of Continuous Action	AiML	5			2004	Analytical investigations of agency are mostly con- cerned with a description ex post acto. However, continuous action (being doing something) needs to be considered as well. The paper shows that while the modal-logical treatment of agency in branch- ing time-based stit theory is currently unable to handle continuous action, the stit framework can be extended such as to handle these cases as well. Our new operator, istit, provides for an adequate ex- pression of the notion of being doing something, and we present a simple axiomatisation. In our extended framework, agency, ability, and refraining are linked to an agent's current strategy.	Continuous Action, STIT
Waaler, Arild	Consistency Proofs for Systems of Multi-agent Only Knowing	AiML	5			2004	A new and natural multi-modal system of only knowing is proposed along with a sequent calculus. The main technical results are cut-elimination theorems and a proof of the consistency of the logic; the latter result follows from the subformula property of cut-free proofs. The system is extended to a multi-modal logic which allows the representation of belief states with confidence levels in a multi-agent context.	MAS, Only know, sequent calculous
Demolombe, Robert	Transitivity and Propagation of Trust in Information Sources: An Analysis in Modal Logic	CLIMA	6814		13-28	2011	The paper is about trust in information sources in the context of Multi Agents Systems and it is focused on information and trust propagation. Trust definition is inspired from Cognitive Science and it is seen as a truster's belief in some trustee's properties which are called: sincerity, competence, vigilance, cooperativity, validity and completeness. These definitions are formalized in Modal Logic and it is shown that even if trust, in that sense, is not transitive, we can find interesting sufficient conditions based on trust that guarantee that the truth of an information is propagated along a chain of information sources.	trust in information sources, Multi Agents Systems, Modal Logic
Lorini, Emiliano; Perrussel, Laurent & Th?venin, Jean-Marc	A Modal Framework for Relating Belief and Signed Information	CLIMA	6814		58-73	2011	The aim of this paper is to propose a modal framework for reasoning about signed information. This modal framework allows agents to keep track of information source as long as they receive information in a multi-agent system. Agents gain that they can elaborate and justify their own current belief state by considering a reliability relation over the sources of information. The belief elaboration process is considered under two perspectives: (i) from a static point of view an agent aggregates received signed information according to its preferred sources in order to build its belief and (ii) from a dynamic point of view as an agent receives information it adapts its belief state about signed information. Splitting the notions of beliefs and signed statement is useful for handling the underlying trust issue: an agent believes some statement because it may justify the statement's origin and its reliability.	signed information,information source, multi agent system, reliability relation
G?ngora, PedroArturo; Ufferman, Eric & Hern?ndez-Quiroz, Francisco	Formal Semantics of a Dynamic Epistemic Logic for Describing Knowledge Properties of π-Calculus Processes	CLIMA	6245		65-81	2010	The π-calculus process algebra describes the interaction of concurrent and communicating processes. The π-calculus, however, has neither explicit agency nor epistemic capabilities. In this paper, we present the formal syntax and semantics of a multi-agent dynamic epistemic logic. In this logic, the epistemic actions of agents are π-calculus processes. A process of the language is translated to a class of model updating functions reflecting the epistemic changes after the execution of such processes. Our proposal combines the capabilities of two approaches: it is possible to model structured interaction among agents as elaborated π-calculus programs, and it is also possible to describe the dynamic knowledge implications of such programs. We show the utility of our language by encoding the Dining Cryptographers protocol.	π-calculus,multi-agent dynamic epistemic logic,communication
Kamide, Norihiro	Embedding Linear-Time Temporal Logic into Infinitary Logic: Application to Cut-Elimination for Multi-agent Infinitary Epistemic Linear-Time Temporal Logic	CLIMA	5405		57-76	2009	Linear-time temporal logic (LTL) is known as one of the most useful logics for verifying concurrent systems, and infinitary logic (IL) is known as an important logic for formalizing common knowledge reasoning. The research fields of both LTL and IL have independently been developed each other, and the relationship between them has not yet been discussed before. In this paper, the relationship between LTL and IL is clarified by showing an embedding of LTL into IL. This embedding shows that globally and eventually operators in LTL can respectively be represented by infinitary conjunction and infinitary disjunction in IL. The embedding is investigated by two ways: one is a syntactical way, which is based on Gentzen-type sequent calculi, and the other is a semantical way, which is based on Kripke semantics. The cut-elimination theorems for (some sequent calculi for) LTL, an infinitary linear-time temporal logic ILT ω (i.e., an integration of LTL and IL), a multi-agent infinitary epistemic linear-time temporal logic IELT ω and a multi-agent epistemic bounded linear-time temporal logic ELT l are obtained as applications of the resulting embedding theorem and its extensions and modifications. In particular, the cut-elimination theorem for IELT ω gives a new proof-theoretical basis for extremely expressive time-dependent multi-agent logical systems with common knowledge reasoning.	MAS、LTL、IL
Pereira, David; Oliveira, Eug?nio & Moreira, Nelma	Formal Modelling of Emotions in BDI Agents	CLIMA	5056		62-81	2008	Emotional-BDI agents are BDI agents whose behaviour is guided not only by beliefs, desires and intentions, but also by the role of emotions in reasoning and decision-making. The EBDI logic is a formal system for expressing the concepts of the Emotional-BDI model of agency. In this paper we present an improved version of the EBDI logic and show how it can be used to model the role of three emotions in Emotional-BDI agents: fear, anxiety and self-confidence. We also focus in the computational properties of EBDI which can lead to its use in automated proof systems.	emotion, BDI

Author	Title	Jur/Symp	Volume	Number	Pages	Year	abstract	key word
Hakli, Raul & Negri, Sara	Proof Theory for Distributed Knowledge	CLIMA	5056		100–116	2007	The proof theory of multi–agent epistemic logic extended with operators for distributed knowledge is studied. A proposition A is distributed knowledge within a group G if A follows from the totality of what the individual members of G know. There are known axiomatizations for epistemic logics with the distributed knowledge operator, but apparently no cut–free proof system for such logics has yet been presented. A Gentzen–style contraction–free sequent calculus system for propositional epistemic logic with operators for distributed knowledge is given, and a cut–elimination theorem for the system is proved. Examples of reasoning about distributed knowledge that use the calculus are given.	distributed knowledge
Jamroga, Wojciech & Bulling, Nils	A Logic for Reasoning about Rational Agents	CLIMA	5056		42–61	2007	We have recently proposed an extension of alternating–time temporal logic for reasoning about behavior and abilities of agents under various rationality assumptions. The logic, called ATLP ("alternating–time temporal logic with plausibility") used abstract, unstructured terms for addressing rationality assumptions. Here, we propose a more complex language of terms that allows to specify sets of rational strategy profiles in the object language, building upon existing work on logical characterizations of game–theoretic solution concepts. In particular, we recall how the notions of Nash equilibrium, subgame–perfect Nash equilibrium, and Pareto optimality can be characterized with logical formulae and we show how these can be used within ATLP for reasoning about what rational agents should achieve. We also prove complexity results for model checking of ATLP formulae.	ATL, plausibility
NIDE, Naoyuki, Shiro Takata & Fujita, Megumi	BDI logic with probabilistic transitio and fixed–point operator	CLIMA 10th				2009	One of the advantages of the BDI (Belief–Desire–Intention) model is thatwe can formally discuss and prove properties about themental states (beliefs, desires and intentions) and behaviors ofrational agents using amodallogic called BDI logic. However, various extensions, such as probabilistic state transitions in reinforcement learning and cooperative acts in multi–agent environments, have been attempted in the BDI model. Since those notions are dif?cult to treat precisely in traditional BDI logic, the advantage of formalization in BDI logic is diminished.In this paper, we propose an extension ofBDIlogic, calledTOMATO, which introduces probabilistic state transitions and a ?xed–point operator. We can strictly describe and infer various properties of rational agents with those extended notions by using TOMATO	BDI, MAS, probability
Chesani, Federico; Gavanelli, Marco; Alberti, Marco; Lamma, Evelina; Mello, Paola & Torroni, Paolo	Specification and Verification of Agent Interaction Using Abductive Reasoning	CLIMA 6th	3900		243–264	2005	Amongst several fundamental aspects in multi–agent systems design, the definition of the agent interaction space is of the utmost importance. The specification of the agent interaction has several facets: syntax, semantics, and compliance verification. In an open society, heterogenous agents can participate without showing any credentials. Accessing their internals or their knowledge bases is typically impossible, thus it is impossible to prove a priori that agents will indeed behave according to the society rules. Within the SOCS (Societies Of ComputeeS) project, a language based on abductive semantics has been proposed as a mean to define interactions in open societies. The proposed language allows the designer to define open, extensible and not over–constrained protocols. Beside the definition language, a software tool has been developed with the purpose of verifying at execution time if the agents behave correctly with respect to the defined protocols. This paper provides a tutorial overview of the theory and of the tools the SOCS project provided to design, define and test agent interaction protocols.	MAS, interactive
