Morph Gentzen Plan Computation

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Abstract New planning techniques with model diagrams and applications to computable models with morph Gentzen computing on relevant worlds are presented. Generic diagrams are applied to model computing with localized minimal efficient computable KR on AI worlds. Diagrammatic reasoning is defined in terms of inferences directed by the G-diagrams for models. G-diagrams are applied towards KR from planning with nondeterminism and planning with free proof trees and predictive diagrams. The IM Morph Gentzen Logic for computing for multimedia is the basis to new projects with important computing applications. The basic principles are a mathematical logic where a Gentzen or natural deduction systems is defined by taking arbitrary structures and multimedia objects coded by diagram functions. A specific sound and complete computing logic is applied to VR plans with Morph Gentzen as the basis.

1. Introduction

The paper is towards foundations for multiagent planning with Morph Gentzen computing logic. Multiagent visual diagrammatic planning and spatial computing are applications areas. Visual intelligent objects are applied with virtual intelligent trees to carry on visual planning and VR computation with virtual trees. KR is on generalized diagrams, abbreviated by *G-diagram,* from [No83,88,91,99], invented for AI planning and reasoning, formulating various notions of generalized and free diagrams. It shows that G-diagrams from the basis for minimal efficient knowledge representation, henceforth abbreviated by KR, paradigms. Areas touched upon are: foundational and formal. Essential characteristics of visual representations, diagram understanding and interpretation, properties of animated and changing diagrams, diagram specification techniques, diagrammatic knowledge representation and inference, visual reasoning with diagrammatic programming languages, modeling interaction with diagrams, sound logical reasoning with diagrams, combination of diagrammatic knowledge and domain knowledge. We also show the applicability of G-diagram method for KR to partial deduction and abduction from [NH93], where we have defined adductive diagrams. Furthermore, we make a brief connection form [NH93] to KR for proof abstraction methods in AI [Ai96,MH91], in the present paper, to show the applicability of the methods we are presenting with free proof trees[No 95]. Many examples are drawn from theories of AI to planning for robots to show the applicability of the techniques and theories proposed. World model revision is one of the difficult aspects of nonmonotonic logic systems. Our papers [No83,88,91] presented a solution to it by the generalized diagram formulation, where models are implicitly revised through dynamic changes to the diagrams from which the models are built. Thus we show that KR by G-diagrams simplifies the world revision problem. The formulation of default in Nourani [No83,91], as further applied to abductive reasoning in this paper is referring to model-theoretic consistency. Generalized diagrams are used to build models with a minimal family of generalized Skolem functions. The minimal set of function symbols is functions with which a model can be built inductively. The functions can correspond to objects defining shapes and depicting pictures. The models presented with the G-diagrams are computable [No91]. AI *Worlds* are relevant descriptions for problem solving in the real world parts we want models for. G-diagrams can analogically model the semantics of a problem domain. The areas where we have applied G-diagrams include formal theories [No88,NH93], computational models alternate diagrammatic computing [No91,95,No95a,NH93], the synergy between cognitive theories, formal theories, and computational models for aircraft navigation systems [No99b]. The application to proof abstraction is alluded to and presented further in [NH93].

2. KR Computable AI World Models

Knowledge representation has two significant roles: to define a model for the AI world, and to provide a basis for reasoning techniques to get at implicit knowledge. An ordinary diagram is the set of atomic and negated atomic sentences that are true in a model. Generalized diagrams are diagrams definable by a minimal set of functions such that everything else in the models closure can be inferred, by a minimal set of terms defining the model. Thus providing a minimal characterization of models, and a minimal set of atomic sentences on which all other atomic sentences depend. The computing and AI enterprise requires general techniques of model construction and extension, since there are dynamically changing world descriptions and theories. The techniques in [No83,No 91] for model building as applied to the problem of AI reasoning allows us to build and extend models through diagrams. This requires us to define the notion of generalized diagram. The diagrams are used to build models with a minimal family of generalized Skolem functions. The minimal sets of function symbols are those with which a model can be built inductively. We focus on such models, since they are computable, e.g., [No91]. The G-diagram methods applied and further developed here, allows us to formulate AI world descriptions, theories, and models in a minimal computable manner. It further allows us to view the world from only the relevant functions. Thus models and proofs for AI problems can be characterized by models computable by a set of functions.

2.1 Worlds and KR on Model Diagrams

Proofs can be abstracted by generalizing away from constants in the proof. Thus, such a generalized proof can be defined by a whole class of minimal diagrams. This process is usually realized via partial deduction, which can be regarded as the proof-theoretical way of abducting diagrams whose literals are necessary conditions for the proof. Under certain restrictions partial deduction can be transformed into abduction [Ho92]. We want to present a formal relation between partial deduction and abduction from a model-theoretical point of view. However, it was not clear how PD can be given a model-theoretical semantics and how knowledge is to be represented to a proof system. This is one reason why the formulation of nonmonotonic reasoning with G-diagrams presented by Nourani [No83,No91] could be applicable here. Let us now view the deductive methods. The proof-theoretic example is SLDNF-resolution, which is a well-known deductive mechanism (Remark: This makes it easier for us to link diagrams to PD and Abductive Reasoning). A SLDNF-proof can be considered as the unfolding of an AND/OR-tree, which is rooted in the formula to be proven, whose branches are determined by formulas of the theory, and whose leaves are determined by atomic formulas which are true in an AI world. In the present approach, as we shall further define, leaves could be free Skolemized trees. Removing the assumption that proof-tree leaves get instantiated with atomic formulas, we get a more general notion of a proof, which is usually called "partial deduction" [Ho92]. The proof methods are driven form knowledge represented on G-diagrams. Partial deduction usually computes from a formula and a theory an existential quantified diagram. In the present paper we also instantiate proof tree leaves with free Skolemized trees[No95a], where free trees are substituted for the leaves. In the present approach, as we shall further define, leaves could be free Skolemised trees. By a free Skolemised tree we intend a term made of constant symbols and Skolem functions terms. By dropping the assumption that proof-tree leaves get instantiated with atomic formulas, we get a more general notion of a proof. The mathematical formalization that allows us to apply the method of free proof trees is based on Nourani [No95a] and is further developed and applied to AI here.

3. Generalized Diagrams and Relevant Worlds

3.1 Generalized Diagrams

In order to point out the use of the generalized method of diagrams we present a brief view of the problems faced at planning from [No95a]. The diagram of a structure in the standard model-theoretic sense is the set of atomic and negated atomic sentences that are true in that structure. The generalized diagram (G-diagram) [No91,No95] is a diagram in which the elements of the structure are all represented by a minimal specified set of function symbols and constants. Thus it is sufficient to define the truth of formulas only for the terms generated by the minimal family of functions and constant symbols. Such assignment implicitly defines the diagram. This allows us to define a canonical model of a theory in terms of a minimal family function symbols. By definition a diagram is a set of atomic and negated atomic sentences, and can thus be considered as a basis for defining a model, provided we could by algebraic extension, define the truth-value of arbitrary formulas instantiated with arbitrary terms. Thus all compound sentences build out of atomic sentences then could be assigned a truth-value, handing over a model. The following examples would run throughout the paper Consider the primitive first order language (FOL)
L = {c},{f(X)},{p(X),q(X)}. Let us apply Prolog notation convention for constants and variables) and the simple theory {for all X: p(X) q(X),p(c)}, and indicate what is meant by the various notions. [model] = {p(c),q(c),q(f(c)),q(f(f(c))),...},{p(c) &q(c), p(c) & p(X), p(c) &p(f(X)), ...}, {p(c) v p(X), p(c) v p(f(X)), p(c) p(c)...}
[diagram] = {p(c),q(c),p(c),q(f(c)),q(f(f(c))),...},...,q(X)}, i.e. diagram = the set of atomic formulas of a model. Thus the diagram is [diagram]= {p(c),q(c),q(f(c)),q(f(f(c))), ...,q(X)}. Based on the above, we can define generalized diagrams. And what we don't know on a generalized diagram is defined in terms of generalized Skolem functions. The term generalized is applied to indicate that such diagrams are defined by algebraic extension from basic terms and constants of a language to fully define diagrams making use of only a minimal set of functions. Generalized diagrams is [generalized diagram]= {p(c),q(c),p(f(t)),q(f(t))} for t defined by induction, as {t0=c , and tn= {f(t(n-1))} for n>0. It is thus not necessary to redefine all f(X)'s since they are instantiated. Nondeterministic diagrams are those in which some formulas are assigned an indeterminate symbol, neither true nor false, that can be arbitrarily assigned in due time. *Free Skolemized diagrams* are those in which instead of an indeterminate symbols, there are free Skolem functions, that could be universally quantified. [Free_Skolemized-Diagram]= {p(c),q(c),p(f(t)),q(f(c)),q(f(f(c))),q_F.s(s)}, where t and s are as defined in the sections before. These G-diagrams are applicable to KR for planning with incomplete knowledge [No95] and free