Bentahar, Jamal; Moulin, Bernard; Meyer, John–JulesCh. & Lesp?rance, Yves	A New Logical Semantics for Agent Communication	CLIMA 7th	4371		151–170	2006	In this paper we develop a semantics of our approach based on commitments and arguments for conversational agents. We propose a logical model based on CTL* (Extended Computation Tree Logic) and on dynamic logic. Called Commitment and Argument Network (CAN), our formal framework based on this hybrid approach uses three basic elements: social commitments, actions that agents apply to these commitments and arguments that agents use to support their actions. The advantage of this logical model is to gather all these elements and the existing relations between them within the same framework. The semantics we develop here enables us to reflect the dynamics of agent communication. It also allows us to establish the important link between commitments as a deontic concept and arguments. On the one hand CTL* enables us to express all the temporal aspects related to the handling of commitments and arguments. On the other hand, dynamic logic enables us to capture the actions that agents are committed to achieve.	Communication, Commitment, Argument
Thomas Ågotnes, Wiebe van der Hoek, Michael Wooldridge	Conservative Social Laws	ECAI	242			2012	Social laws – sets of constraints imposed on the behaviour of agents within a multi–agent system with the goal of some desirable overall behaviour resulting – are an important mechanism for coordinating multi–agent behaviour. When considering social laws in human environments, the inspiration for social laws in multiagent systems, we argue that a key design principle is least change. That is, social laws are more likely to be accepted and adopted, and hence successful, if they are conservative, in the sense that they represent the smallest change possible from the pre–existing status quo that is required to effect the desired objective. Our aim in the present paper is to introduce, formalise, and investigate the notion of a conservative social law for multi–agent systems. To make the idea of a conservative social law precise, we formalise the notion of a distance metric for social laws, and discuss a range of possible properties for such metrics. We then formulate the conservative social law problem, (i.e., the problem of constructing an effective social law that requires the least change according to this metric), discuss some possible interpretations of distance in this context, and discuss some issues surrounding conservative social laws.	Social Lows; MAS; METRIC

Author	Title	Jur/Symp	Volume	Number	Pages	Year	abstract	key word
Salem Benferhat, Célia da Costa Pereira, Andrea G.B. Tettamanz	Hybrid Possibilistic Conditioning for Revision under Weighted Inputs	ECAI	242			2012	We propose and investigate new operators in the possibilistic belief revision setting, obtained as different combinations of the conditioning operators on models and countermodels, as well as of how weighted inputs are interpreted. We obtain a family of eight operators that essentially obey the basic postulates of revision, with a few slight differences. These operators show an interesting variety of behaviors, making them suitable to representing changes in the beliefs of an agent in different contexts.	belief revision; possibilistic;weighted
Gerhard Lakemeyer, Yves Lespérance	Efficient Reasoning in Multiagent Epistemic Logics	ECAI	242			2012	In many applications, agents must reason about what other agents know, whether to coordinate with them or to come out on top in a competitive situation. However in general, reasoning in a multiagent epistemic logic such as Kn has high complexity. In this paper, we look at a restricted class of knowledge bases that are sets of modal literals. We call these proper epistemic knowledge bases (PEKBs). We show that after a PEKB has been put in prime implicate normal form (PINF), an efficient database-like query evaluation procedure can be used to check whether an arbitrary query is entailed by the PEKB. The evaluation procedure is always sound and sometimes complete. We also develop a procedure to convert a PEKB into PINF. As well, we extend our approach to deal with introspection.	MAS; Epistemic Logic; Knowledge Bases
Roberto Micalizio, Gianluca Torta	Diagnosing Delays in Multi-Agent Plans Execution	ECAI	242			2012	The paper introduces the notion of Temporal Multi-Agent Plan (TMAP) and proposes a methodology, based on Simple Temporal Problems (STP), for detecting and diagnosing action execution delays. Actions are characterized by a finite set of behavioral modes, and each behavioral mode is a continuous interval of possible durations of the action. Nominal modes represent the expected durations, whereas faulty modes represent delays. Solving such diagnostic problems requires to find an assignment of modes to the actions that is consistent with the received observations and maximizes the likelihood of the delayed durations. An implementation of the approach and some preliminary experimental results are also discussed.	Delays; MAS; Actions; Simple Temporal Problems
Michal Sindlar, Mehdi Dastani, John-Jules Meyer	Mental State Ascription Using Dynamic Logic	ECAI	215			2010	In situations where the behavior of a system must be interpreted because its state is not accessible, it is useful to explain observed behavior in mentalistic terms. This paper presents a formalism based on propositional dynamic logic to model ascription of beliefs, goals, or plans on grounds of observed actions. The formalism is used to provide semantics for an existing approach to abducing the mental state of an observed agent; in doing so it is shown how behavior-producing rules can be given different explanatory interpretations.	Mental State; Propositional Dynamic Logic;
Jérôme Lang, Leendert van der Torre	From Belief Change to Preference Change	ECAI	178			2008	Various tasks need to consider preferences in a dynamic way. We start by discussing several possible meanings of preference change, and then focus on the one we think is the most natural: preferences evolving after some new fact has been learned. We define a family of such preference change operators, parameterized by a revision function on epistemic states and a semantics for interpreting preferences over formulas. We list some natural properties that this kind of preference change should fulfill and give conditions on the revision function and the semantics of preference for each of these properties to hold.	Preferences Change; Revision Function
Jianbing Ma, Weiru Liu	A General Model for Epistemic State Revision using Plausibility Measures	ECAI	178			2008	In this paper, we present a general revision model on epistemic states based on plausibility measures proposed by Friedman and Halpern. We propose our revision strategy and give some desirable properties, e.g., the reversible and commutative properties. Moreover, we develop a notion called plausibility kinematics and show that our revision strategy follows plausibility kinematics. Furthermore, we prove that the revision following plausibility kinematics satisfies the principle of minimal change based on some distance measures. Finally, we discuss a revision operator defined for plausibility functions and its relationship with iterated belief revision proposed by Darwiche and Pearl. We show that the revision operator satisfies all the DP postulates when it is Max-Additive.	Plausibility Measures; Epistemic States; Revision Model
Thomas Génin, Samir Aknine	Coalition Formation Strategies for Self-Interested Agents	ECAI	178			2008	Coalition formation is a major research issue in multiagent systems in which the agents are self-interested. In these systems, agents have to form groups in order to achieve common goals, which they are not able to achieve individually. A coalition formation mechanism requires two definition levels: firstly agents need a common protocol to reach an agreement and secondly individual strategies are required to make efficient proposals. Both issues are addressed in this paper. First, we propose a two-phase decentralized protocol that allows agents to interact directly through message passing. Secondly we propose some strategies which allow agents to make clever proposals using the information that has already been collected from other agents. The experimental evaluation shows that the proposed mechanism allows agents to efficiently form coalitions and that the strategies make real improvements for the coalition search process.	Coalition Formation;
Benoit Gaudou, Andreas Herzig, Dominique Longin, Matthias Nickles	A New Semantics for the FIPA Agent Communication Language based on Social Attitudes	ECAI	141			2006	One of the most important aspects of the research on agent interaction is the definition of agent communication languages (ACLs), and the specification of a proper formal semantics of such languages is a crucial prerequisite for the usefulness and acceptance of artificial agency. Nevertheless, those ACLs which are still mostly used, especially the standard FIPA-ACL, have a communication act semantics in terms of the participating agents' mental attitudes (viz. beliefs and intentions), which are in general undeterminable from an external point of view due to agent autonomy. In contrast, semantics of ACLs based on commitments are fully verifiable, but not sufficiently formalized and understood yet. In order to overcome this situation, we propose a FIPA-ACL semantics which is fully verifiable, fully formalized, lean and easily applicable. It is based on social attitudes represented using a logic of grounding in straightforward extension of the BDI agent model.	Agent Communication Languages; BDI Agent

Author	Title	Jur/Symp	Volume	Number	Pages	Year	abstract	key word