proof trees[No 95,NH93]. A *generalized free diagram* (GF-diagram) is a diagram that is defined by algebraic extension form a minimal set of function symbols. [generalized free diagram] = {p(c),q(c),p(f(t)),q(f(t)), q_F.s(s)} for t and s as before. The AI planning example [No91,No 95] a generalized diagram for the blocks world problem solver applies the function put :blocks,blocks blocks x blocks. The diagram has to assign truth values to top(x,y,z), where x, any y are block names, and z is a table configuration. Let Tab be the initial table configuration {A,B,C}. For example, one can define the G-diagram for the blocks-world by top(x,y,z) = T,

if z = put(x,y,Tab)

or z= put(x,w,put(w,y,Tab));

= F, otherwise. where x,y,w are variables assigned from {A,B,C} and z is a variable representing table configurations.)

3.2 Predictive Diagrams For KR

Here we present the notion of an predictive diagram and apply it for KR to provide a model-theoretic characterization for PD and related proof trees. A *predictive diagram* for a theory T is a diagram D[M], where M is a model for T, and for any formula q in M, either the function f: q {0,1} is defined, or there exists a formula p in D[M], such that T U {p} proves q; or that T proves q by minimal abduction. A *generalized predictive diagram*, is an predictive diagram with D[M] defined from a minimal set of functions. The predictive diagram could be minimally represented by a set of functions {f1,...,fn} that inductively define the model. The free trees [No 95] defined by the notion of provability implied by the definition, could consist of some extra Skolem functions {g1,...,gk},that appear at free trees. The f terms and g terms, tree congruences, and predictive diagrams then characterize partial deduction with free trees. A special consistency checking scheme, based on Hilbert's epsilon symbol [NH93] is used. These extensions of PD to an abductive, nonmonotonic reasoning approach allow us to link with the model-diagram computing basis non-monotonic reasoning Nourani [No83,91,No95a]. By viewing PD from predictive diagrams we could define models for PD from predictive diagrams - thus a model theoretic formulation for PD emerges [NH93]. We then apply Hilbert models to the proof-model computations [NH93].

3.3 Virtual Trees

A virtual tree is a tree on constant symbols and Skolem function terms. In the present paper we also instantiate proof tree leaves with free Skolemized trees. Thus virtual trees are substituted for the leaves. A plan is a sequence of operations in the universe that could result in terms that instantiate the truth of the goal formulas in the universe. That is what goes on as far as the algebra of the model is concerned. It is a new view of planning prompted by our method of planning with GF-diagrams and free Skolemized trees. It is a model-theoretic view. Proof-theoretically a plan is the sequence of proof steps that yields the proof for the goal formula. The proof theoretic view is what the usual AI literature presents. The planning process at each stage can make use of GF-diagrams by taking the free interpretation, as tree-rewrite computations, for example, of the possible proof trees that correspond to each goal satisfiability. The techniques we have applied are to make use of the free Skolemized proof trees in representing plans in terms of generalized Skolem functions. In planning with GF-diagrams that part of the plan that involves free Skolemized trees is carried along with the proof tree for a plan goal. Proofs can be abstracted by generalizing away from constants in the proof. Thus, such a generalized proof can be defined by a whole class of minimal diagrams. This process is usually realized via partial deduction, which can be regarded as the proof-theoretical way of abducting diagrams whose littorals are necessary conditions for the proof. Under certain restrictions partial deduction can be transformed into abduction[Ho92]. We want to present a formal relation between partial deduction and abduction from a model-theoretical point of view. However, it is not clear yet how PD can be given a model-theoretical semantics. This is one reason why the formulation of nonmonotonic reasoning presented at Nourani [No91] could be applicable here. In our projects leaves could be free Skolemized trees. By a free Skolemized tree we intend a term made of constant symbols and Skolem function terms. By dropping the assumption that proof-tree leaves get instantiated with atomic formulas, we get a more general notion of a proof, which is usually called "partial deduction" [Ho92]. Partial deduction usually computes from a formula and a theory an existential quantified diagram. By not requiring the proof-tree leaves to get instantiated with atomic formulas, we get a more general notion of a proof. The mathematical formalization that allows us to apply the method of free proof trees is based on Nourani [No95a] and is further developed and applied to theorem proving. The free trees defined by the notion of provability implied by the definition, could consist of some extra Skolem functions {g1,...,gk}, that appear at free trees. The f terms and g terms, tree congruences, and predictive diagrams then characterize partial deduction with free trees. These extensions of PD to an abductive, nonmonotonic reasoning approach allow us to link them with the diagrammatic models for nonmonotonic reasoning [No83,No91]. By viewing PD from predictive diagrams we could define models for PD from predictive diagrams - thus a model theoretic formulation for PD emerges. We then define Hilbert models to handle the proof-model problems further on. The idea is that if the free proof tree is constructed then the plan has a model in which the goals are satisfied. The model is the initial model of the AI world for which the free Skolemized trees were constructed. Thus we had stated the Free Proof Tree Sound Computing theorem since [No95].

Theorem For the free proof trees defined for a goal formula from the GF-diagram there is an initial model satisfying the goal formulas. It is the standard model definable by the GF-diagram.□

4. Morph Gentzen Computing

The IM Morphed Gentzen computing logic for multimedia are new projects with important computing applications since [No96a,98]. The basic principles are a mathematical logic where a Gentzen[Ge43] or natural deduction [Pr65] systems is defined by taking arbitrary structures and multimedia objects coded by diagram functions. Multimedia objects are viewed as syntactic objects defined by functions, to which the deductive system is applied. Thus we define a syntactic morphing to be a technique by which multimedia objects and hybrid pictures are homomorphically mapped via their defining functions to a new hybrid picture. Functorial topological structures can be defined without difficulty. The deduction rules are a Gentzen system augmented by Morphing, and Trans-morphing. The logical language has function names for hybrid pictures. The *MIM Morph Rule* - An object defined by the functional n-tuple <f1,...,fn> can be Morphed to an object defined by the functional n-tuple <h(f1),...,h(fn)>, provided h is a homomrphism of abstract signature structures[Nourani 93c]. The *MIM Trans-Morph Rules*- A set of rules whereby combining hybrid pictures p1,...,pn defines an Event {p1,p2,...,pn} with a consequent hybrid picture p. Thus the combination is an impetus event. By trans-morphing hybrid picture's corresponding functions a new hybrid picture is deduced. The techniques can be applied to arbitrary topological structures. The languages and MIM rules are applied to algebraic structures. The deductive theory is a Gentzen system in which hybrid pictures are named by parameterized functions; augmented by the MIM morph and transmorph rules. The Model theory is defined from Intelligent syntax languages [No96a]. A computational logic for intelligent languages is presented in brief with a soundness and completeness theorem in [No96a]. The idea is to do it at abstract models syntax trees without specifics for the shapes and topologies applied. We start with L 1, and further on might apply well-behaved infinitary languages. A soundness and completeness theorem has been put forth [No97].

Theorem [Nourani 1997-No96a] Morph Gentzen Logic is sound and complete.

Proof hints start at the abstract on Virtual Morph Gentzen at the first author's name http://logic.univie.ac.at

5. Intelligent Trees and Spatial KR

Visual objects connected by agents carrying information represent the visual field amongst objects about the field, and carried onto intelligent trees for computation. Intelligent trees compute the spatial field information with the diagram functions. The trees defined have function names corresponding to computing agents. The computing agent functions have a specified module defining their functionality. The agents and objects are applied to compute field information where all computation is expressed and carried on intelligent tree language. By an intelligent language we intend a language with syntactic constructs that allow function symbols and corresponding objects, such that the function symbols are implemented by computing agents. A set of function symbols in the language, referred to by AF, is the set modeled in the computing world by AI Agents with across and/or over board capability. Intelligent languages are defined in [No96a,No98b] with syntactic constructs that allow function symbols and corresponding objects, such that the function symbols are implemented by computing agents. We define a function symbol f to be an *intelligent function* iff f is a member to the Agent Function Set. This is a free form definition that allows us to define tree algebras for intelligent spatial information computing theories.