Yulin Ding, Yan Zhang	CTL Model Update: Semantics, Computations and Implementation	ECAI	141			2006	Minimal change is a fundamental principle for modeling system dynamics. In this paper, we study the issue of minimal change for Computational Tree Logic (CTL) model update. We first propose five primitive operations which capture the basic update of the CTL model, and then define the minimal change criteria for CTL model update based on these primitive operations. We provide essential semantic and computational characterizations for our CTL model update approach. We develop a formal algorithm to implement this update that employs the underlying minimal change principle. We also present a CTL model update example using the well known microwave oven scenario.	Computational Tree Logic (CTL); Model Update
Marcelo A. Falappa, Eduardo L. Fermé, Gabriele Kern-Isberner	On the Logic of Theory Change: Relations between Incision and Selection Functions	ECAI	141			2006	This work elaborates on the connection between partial meet contractions and kernel contractions in belief change theory. We present a way to define incision functions (used in kernel contractions) from selection functions (used in partial meet contractions) and vice versa. Then we make precise under which conditions there are exact correspondences between selection and incision functions so that the same contraction operations can be obtained by using either of them.	Belief Change; Incision Function
Robert Demolombe, Philippe Bretier, Vincent Louis	Norms with deadlines in Dynamic Deontic Logic	ECAI	141			2006	In this paper we extend the logical framework defined by K. Segerberg about norms and actions to norms that refer to deadlines. We also characterize the circumstances where these norms are violated.	Dynamic Deontic Logic; Deadlines; Norms
Nicolas Troquard, Laure Vieu	Towards a logic of agency and actions with duration	ECAI	141			2006	As far as we know, there is no multi-agent system allowing to talk both about choices of agents or groups of agents, strategies, and about sufficiently rich actions. This paper aims at offering a path towards a new more expressive logical framework by mixing a STIT-like logic of agency with a PDL-like logic of action. We present the syntax and ontological motivations, and we highlight the expressivity of the resulting framework on an example.	MAS; STIT; PDL; Duration
Yi Jin, Michael Thielscher	Iterated Belief Change for Reasoning Agents	ECAI				2004	Action formalisms like the fluent calculus have been developed to endow logic-based agents with the abilities of reasoning about the effects of actions, executing high-level strategies, and planning. In this paper we extend the fluent calculus by a method for belief change, which allows agents to revise their internal model if they make observations that contradictthis model. Unlike the existing combination of the situation calculus with belief revision, our formalism satisfies all of the standard postulates for (iterated) belief change. Furthermore, we have extended the action programming language FLUX by a computational approach to belief change which is provably equivalent to the axiomatic characterization in the fluent calculus.	Reasoning about actions and change, Iterated Belief Revision
Broersen, Jan	Modeling Attempt and Action Failure in Probabilistic STIT Logic	IJCAI	2		792	2011	We de?ne an extension of stit logic that encompasses subjective probabilities representing beliefs about simultaneous choice exertion of other agents. The formalism enables us to express the notion of 'attempt' as a choice exertion that maximizes the chance of success with respect to an action effect. The notion of attempt (or effort) is central in philosophical and legal discussions on responsibility and liability.	STIT, attempt,probability
Logan Brooks, Wayne Iba, Sandip Sen	Modeling the Emergence and Convergence of Norms	IJCAI	1		97	2011	In many multi-agent systems, the emergence of norms is the primary factor that determines overall behavior and utility. Agent simulations can be used to predict and study the development of these norms. However, a large number of simulations is usually required to provide an accurate depiction of the agents' behavior, and some rare contingencies may still be overlooked completely. The cost and risk involvedwith agent simulations can be reduced by analyzing a system theoretically and producing models of its behavior. We use such a theoretical approach to examine the dynamics of a population of agents playing a coordination game to determine all the norms to which the society can converge, and develop a system of linear recurrence relations that predict how frequently each of these norms will be reached, as well as the average convergence time. This analysis produces certain guarantees about system behavior that canot be provided by a purely empirical approach, and can be used to make predictions about the emergence of norms that numerically match those obtained through large-scale simulations.	Norms, Agent Interaction, Convergence
Nadeschda Nikitina, Sebastian Rudolph, Birte Glimm	Reasoning-Supported Interactive Revision of Knowledge Bases	IJCAI	2		1027	2011	Quality control is an essential task within ontology development projects, especially when the knowledge formalization is partially automatized. We propose a method for integrating newly acquired, possibly low-quality axioms into an existing ontology after their manual inspection; based on the decision whether the axiom is desired or not, several of the yet unevaluated axioms are evaluated automatically. Since the evaluation order can signi?- cantly increase the amount of automatization, we further propose the notion of axiom impact. Finally, we introduce decision spaces as structures to ef?ciently compute the axiom impact and the implicit evaluation decisions. Compared to a na¨?ve implementation, this reduces the number of costly reasoning operations on average by 75%.	Ontology, Knowledge Base
Ofer Arieli, Arnon Avron, Anna Zamansky	What Is an Ideal Logic for Reasoning with Inconsistency?	IJCAI	2		706	2011	Many AI applications are based on some underlying logic that tolerates inconsistent information in a non-trivial way. However, it is not always clear what should be the exact nature of such a logic, and how to choose one for a specific application. In this paper, we formulate a list of desirable properties of "ideal" logics for reasoning with inconsistency, identify a variety of logics that have these properties, and provide a systematic way of constructing, for every n>2, a family of such n-valued logics.	n valued-logic, Inconsistent

Author	Title	Jur/Symp	Volume	Number	Pages	Year	abstract	key word
Peter Nov?k, Wojciech Jamroga	Agents, Actions and Goals in Dynamic Environments	IJCAI	1			2011	In agent-oriented programming and planning, agents' actions are typically specified in terms of postconditions, and the model of execution assumes that the environment carries the actions out exactly as specified. That is, it is assumed that the state of the environment after an action has been executed will satisfy its postcondition. In reality, however, such environments are rare: the actual execution of an action may fail, and the envisaged outcome is not met. We provide a conceptual framework for reasoning about success and failure of agents' behaviours. In particular, we propose a measure that reflects how good" an environment is with respect to agent's capabilities and a given goal it might pursue. We also discuss which types of goals are worth pursuing depending on the type of environment the agent is acting in."	Agent Environment, Actions, Success and Failure
Simeon Visser, John Thangarajah, James Harland	Reasoning about Preferences in Intelligent Agent System	IJCAI	1		426	2011	Agent systems based on the BDI paradigm need to make decisions about which plans are used to achieve their goals. Usually the choice of which plan to use to achieve a particular goal is left up to the system to determine. In this paper we show how preferences, which can be set by the user of the system, can be incorporated into the BDI execution process and used to guide the choices made.	Preference, BDI Logic
Alessandro Artale, Carsten Lutz, David Toman	A Description Logic of Change?	IJCAI				2009	We combine the modal logic S5 with the description logic (DL) ALCQI. The resulting multi-dimensional DL S5ALCQI supports reasoning about change by allowing to express that concepts and roles change over time. It cannot, however, discriminate between changes in the past and in the future. Our main technical result is that satis?ability of S5ALCQI concepts with respect to general TBoxes (including GCIs) is decidable and 2-EXPTIME-complete. In contrast, reasoning in temporal DLs that are able to discriminate between past and future is inherently undecidable. We argue that our logic is suf?cient for reasoning about temporal conceptual models with time-stamping constraints.	Modal Logic, S5, Description Logic, TBox, Change
Lutz Schr?¶der, Dirk Pattinson, Clemens Kupke	Nominals for Everyone	IJCAI				2009	It has been recognised that the expressivity of description logics bene?ts from the introduction of non-standard modal operators beyond existential and number restrictions. Such operators support notions such as uncertainty, defaults, agency, obligation, or evidence, whose semantics often lies outside the realm of relational structures. Coalgebraic hybrid logic serves as a uni?ed setting for logics that combine non-standard modal operators and nominals, which allow reasoning about individuals. In this framework, we prove a generic EXPTIME upper bound for concept satis?ability over general TBoxes, which instantiates to novel upper bounds for many individual logics including probabilistic logic with nominal	nominals description logic
Natasha Alechina, Brian Logan, Nguyen Hoang Nga Abdur Rakib	A Logic for Coalitions with Bounded Resources	IJCAI				2009	Recent work on Alternating-Time Temporal Logic and Coalition Logic has allowed the expression of many interesting properties of coalitions and strategies. However there is no natural way of expressing resource requirements in these logics. This paper presents a Resource-Bounded Coalition Logic (RBCL) which has explicit representation of resource bounds in the language, and gives a complete and sound axiomatisation of RBCL	ATL, Coalition Logic, Resource Bound
Theodore Patkos, Dimitris Plexousakis	Reasoning with Knowledge, Action and Time in Dynamic and Uncertain Domains	IJCAI				2009	We propose a new framework for reasoning about knowledge, action and time for domains that include actions with non-deterministic and contextdependent effects. The axiomatization is based on the Event Calculus and combines the expressiveness of possible worlds semantics with the ef?- ciency of approaches that dispense the use of the accessibility relation. The framework is proved logically sound and, when restricted to deterministic domains, is also logically complete. To prove correctness of the approach, we construct a knowledge theory based on a branching version of the Event Calculus and study their correlation.	Event Calculos, Reasoning, Deterministic
Hunter, Aaron & Delgrande, James P.	Iterated Belief Change: A Transition System Approach	IJCAI				2005	We use a transition system approach to reason about the evolution of an agent's beliefs as actions are executed. Some actions cause an agent to perform belief revision and some actions cause an agent to perform belief update, but the interaction between revision and update can be nonelementary. We present a set of basic postulates describing the interaction of revision and update, and we introduce a new belief evolution operator that gives a plausible interpretation to alternating sequences of revisions and updates	Belief Revision, Update, Iterated
Budzynska, Katarzyna; Kacprzak, Magdalena & Rembelski, Pawel	Logic for Reasoning about Components of Persuasive Actions	ISMIS	5722		201-210	2009	The aim of the paper is to propose an extension for a model of logic $¥mathcal AG_n$. Thus far, $¥mathcal AG_n$ was applied for reasoning about persuasiveness of actions in multi-agent systems, i.e., we examined which arguments, provided by agents, are successful and how big such a success is. Now we enrich our approach in order to study why these arguments are efficient and what attributes cause their success. Therefore, we propose to specify persuasive actions with three parameters: content, goal and means of sending messages. As a result, we can formally express what an agent wants to achieve by executing an action, whether this action can be successful, and if not, recognize the reasons which can cause the failure.	Success of persuasion; nonverbal arguments; formal models of persuasive actions, MAS

Author	Title	Jur/Symp	Volume	Number	Pages	Year	abstract	key word
Demolombe, Robert & Parra, PilarPozos	Belief Revision in the Situation Calculus Without Plausibility Levels	ISMIS	4203		504–513	2006	The Situation Calculus has been used by Scherl and Levesque to represent beliefs and belief change without modal operators thanks to a predicate plays the role of an accessibility relation. Their approach has been extended by Shapiro et al. to support belief revision. In this extension plausibility levels are assigned to each situation, and the believed propositions are the propositions that are true in all the most plausible accessible situations. Their solution is quite elegant from a theoretical point of view but the definition of the plausibility assignment, for a given application domain, raises practical problems. This paper presents a new proposal that does not make use of plausibilities. The idea is to include the knowledge producing actions into the successor state axioms. In this framework each agent may have a different successor state axiom for a given fluent. Then, each agent may have his subjective view of the evolution of the world. Also, agents may know or may not know that a given action has been performed. That is, the actions are not necessarily public.	Plausibility, SItuation Calculus
Zhang, Yan	Updating Epistemic Logic Programs	Journal of Logic and Computation	19	2	405–423	2009	We consider the problem of updating non–monotonic knowledge bases represented by epistemic logic programs where disjunctive information and notions of knowledge and belief can be explicitly expressed. We propose a formulation for epistemic logic program update based on a principle called minimal change and maximal coherence. The central feature of our approach is that during an update or a sequence of updates, contradictory information is removed on a basis of minimal change under the semantics of epistemic logic programs and then coherent information is maximally retained in the update result. Through various update scenarios, we show that our approach provides both semantic and syntactic characterizations for an update problem. We also investigate essential semantic properties of epistemic logic program update.	non–monotonic knowledge
Lakemeyer, Gerhard	The Situation Calculus: A Case for Modal Logic	Journal of Logic, Language and Information	19		431–450	2010	The situation calculus is one of the most established formalisms for reasoning about action and change. In this paper we will review the basics of Reiter's version of the situation calculus, show how knowledge and time have been addressed in this framework, and point to some of the weaknesses of the situation calculus with respect to time. We then present a modal version of the situation calculus where these problems can be overcome with relative ease and without sacrificing the advantages of the original.	Situation calculus; Epistemic logic; Dynamic logic
Mohalik, Swarup & Ramanujam, R.	Automata for Epistemic Temporal Logic with Synchronous Communication	Journal of Logic, Language and Information	19		451–484	2010	We suggest that developing automata theoretic foundations is relevant for knowledge theory, so that we study not only what is known by agents, but also the mechanisms by which such knowledge is arrived at. We define a class of epistemic automata, in which agents' local states are annotated with abstract knowledge assertions about others. These are finite state agents who communicate synchronously with each other and information exchange is 'perfect'. We show that the class of recognizable languages has good closure properties, leading to a Kleene–type theorem using what we call regular knowledge expressions. These automata model distributed causal knowledge in the following way: each agent in the system has a partial knowledge of the temporal evolution of the system, and every time agents synchronize, they update each other's knowledge, resulting in a more up–to–date view of the system state. Hence we show that these automata can be used to solve the satisfiability problem for a natural epistemic temporal logic for local properties. Finally, we characterize the class of languages recognized by epistemic automata as the regular consistent languages studied in concurrency theory.	Epistemic logic; Automata theory; Decidability; Knowledge expressions
Dixon, Lucas; Smaill, Alan & Tsang, Tracy	Plans, Actions and Dialogues Using Linear Logic	Journal of Logic, Language and Information	18	2	251–289	2009	We describe how Intuitionistic Linear Logic can be used to provide a unified logical account for agents to find and execute plans. This account supports the modelling of agent interaction, including dialogue; allows agents to be robust to unexpected events and failures; and supports significant reuse of agent specifications. The framework has been implemented and several case studies have been considered. Further applications include human?computer interfaces as well as agent interaction in the semantic web.	Dialogue; Planning; Linear Logic; Agents
Schmidt, RenateA. & Tishkovsky, Dmitry	On combinations of propositional dynamic logic and doxastic modal logics	Journal of Logic, Language and Information	17	1	109–129	2008	We prove completeness and decidability results for a family of combinations of propositional dynamic logic and unimodal doxastic logics in which the modalities may interact. The kind of interactions we consider include three forms of commuting axioms, namely, axioms similar to the axiom of perfect recall and the axiom of no learning from temporal logic, and a Church?Rosser axiom. We investigate the influence of the substitution rule on the properties of these logics and propose a new semantics for the test operator to avoid unwanted side effects caused by the interaction of the classic test operator with the extra interaction axioms.	Combinations of modal logics; Dynamic logic; Doxastic logic; Epistemic logic; Reasoning about actions; Belief and knowledge
Nelken, Rani & Shan, Chung–Chieh	A Modal Interpretation of the Logic of Interrogation	Journal of Logic, Language and Information	15	3	251–271	2006	We propose a novel interpretation of natural–language questions using a modal predicate logic of knowledge. Our approach brings standard model–theoretic and proof–theoretic techniques from modal logic to bear on questions. Using the former, we show that our interpretation preserves Groenendijk and Stokhof's answerhood relation, yet allows an extensional interpretation. Using the latter, we get a sound and complete proof procedure for the logic for free. Our approach is more expressive; for example, it easily treats complex questions with operators that scope over questions. We suggest a semantic criterion that restricts what natural–language questions can express. We integrate and generalize much previous work on the semantics of questions, including Beck and Sharvit's families of subquestions, non–exhaustive questions, and multi–party conversations.	natural language semantics; questions; quantification; modal logic

Author	Title	Jur/Symp	Volume	Number	Pages	Year	abstract	key word