5.1 Spatial Information and Morph Gentzen

Multiagent spatial vision techniques are introduced in the author's projects since 1994. The duality for our problem solving paradigm is generalized to be symmetric by the present paper to formulate Double Vision Computing. The basic technique is that of viewing the world as many possible worlds with agents at each world that compliment one another in problem solving by cooperating. The author presented an asymmetric view of the application of this computing paradigm and the basic techniques were proposed for various AI systems [No91]. The object co-object pairs and agents solve problems on boards by cooperating agents. The cooperative problem solving paradigms have been applied ever since the AI methods put forth by Hays-Roth. However, the muliagent multiboard techniques due to [No99b] since 1994. The techniques to be presented are to be applied to Mobile Multimedia. Communication and computation. Multimedia visual-object languages can be programmed with IM with a simple syntax. The techniques to be presented are to be applied for (a) Precomputed video-object composition and combination for spatial morph Gentzen computing with visual objects (b) High speed visual spacecraft navigation(No01) by multiagent multimedia. The autonomous space vehicles, e.g., Mars Rovers, are example areas where we have provided applications for spatial agent computing.. Space examples are areas where there are specific terrains precomputed for missions. For such environments Morph Getnzen logic can be designed to carry out autonomous intelligent multimedia activities. MIM terrain logic is designed where a combinations known terrain events vision sensed starts a specific autonomous activity by a Mars Rover in real-time.

6. Mult-iagent Visual Planning

6.1 Visual Context and Objects

The visual field is represented by visual objects connected with agents carrying information amongst objects about the field, and carried onto intelligent trees for computation. Intelligent trees compute the spatial field information with the diagram functions. The trees defined have function names corresponding to computing agents. Multiagent spatial vision techniques are introduced in our papers [No98a]. The basic technique is that of viewing the world as many possible worlds with agents at each world that compliment one another in problem solving by cooperating. The author presented an asymmetric view of the application of this computing paradigm and the basic techniques were proposed for various AI systems [No91]. The double vision computing paradigm with objects and agents might be depicted by the following figure. For computer vision the duality has obvious anthropomorphic parallels. The object co-object pairs and agents solve problems on boards by co-operating agents. The co-operative problem solving paradigms have been applied ever since the AI methods put forth by [HR85], [Ni86]. The muliagent multi-board techniques due to [No99b].