Berndt, Jan Ole & Herzog, Otthein	Efficient Multiagent Coordination in Dynamic Environments	Web Intelligence and Intelligent Agent Technology, IEEE/WIC/ACM I.C.	2		188-195	2011	Agent coordination is a fundamental task in designing and operating multiagent systems. However, in dynamically changing environments, coordination must balance proactive and reactive behaviors in order to enable efficient operations while retaining the necessary flexibility to react to unforeseen events. This paper introduces adaptive agent relationships for coping with these contradictory requirements. In this approach, agents dynamically establish relationships which are represented as interaction patterns. On the one hand, these patterns enable efficient coordination by restricting the number of potential interaction flows to those offering the best estimated outcome. On the other hand, they can adapt to environmental changes, as the agents continuously reconsider their relationships in a feedback loop of estimated interaction flows and actually observed coordination outcomes. The paper formalizes the agent decision-making process enabling adaptive relationships and applies it to a logistics network scenario. A comparative evaluation demonstrates its ability to efficiently coordinate agent interaction in a dynamic environment.	MAS; dynamic environment; coordination
Bouchet, Francois & Sansonnet, Jean-Paul	Influence of Personality Traits on the Rational Process of Cognitive Agents	Web Intelligence and Intelligent Agent Technology, IEEE/WIC/ACM I.C.	2		81-88	2011	In this paper we present an approach based on the principle that psychological capacities, especially personality traits, influence the decision making process of rational agents. While using the FFM/NEO PI-R taxonomy, we propose a model for the expression of personality traits in terms of so-called influence operators that add meta control rules to the cycle of rational BDI agents.	cognitive agents; BDI
da Costa Pereira, Celia & Tettamanzi, Andrea G.B.	A Syntactic Possibilistic Belief Change Operator for Cognitive Agents	Web Intelligence and Intelligent Agent Technology, IEEE/WIC/ACM I.C.	2		38-45	2011	We propose a syntactic possibilistic belief-change operator, which operates on a belief base represented as a fuzzy set of formulas. Such a set may be regarded as a finite and compact encoding of a possibility distribution over a possibly infinite set of interpretations. The proposed operator is designed so that it behaves like a semantic possibilistic belief-change operator for BDI agents recently proposed in the literature. The equivalence of the semantic and syntactic operators is then proved.	syntactic, belief-change, possibilistic
da Costa Pereira, Celia; Tettamanzi, Andrea G.B. & Villata, Serena	Graded Reinstatement in Belief Revision	Web Intelligence and Intelligent Agent Technology, IEEE/WIC/ACM I.C.	2		58-61	2011	An important issue in belief revision is the possible loss of previous information which later might turn to be correct when new information becomes available to the agent. Starting from the fuzzy argument labeling based on trust, we mirror argument reinstatement in belief reinstatement, and we show the conditions under which the belief reinstatement is total, partial, or nonexistent.	belief revision
Halac, Tayfun Gokmen; Ekinci, Erdem Eser & Dikenelli, Oguz	Description Logic Based BDI Implementation for Goal-Directed Semantic Agents	Web Intelligence and Intelligent Agent Technology, IEEE/WIC/ACM I.C.	2		62-65	2011	The Semantic Web, in its visionary architecture, employs intelligent agents fulfilling the user goals on the web content that is declared with Description Logic (DL) based Semantic Web languages. In order to meet this task, two important points must be taken into account in agent frameworks. First, frameworks must support comprehensive goal models that allow to pursue goals rationally. Second, these goal models must be integrated with the Semantic Web languages to enable defining goals depending on the web content. However, to execute and manage such goal models, elements of the agent architecture must be adapted with respect to the Semantic Web languages and the DL components behind these languages. For this purpose, in this paper, we propose a DL based goal model and introduce a Belief-Desire-Intention (BDI) architecture which is built on top of DL components. In this architecture, we focus on how declarative goals are represented and managed.	description logic; BDI
van Oijen, Joost & Dignum, Frank	Scalable Perception for BDI-Agents Embodied in Virtual Environments	Web Intelligence and Intelligent Agent Technology, IEEE/WIC/ACM I.C.	2		46-53	2011	Virtual characters in (serious) games are increasingly required to perform complex tasks in dynamic virtual environments. The use of BDI-agents seems a good fit to realize the intelligent behavior for virtual characters. However, although perception is part of the BDI model, it is not really geared towards real time virtual environments. In this paper we present a framework for perceptual attention for BDI-agents embodied in a virtual environment in the scope of a middleware for connecting a multi-agent system and a game engine. Attention for agents is controlled using an underlying subscription mechanism for sensing the environment. Evaluations are provided based on an implemention of the framework.	BDI

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Zuckerman, Inon & Hadad, Meirav	Reasoning about Groups: A Cognitive Model for the Social Behavior Spectrum	Web Intelligence and Intelligent Agent Technology, IEEE/WIC/ACM I.C.	2		125-132	2011	An important aspect of social intelligence is the ability to correctly capture the social structure and use it to navigate and achieve ones goals. In this work we suggest a mental model that provides agents with similar social capabilities. The model captures the entire social behavior spectrum, and provides design principles that allow agents to reason and change their behavior according to their perception of the cooperative/competitive nature of the society. We also describe computationally the maximum attainable benefits when agents belong to different kinds of social groups. We conclude by exploring the group membership problem as a constraints satisfaction problem, and evaluate few heuristics.	social behavior; cognitive
Signoretti, Alberto; Feitosa, Antonino; Campos, Andre M.; Canuto, Anne M.; Xavier-Junior, Joao C. & Fialho, Sergio V.	Using an Affective Attention Focus for Improving the Reasoning Process and Behavior of Intelligent Agents	Web Intelligence and Intelligent Agent Technology, IEEE/WIC/ACM I.C.	2		97-100	2011	Simulations based on cognitively rich agents can become a very intensive computing task, especially when the simulated world represents a complex system. Those simulations can however benefit from optimizations coming from the way in which agents react to changes in the simulated environment. This paper presents an approach for improving the efficiency of the decision-making process of autonomous agents in a simulation. The optimization is reached by dynamically adapting the agent's perception to a bounded subset of all the agent's surrounding elements, which contains only the most important elements for the agent at the current time. In other words, the agent is modeled as having a dynamic focus of attention.	agent simulation, dynamic focus; perception
El-Menshawy, M.; Bentahar, J.; Dssouli, R.	A New Semantics of Social Commitments Using Branching Space-Time Logic	WI-IAT	2			2009	Commitments based on branching time logic are powerful representations for modeling multi-agent interactions. Current approaches into commitments have conceived these representations and evolved the commitments as "world-wide" states called moments. These approaches do not capture the space and space-like dimensions and ignore the causal relation between the participating agents. This paper presents a significant step towards developing a new logical semantics of social commitments based on Branching Space-Time (BST) logic. The contributions of this paper are threefold: first, we reformulate BST-logic from philosophical perspective to computational logic being used in computer science discipline; second, we enhance this logic with social commitments (propositional and conditional) and space-like modalities; and third, we present a new semantics model for social commitments and two-party operations that manipulate commitments in the same framework.	Binary search trees;Computer science;Conferences;Context;Decision support systems;Intelligent agent;Logic
Yinglong Ma, Jun Wei	A Default Extension to Distributed Description Logics	WI-IAT				2004	Description Logic is now an active research area, which is applied universally to knowledge representation, Semantic Web and Ontology language. Compared with Description Logic, Distributed Description Logic can be used to better establish distributed ontologies from distributed information sources. But little attention has been paid to the problem of endowing Distributed Description Logic with default reasoning capabilities to deal with incomplete or conflict information. In this paper we present a default extension to Distributed Description Logics to handle the heterogeneity and incompleteness of different information sources. We extend Distributed Description Logics by adding default information into a distributed knowledge base, and discuss the default satisfiability based on Distributed Description Logics with default rules. To perform default reasoning, a default Tableau algorithm is developed to check satisfiability of complex concepts and subsumption assertions.	Description Logic; Distributed Information Source
Raymond Y.K. Lau, Brant Essam, Siu Y. Chan, Zi Huang	Belief Revision for Adaptive Negotiation Agents	WI-IAT				2003	Existing negotiation agents are primitive in terms of what they can learn and how responsive they are towards the changing negotiation contexts. These weakness can be alleviated if an expressive representation language is used to represent negotiation contexts and a sound inference mechanism is applied to reason about the preferential changes arising in these negotiation contexts. This paper illustrates a novel adpative negotiation agent model, which is underpinned by the well-known AGM belief revision logic. Our preliminary experiments show that the performance of the belief-based adaptive negotiation agents is promising.	Belief Revision; AGM; negotiation

Author	Title	Jur/Symp	Volume	Number	Pages	Year	abstract	key word
Kido, Hiroyuki & Nitta, Katsumi	Practical argumentation semantics for socially efficient defeasible consequence	AAMAS			267—274	2011	An abstract argumentation framework and the semantics, often called Dungean semantics, give a general framework for nonmonotonic logics. In the last fifteen years, a great number of papers in computational argumentation adopt Dungean semantics as a fundamental principle for evaluating various kinds of defeasible consequences. Recently, many papers address problems not only with theoretical reasoning, i.e., reasoning about what to believe, but also practical reasoning, i.e., reasoning about what to do. This paper proposes a practical argumentation semantics specific to practical argumentation. This is motivated by our hypothesis that consequences of such argumentation should satisfy Pareto optimality because the consequences strongly depend on desires, aims, or values an individual agent or a group of agents has. We define a practical argumentation framework and two kinds of extensions, preferred and grounded extensions, with respect to each group of agents. We show that evaluating Pareto optimality can be translated to evaluating preferred extensions of a particular practical argumentation framework. Furthermore, we show that our semantics is a natural extension of Dungean semantics in terms of considering more than one defeat relation. We give a generality order of four practical argumentation frameworks specified by taking into account Dungean semantics and Pareto optimality. We show that a member of preferred extensions of the most specific one is not just Pareto optimal, but also it is theoretically justified.	argumentation, collective decision making, logic-based approaches and methods, reasoning
van Benthem, Johan & Pacuit, Eric	The Tree of Knowledge in Action:Towards a Common Perspective	AiM	6			2006	We survey a number of decidability and undecidability results concerning epistemic temporal logic. The goal is to provide a general picture which will facilitate the 'sharing of ideas' from a number of different areas concerned with modeling agents in interactive social situations.	Temporal Logic, decidability
Fern?ndez, David & Joosten, Joost	Kripke Models of Transfinite Provability Logic	AiML				2012	For any ordinal , we can de ne a polymodal logic GLP , with a modality [ ] for each < . These represent provability predicates of increasing strength. Although GLP has no non-trivial Kripke frames, Ignatiev showed that indeed one can construct a universal Kripke frame for the variable-free fragment with natural number modalities, denoted GLP0 !. In this paper we show how to extend these constructions for arbitrary . More generally, for each ordinals ; we build a Kripke model I and show that GLP0 is sound for this structure. In our notation, Ignatiev's original model becomes I 0 ! ."	proof theory, modal logic, provability logic
Kupke, Clemens & Pattinson, Dirk	On Modal Logics of Linear Inequalities	AiML			235-255	2010	We consider probabilistic modal logic, graded modal logic and stochastic modal logic, where linear inequalities may be used to express numerical constraints between quantities. For each of the logics, we construct a cut-free sequent calculus and show soundness with respect to a natural class of models. The completeness of the associated sequent calculi is then established with the help of coalgebraic semantics which gives completeness over a (typically much smaller) class of models. With respect to either semantics, it follows that the satis ability problem of each of these logics is decidable in polynomial space.	Probabilistic modal logic, graded modal logic, linear inequalities
Rajeev Gor?, Linda Postniece & Tiu, Alwen	Cut-elimination and Proof Search for Bi-Intuitionistic Tense Logic	AiML				2010	We consider an extension of bi-intuitionistic logic with the traditional modalities , , and from tense logic Kt. Proof theoretically, this extension is obtained simply by extending an existing sequent calculus for bi-intuitionistic logic with typical inference rules for the modalities used in display logics. As it turns out, the resulting calculus, LBiKt, seems to be more basic than most intuitionistic tense or modal logics considered in the literature, in particular, those studied by Ewald and Simpson, as it does not assume any a priori relationship between the modal operators and . We recover Ewald's intuitionistic tense logic and Simpson's intuitionistic modal logic by modularly extending LBiKt with additional structural rules. The calculus LBiKt is formulated in a variant of display calculus, using a form of sequents called nested sequents. Cut elimination is proved for LBiKt, using a technique similar to that used in display calculi. As in display calculi, the inference rules of LBiKt are ¥shallow rules in the sense that they act on top-level formulae in a nested sequent. The calculus LBiKt is ill-suited for backward proof search due to the presence of certain structural rules called ¥display postulates" and the contraction rules on arbitrary structures. We show that these structural rules can be made redundant in another calculus	bi-intuitionistic logic
Konur, Savas	An interval logic for natural language semantics	AiML			177-191	2008	Most temporal logics, particularly interval temporal logics, are not expressive enough to capture meanings of natural language constructions, and they are not convenient to represent temporal expressions. In addition, these formal systems exhibit high computational complexity. In this paper we introduce a decidable event-based interval logic, called EIL. EIL can express the semantics of some natural language constructions.	interval temporal logics, natural language semantics, temporal prepositions, decidability, complexity, tableau-methods
Kurucz, Agi	On axiomatising products of Kripke frames, part II	AiML			219-230	2008	We generalise some results of [7, 5] and show that if L is an α-modal logic (for some ordinal α ? 3) such that (i) L contains the product logic Kα and (ii) the product of α-many trees of depth one and with arbitrary large ?nite branching is a frame for L, then any axiomatisation of L must contain in?nitely many propositional variables. As a consequence we obtain that product logics like Kα, K4α, S4α, GLα, and Grzα cannot be axiomatised using ?nitely many propositional variables, whenever α ? 3.	many-dimensional modal logic, axiomatisation

Author	Title	Jur/Symp	Volume	Number	Pages	Year	abstract	key word
Tulenheimo, Tero	Modal logic of time division	AiML			363–387	2008	. A logic LTD is de?ned, inspired by [37]. It is syntactically like basic modal logic with an additional unary operator but it has an interval–based semantics on structures with arbitrary linear frames. ψ is interpreted as meaning 'the current interval has a ?nite partition whose all members satisfy ψ.' LTD is translatable into weak monadic secondorder logic but not into ?rst–order logic. The expressive power and the decidability properties of LTD and its fragments are studied.	decidability, expressive power, interval tense logic, linear order, negation, order type, von Wright, weak monadic second–order logic
Dastani, Mehdi	Programming Multi–agent Systems	CLIMA	5405		13–16	2008	Multi–agent systems consist of a number of interacting autonomous agents, each of which is capable of sensing its environment (including other agents) and deciding to act in order to achieve its own objectives. In order to guarantee the overall design objectives of multi–agent systems, the behavior of individual agents and their interactions need to be regulated and coordinated [23,29,30]. The development of multi–agent systems therefore requires programming languages that facilitate the implementation of individual agents as well as mechanisms that control and regulate individual agents' behaviors. It also requires computational tools to test and verify programs that implement multi–agent systems [7].	programming; MAS
Solhaug, Bj?rnar & Waaler, Arild	Logical Spaces in Multi–agent Only Knowing Systems	CLIMA 6th	3900		77–95	2005	We present a weak multi–agent system of Only knowing and an analysis of the logical spaces that can be defined in it. The logic complements the approach to generalizing Levesque 's All I Know system made by Halpern and Lakemeyer. A novel feature of our approach is that the logic is defined entirely at the object level with no reference to meta–concepts in the definition of the axiom system. We show that the logic of Halpern and Lakemeyer can be encoded in our system in the form of a particular logical space.	MAS,, weak
Chris Burnett, Timothy J. Norman, Katia Sycara	Trust Decision–Making in Multi–Agent Systems	IJCAI	1			2011	Trust is crucial in dynamic multi–agent systems, where agents may frequently join and leave, and the structure of the society may often change. In these environments, it may be difficult for agents to form stable trust relationships necessary for confident interactions. Societies may break down when trust between agents is too low to motivate interactions. In such settings, agents should make decisions about who to interact with, given their degree of trust in the available partners. We propose a decision–theoretic model of trust decision making allows controls to be used, as well as trust, to increase confidence in initial interactions. We consider explicit incentives, monitoring and reputation as examples of such controls. We evaluate our approach within a simulated, highly–dynamic multi–agent environment, and show how this model supports the making of delegation decisions when trust is low.	trust; decision making
Fiorino, Guido	Refutation in Dummett Logic Using a Sign to Express the Truth at the Next Possible World	IJCAI	2		869	2011	In this paper we use the Kripke semantics characterization of Dummett logic to introduce a new way of handling non–forced formulas in tableau proof systems. We pursue the aim of reducing the search space by strictly increasing the number of forced propositional variables after the application of noninvertible rules. The focus of the paper is on a new tableau system for Dummett logic, for which we have an implementation.	dummett logic; possible world