6.2 IM_BID and Planning

The BID model Breizier-Treure et.al. [DKT95,BJT96] has to be enhanced to be applicable to intelligent mutliagent Morph Gentzen computing [No97]. Let us start with a multi-board model where the multiagent computations are based on many boards, the boards correspond to either virtual possible worlds or to alternate visual views to the world, or to the knowledge and active databases. The board notion is a generalization of the Blackboard problem solving model since Hayes-Roth, e.g., [Ni86]. The blackboard model consists of a global database called the blackboard and logically independent sources of knowledge called the knowledge sources. The knowledge sources respond opportunistically to the changes on the blackboard. Starting with a problem the blackboard model provides enough guidelines for sketching a solution. Agents can cooperate on a board with very specific engagement rules not to tangle the board nor the agents. The multiagent multi-board model, henceforth abbreviates as MB, is a virtual platform to an intelligent multimedia BID agent computing model. We are faced with designing a system consisting of the pair <IM_BID,MB>, where IM_BID is a multiagent multimedia computing paradigm where the agents are based on the BID model. The agents with motivational attitudes model is based on some of the assumptions described as follows. Agents are assumed to have the extra property of rationality: they must be able to generate goals and act rationally to achieve them, namely planning, replanting, and plan execution. Moreover, an agent's activities are described using mentalists notions usually applied to humans. To start with the way the mentalists attitudes are modulated is not attained by the BID model. It takes the structural IM_BID to start it. The preceding chapters and sections on visual context and epistemics have brought forth the difficulties in tackling the area with a simple agent computing model. The BID model does not imply that computer systems are believed to actually "have" beliefs and intentions, but that these notions are believed to be useful in modeling and specifying the behavior required to build effective multi-agent systems. The first BID assumption is that motivational attitudes, such as beliefs, desires, intentions and commitments are defined as reflective statements about the agent itself and about the agent in relation to other agents and the world. These reflective statements are modeled in DESIRE in a meta-language, which is order sorted predicate logic. At BID the functional or logical relations between motivational attitudes and between motivational attitudes and informational attitudes are expressed as meta-knowledge, which may be used to perform meta-reasoning resulting in further conclusions about motivational attitudes. If we were to plan with BID with intelligent multimedia the logical relations might have to be amongst worlds forming the attitudes and event combinations. For example, in a simple instantiation of the BID model, beliefs can be inferred from meta-knowledge that any observed fact is a believed fact and that any fact communicated by a trustworthy agent is a believed fact. With IM_BID, the observed facts are believed facts only when a conjunction of certain worlds views and evens are in effect and physically logically visible to the windows in effect. Since planning with IM_BID is at times with the window visible agent groups, communicating, as two androids might, with facial gestures, for example Picard [Pi98]. In virtual or the "real-world" AI epistemics, we have to note what the positivists had told us some years ago: the apparent necessary facts might be only tautologies and might not amount to anything to the point at the specifics. It might all come to terms with empirical facts and possible worlds when it comes to real applications. A second BID assumption is that information is classified according to its source: internal information, observation, communication, deduction, assumption making. Information is explicitly labeled with these sources. Both informational attitudes (such as beliefs) and motivational attitudes (such as desires) depend on these sources of information. Explicit representations of the dependencies between attitudes and their sources are used when update or revision is required. A third assumption is that the dynamics of the processes involved are explicitly modeled. A fourth assumption is that the model presented below is generic, in the sense that the explicit meta-knowledge required to reason about motivational and informational attitudes has been left unspecified. To get specific models to a given application this knowledge has to be added. A fifth assumption is that intentions and commitments are defined with respect to both goals and plans. An agent accepts commitments towards himself as well as towards others as social commitments. For example, a model might be defined where an agent determines which goals it intends to fulfill, and commits to a selected subset of these goals. Similarly, an agent can determine which plans it intends to perform, and commits to a selected subset of these plans. Most reasoning about beliefs, desires, and intentions can be modeled as an essential part of the reasoning an agent needs to perform to control its own processes. The task of belief determination requires explicit meta-reasoning to generate beliefs. Desire determination:Desires can refer to a (desired) state of affairs in the world, but also to (desired) actions to be performed. Intention and commitment determination: Intended and committed goals and plans are determined by the component intention_and_commitment_determination. This component is decomposed into goal_determination and plan_determination. Each of these subcomponents first determines the intended goals and/or plans it wishes to pursue before committing to a specific goal and/or plan. Since the basic IM computing visual objects are hybrid pictures we define new planning techniques with hybrid pictures. The IM planning does not only applies planning with agents, it applies Morph Gentzen rules to hybrid pictures to achieve plan goals. The hybrid pictures carryout responsive, proactive, and reactive planning, only initiated and directed by a planning system. An example IM planning mission is as follows.

Hybrid picture 1- Spacecraft A Navigation Window

Agents: A1 Computes available docking times based on the visual field on the window.

A2 carrysout docking sequence based on messages to Spacecraft B

Hybrid picture 2 Spacecraft B Navigation Window

Agents: B1 carries on course based on its visual field window

B2 Accepts and carries out docking maneuvers from external hovering craft agents

Plan Goal Engage docking between A and B at appropriate A and B field windows. Morph Gentzen computing can be applied to the hybrid pictures to satisfy a plan goal. Thus morphing is applied with precise fluidity to plan computation. The plan computations basis since [Wi84] can be applied with the above.

6.3 VR

The above sections are a preliminary overview to meta-contextual logic with applications to Virtual Reality. Designated functions define agents, as specific function symbols, to represent languages with only abstract definition known at syntax. The languages are called “Intelligent.” For example, a function Fi can be agent corresponding to a language Li. Li can in turn involve agent functions amongst its vocabulary. Thus context might be defined at Li. An agent Fi might be as abstract as a functor defining functions and context with respect to a set and a linguistics model. Generic diagrams for models are defined as yet a second order lift from context. The techniques allowed us to define a computational linguistics and model theory for intelligent languages. Meta-contextual logic is combined with Morph Gentzen has applications towards Virtual Reality- VR computing since the trees on the languages can carry visual configurations via functions.

Proposition Morph Gentzen and Intelligent languages provide a sound and complete logical basis to VR.

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