Giuseppe De Giacomo, Yves Lesp?rance, Hector J. Levesque	Efficient Reasoning in Proper Knowledge Bases with Unknown Individuals	IJCAI	2		827	2011	This work develops an approach to ef?cient reasoning in ?rst–order knowledge bases with incomplete information. We build on Levesque's proper knowledge bases approach, which supports limited incomplete knowledge in the form of a possibly in– ?nite set of positive or negative ground facts. We propose a generalization which allows these facts to involve unknown individuals, as in the work on labeled null values in databases. Dealing with such unknown individuals has been shown to be a key feature in the database literature on data integration and data exchange. In this way, we obtain one of the most expressive ?rst–order open–world settings for which reasoning can still be done ef?ciently by evaluation, as in relational databases. We show the soundness of the reasoning procedure and its completeness for queries in a certain normal form.	knowledge base; unknown
Hankz Hankui Zhuo, Lei Li	Multi–Agent Plan Recognition with Partial Team Traces and Plan Libraries	IJCAI	1		484	2011	Multi–Agent Plan Recognition (MAPR) seeks to identify the dynamic team structures and team behaviors from the observed activity sequences (team traces) of a set of intelligent agents, based on a library of known team activity sequences (team plans). Previous MAPR systems require that team traces and team plans are fully observed. In this paper we relax this constraint, i.e., team traces and team plans are allowed to be partial. This is an important task in applying MAPR to real–world domains, since in many applications it is often difficult to collect full team traces or team plans due to environment limitations, e.g., military operation. This is also a hard problem since the information available is limited. We propose a novel approach to recognizing team plans from partial team traces and team plans. We encode the MAPR problem as a satisfaction problem and solve the problem using a state–of–the–art weighted MAX–SAT solver. We empirically show that our algorithm is both effective and efficient.	Multi–Agent Plan Recognition
Heng Zhang, Yan Zhang, Mingsheng Ying Yi Zhou	Translating First–Order Theories into Logic Programs	IJCAI	2		1126	2011	This paper focuses on computing first–order theories under either stable model semantics or circumscription. A reduction from first–order theories to logic programs under stable model semantics over finite structures is proposed, and an embedding of circumscription into stable model semantics is also given. Having such reduction and embedding, reasoning problems represented by first–order theories under these two semantics can then be handled by using existing answer set solvers. The effectiveness of this approach in computing hard problems beyond NP is demonstrated by some experiments.	first–order theories

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Kowalski, Robert	Artificial Intelligence and Human Thinking	IJCAI				2011	Research in AI has built upon the tools and techniques of many different disciplines, including formal logic, probability theory, decision theory, management science, linguistics and philosophy. However, the application of these disciplines in AI has necessitated the development of many enhancements and extensions. Among the most powerful of these are the methods of computational logic. I will argue that computational logic, embedded in an agent cycle, combines and improves upon both traditional logic and classical decision theory. I will also argue that many of its methods can be used, not only in AI, but also in ordinary life, to help people improve their own human intelligence without the assistance of computers.	human thinking
Nils Bulling, Wojciech Jamroga	Alternating Epistemic Mu-Calculus	IJCAI	1		109	2011	Alternating-time temporal logic (ATL) is a well-known logic for reasoning about strategic abilities of agents. An important feature that distinguishes variants of ATL for imperfect information scenarios is that the standard fixed point characterizations of temporal modalities do not hold anymore. In this paper, we show that adding explicit fixed point operators to the next-time″ fragment of ATL already allows to capture abilities that could not be expressed in ATL. We also illustrate that the new language allows to specify important kinds of abilities	the agents are not assumed to remember their strategy by definition
Roberto Centeno, Holger Billhardt	Using Incentive Mechanisms for an Adaptive Regulation of Open Multi-Agent Systems	IJCAI	1			2011	In this paper we propose a mechanism that encourages agents, participating in an open MAS, to follow a desirable behaviour, by introducing modifications in the environment. This mechanism is deployed by using an infrastructure based on institutional agents called incentivators. Each external agent is assigned to an incentivator that is able to discover its preferences, and to learn the suitable modifications in the environment, in order to improve the global utility of a system in response to inadequate design or changes in the population of participating agents. The mechanism is evaluated in a p2p scenario.	Adaptive Regulation
S?bastien Picault, Philippe Mathieu	An Interaction-Oriented Model for Multi-Scale Simulation	IJCAI	1			2011	The design of multiagent simulations devoted to complex systems, addresses the issue of modeling behaviors that are involved at different space, time, behavior scales, each one being relevant so as to represent a feature of the phenomenon. We propose here a generic formalism intended to represent multiple environments, endowed with their own spatiotemporal scales and with behavioral rules for the agents they contain. An environment can be nested inside any agent, which itself is situated in one or more environments. This leads to a lattice decomposition of the global system, which appears to be necessary for an accurate design of multi-scale systems. This uniform representation of entities and behaviors at each abstraction level relies upon an interaction-oriented approach for the design of agent simulations, which clearly separates agents from interactions, from the modeling to the code. We also explain the implementation of our formalism within an existing interaction-based platform.	multiagent simulation
Salem Benferhat, Julien Hu?, Sylvain Lagrue Julien Rossit	Interval-Based Possibilistic Logic	IJCAI	2		750	2011	Possibilistic logic is a well-known framework for dealing with uncertainty and reasoning under inconsistent knowledge bases. Standard possibilistic logic expressions are propositional logic formulas associated with positive real degrees belonging to [0,1]. However, in practice it may be dif?cult for an expert to provide exact degrees associated with formulas of a knowledge base. This paper proposes a ?exible representation of uncertain information where the weights associated with formulas are in the form of intervals. We ?rst study a framework for reasoning with interval-based possibilistic knowledge bases by extending main concepts of possibilistic logic such as the ones of necessity and possibility measures. We then provide a characterization of an interval-based possibilistic logic base by means of a concept of compatible standard possibilistic logic bases. We show that intervalbased possibilistic logic extends possibilistic logic in the case where all intervals are singletons. Lastly, we provide computational complexity results of deriving plausible conclusions from interval-based possibilistic bases and we show that the ?exibility in representing uncertain information is handled without extra computational costs	Possibilistic Logic
Jin, Yi & Thielscher, Michael	Iterated Belief Revision, Revised	IJCAI				2005	TheAGMpostulates for belief revision, augmented by the DP postulates for iterated belief revision, provide generally accepted criteria for the design of operators by which intelligent agents adapttheir beliefs incrementally to new information. These postulates alone, however, are too permissive: They support operators by which all newly acquired information is canceled as soon as an agent learns a fact that contradicts some of its current beliefs. In this paper, we present a formal analysis of the de?ciency of the DP postulates, and we show how to solve the problem by an additional postulate of independence. We give a representation theorem for this postulate and prove that it is compatible with AGM and DP.	AGM Belief Revision, postulate
Chomatek, Lukasz & Poniszewska-Mara?da, Aneta	Modern Approach for Building of Multi-Agent Systems	ISMIS	5722		351-360	2009	Different approaches for distributed programming in modern hardware architectures allows the developers to build the efficient solutions of complicated technical and information problems. The technologies such as Web Services allow the applications to create a cross-platform for data exchange. The multi-agent systems, where a communication between the agents is essential for proper work of such applications can be developed using the technology of Service Oriented Architecture (SOA). The presented article presents how to apply the modern programming technologies, design patterns and software architectures to building standards of multi-agent systems.	MAS; Service Oriented Architecture

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Alberti, Marco; Chesani, Federico; Gavanelli, Marco; Lamma, Evelina & Mello, Paola	A Verifiable Logic-Based Agent Architecture	ISMIS	4203		188-197	2006	In this paper, we present the SCIFF platform for multi-agent systems.The platform is based on Abductive Logic Programming, with a uniform language for specifying agent policies and interaction protocols. A significant advantage of the computational logic foundation of the SCIFF framework is that the declarative specifications of agent policies and interaction protocols can be used directly, at runtime, as the programs for the agent instances and for the verification of compliance. We also provide a definition of conformance of an agent policy to an interaction protocol (i.e., a property that guarantees that an agent will comply to a given protocol) and a operational procedure to test conformance.	MAS; abductive logic; protocol
Debenham, John & Lawrence, Elaine	Intelligent Agents That Make Informed Decisions	ISMIS	4203		137-146	2006	Electronic markets with access to the Internet and the World Wide Web, are information-rich and require agents that can assimilate and use real-time information flows wisely. A new breed of "information-based" agents aims to meet this requirement. They are founded on concepts from information theory, and are designed to operate with information flows of varying and questionable integrity. These agents are part of a larger project that aims to make informed automated trading in applications such as eProcurement a reality.	information theor
Cranefield, Stephen & Winikoff, Michael	Verifying social expectations by model checking truncated paths	Journal of Logic and Computation	21	6	1217-1256	2011	One approach to moderating the expected behaviour of agents in open societies is the use of explicit languages for defining norms, conditional commitments and/or social expectations, together with infrastructure supporting conformance checking. This article presents a logical account of the fulfilment and violation of social expectations modelled as conditional rules over a hybrid linear propositional temporal logic. Our semantics captures the intuition that the fulfilment or violation of an expectation must be determined without recourse to information from later states.We define a means of updating expectations from one state to the next based on formula progression, and show how conformance checking was implemented by combining the MCFULLmodel checking algorithm of Franceschet and de Rijke and the semantics for LTL over truncated paths proposed by Eisner et al. We present algorithms for both traditional offline model checking, where the complete model is available at once, and online model checking, where states are added to the model sequentially at runtime.	norms; LTL
Bouyer, Patricia; Cassez, Franck & Laroussinie, Fran?ois	Timed Modal Logics for Real-Time Systems	Journal of Logic, Language and Information	20		169-203	2011	In this paper, a timed modal logic L c is presented for the specification and verification of real-time systems. Several important results for L c are discussed. First we address the model checking problem and we show that it is an EXPTIME-complete problem. Secondly we consider expressiveness and we explain how to express strong timed bisimilarity and how to build characteristic formulas for timed automata. We also propose a compositional algorithm for L c model checking. Finally we consider several control problems for which L c can be used to check controllability.	Model checking; Timed automata; Timed modal logic; Timed control
Kamide, Norihiro	Dynamic Non-Commutative Logic	Journal of Logic, Language and Information	19		33-51	2010	A first-order dynamic non-commutative logic (DN), which has no structural rules and has some program operators, is introduced as a Gentzen-type sequent calculus. Decidability, cut-elimination and completeness theorems are shown for DN or its fragments. DN is intended to represent not only program-based, resource-sensitive, ordered, sequence-based, but also hierarchical (tree-based) reasoning.	Completeness; Cut-elimination; Decidability; Dynamic logic; Non-commutative logic; Sequent calculus
Stranneg?rd, Claes; Ulfsb?cker, Simon; Hedqvist, David & G?rling, Tommy	Reasoning Processes in Propositional Logic	Journal of Logic, Language and Information	19		283-314	2010	We conducted a computer-based psychological experiment in which a random mix of 40 tautologies and 40 non-tautologies were presented to the participants, who were asked to determine which ones of the formulas were tautologies. The participants were eight university students in computer science who had received tuition in propositional logic. The formulas appeared one by one, a time-limit of 45 s applied to each formula and no aids were allowed. For each formula we recorded the proportion of the participants who classified the formula correctly before timeout (accuracy) and the mean response time among those participants (latency). We propose a new proof formalism for modeling propositional reasoning with bounded cognitive resources. It models declarative memory, visual memory, working memory, and procedural memory according to the memory model of Atkinson and Shiffrin and reasoning processes according to the model of Newell and Simon. We also define two particular proof systems, T and NT, for showing propositional formulas to be tautologies and non-tautologies, respectively. The accuracy was found to be higher for non-tautologies than for tautologies ($p < .0001$). For tautologies the correlation between latency and minimum proof length in T was .89 and for non-tautologies the correlation between latency and minimum proof length in NT was .87.	Bounded resources; Proof system; Propositional logic; Psychological experiment; Reasoning
Klugl, Franziska & Rindsfuser, Guido	Agent-Based Route (and Mode) Choice Simulation in Real-World Networks	Web Intelligence and Intelligent Agent Technology, IEEE/WIC/ACM I.C.	2		22-29	2011	Mode and route choice are central elements of traffic simulations. Traditionally they form two subsequent steps in the four-step process where first, the simulated population distributes among available transportation modes and then their movement is assigned to the roads respectively other networks. However, these two phases are better dealt with simultaneously as choices are highly depending on each other. In this paper, we are suggesting an agent-based combined route and mode choice model that is not only able to resemble traditional simulations, but provides the means for new applications. As the simulated agents are active and situated while moving through the network, they are able to react to unforeseen events such as the closing of a link. Thus we can reproduce the self-organized re-distribution of travelers to new routes depending on when/where they are notified about the problem. We illustrate the feasibility and usefulness of our agent-based mode and route choice simulation using a real-world network of a small-size Swiss town.	route choice; simulation

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Rafique, Umair; Huang, Shell Ying & Miao, Chun Yan	Motivation Based Goal Adoption for Autonomous Intelligent Agents	Web Intelligence and Intelligent Agent Technology, IEEE/WIC/ACM I.C.	2		54–57	2011	An intelligent agent situated in some environment needs to know the preferred states it is expected to achieve so that it can work towards achieving them. The preferred states the agent has selected to achieve at a given time are itsgoals″. One popular approach for deciding which preferred state to adopt as goal at a given time is to assign utility values to these states and then choose the one with the highest utility at a given time. However a preferred state can be useful to a varying degree depending upon the situation the agent is in and hence such static utility cannot represent its usefulness indifferent situations. In this paper we propose an approach of representing utility of preferred states based on the concept of motivations which adjusts their utility according to the situation the agent is in.″	motivations
Natasha Alechina, Mark Jago, Brian Logan	Modal logics for communicating rule-based agents	ECAI	141			2006	n this paper, we show how to establish correctness and time bounds (e.g., quality of service guarantees) for multi-agent systems composed of communicating rule-based agents. The formal models of multi-agent systems we study are transition systems where each transition corresponds to either a rule firing or an act of communication by an agent. We present a complete and sound modal logic which formalises how the beliefs of communicating rule-based agents change over time. Using a simple example, we show how this logic can be used to specify temporal properties of belief change in multi-agent systems in a precise and realistic way, and how existing modal logic techniques such as model-checking can be used to state and verify properties of agents.	Belief Change; Modal Logic;
David Fernández-Duque	A sound and complete axiomatization for Dynamic Topological Logic	Journal of Symbolic Logic	77	3		2012	Dynamic Topological Logic ($\mathscr{L}$) is a multimodal system for reasoning about dynamical systems. It is defined semantically and, as such, most of the work done in the field has been model-theoretic. In particular, the problem of finding a complete axiomatization for the full language of $\mathscr{L}$ over the class of all dynamical systems has proven to be quite elusive. Here we propose to enrich the language to include a polyadic topological modality, originally introduced by Dawar and Otto in a different context. We then provide a sound axiomatization for $\mathscr{L}$ over this extended language, and prove that it is complete. The polyadic modality is used in an essential way in our proof.	Dynamic Topological Logic; Sound; Complete; Axiomatization
David Fernández-Duque	Dynamic topological logic of metric spaces	Journal of Symbolic Logic	77	1		2012	Dynamic Topological Logic ($\mathscr{L}$) is a modal framework for reasoning about dynamical systems, that is, pairs $\langle X,f\rangle$ where X is a topological space and $f: X \to X$ a continuous function. In this paper we consider the case where X is a metric space. We first show that any formula which can be satisfied on an arbitrary dynamic topological system can be satisfied on one based on a metric space; in fact, this space can be taken to be countable and have no isolated points. Since any metric space with these properties is homeomorphic to the set of rational numbers, it follows that any satisfiable formula can be satisfied on a system based on $\mathbb{Q}$. We then show that the situation changes when considering complete metric spaces, by exhibiting a formula which is not valid in general but is valid on the class of systems based on a complete metric space. While we do not attempt to give a full characterization of the set of valid formulas on this class we do give a relative completeness result; any formula which is satisfiable on a dynamical system based on a complete metric space is also satisfied on one based on the Cantor space.	Dynamic Topological Logic; Metric Spaces
Neil Tennant	On the degeneracy of the full AGM-theory of theory-revision	Journal of Symbolic Logic	71	2		2006	A general method is provided whereby bizarre revisions of consistent theories with respect to contingent sentences that they refute can be delivered by revision-functions satisfying both the basic and the supplementary postulates of the AGM-theory of theory-revision.	AGM; Revision