Linguistic and Cultural Competencies in Dynamic Possible Worlds

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Abstract

Linguistic and Cultural Competences are closely linked, as they involve the ability to infer and trace truths within knowledge stored in memory. Humans respond to three interrelated questions: Logic, Epistemology, and Ontology. This paper defines a place for Cultural Competence within these philosophies through Epistemic Modal Logic and Dynamic Possible Worlds. Cultural Competence is crucial in social robots: pleasantness goes with it, but it also has practical functions, managing incomplete pieces of knowledge and shortening the customisation. The artificial agent simulates empathy and meta-cognition, enacting justified action plans that conform with ontology and its awareness thanks to the Euclidean S5 accessibility relation between possible worlds.

Keywords

Ontology, Cultural Competence, Epistemic Logic, Robotics

1. Introduction

Culture is a pivotal element in the world of acting and thinking: thus in the way of being humans. Following Pico della Mirandola in his Oration on the Dignity of Man[1], the human being was born with an original lack. Nature did not provide us with any abilities that could make us survive in environments: claws, strength, speed or mainly developed senses. However, the philosopher continued, thanks to that structural void, we filled it with culture; hence humanity could adapt to every biosphere, colonising the entire planet. Not having furs, they made garments; not having claws, they forged weapons; not having the speed to escape, they equipped themselves with shelters. In short, what represented a defect, an original mistake, became a space where creativity and strategies could express themselves in diverse and profitable ways. Culture, or rather cultures, represents the characteristic of our species with which we could inhabit every world (including possible ones).

Moreover, culture does not add meaning. It helps humans select information from a shared world. It is an automatic reduction to manage redundancy and overcome flawed thinking. Culture can be considered a sort of heuristic (one of the others). There is no strong relativism. In fact, it is a simplification that intervenes in specific contexts and is always open to change by human

beings in the course of their action. Any influence of culture on cognition is eliminable in favour of other strategies learned in the phylogenetic or ontogenetic processes. Elisabetta Lalumera[2] showed that the conditioning of language on the decision depends on how the task was set. It is called "conceptual flexibility". It means that a concept is a set of strategies or procedures, some provided by culture, that the individual use flexibly, depending on the type of task. In line with this assumption, Lawrence Barsalou[3] stated that a concept is a 'simulator', which generates different packets of information relevant to the category depending on the context. Being linguistically competent cannot be divorced from the situation, the speakers, or the society that equipped them with strategies.

In short, Cultural Competence is one with Linguistic Competence, which, according to Diego Marconi in The Lexical Competence[4], is divided into inferential and referential competence. Ontology is also inextricably linked to linguistic competence. It represents knowledge, its relations and properties and is connected to the competence to infer within that knowledge stored in the memory, referring to a world. Indeed, when knowing and solving problems, the human being answers three interconnected questions that are the subject of three different philosophical disciplines. "What is truth? How is a truth known? How is the world based on that truth?". The first is Logic, the second is Epistemology, and the third is Ontology. This article aims to define a place for cultural competence within these specialisations (section 2), between epistemic modal logic and dynamic possible worlds, proposing preliminary implementation solutions (section 3).

2. Cultural Competence

Being culturally competent means understanding and behaving according to a specific culture. A social object is a particular point of view, so cultural competence is strictly linked with empathy and the ability to put oneself in others' shoes and reason from their perspective. In the introduction, we anticipated how linguistic competence is one with ontological competence, i.e. the ability to refer to an external world (Epistemology) and infer within one's knowledge (Logic). Reference and reasoning are always flexible strategic choices, the heuristics of which depend on multiple factors, such as those offered by culture, which, in essence, allows individuals to simplify action, especially when explicit social goals are involved and the agent needs more information to personalise their choices in a moment.

2.1. Cultural Ontology

Ontology is traditionally the discourse on Being. It is the explicit conceptualisation of the world, or, somewhat, of a point of view on that domain. The totality is always an abstraction, an approximate choice of what to focus on. It is impossible to grasp the whole at a single glance. On the contrary, when we observe, we are always guided by previous patterns and theories, which lead us to select only certain elements. The senses lead us to observe qualities and not others; culture and language do likewise, defining meanings in which to catalogue elements in the world based on their purposes. Weak relativism means that no antecedent theory by which we observe is rigid - senses aside, however, which can be circumvented by employing *téchne* (if electromagnetism is not visible, it becomes so through experimentation). We cannot deal with

complete ontologies, but always and only with implicit or explicit choices, with reductions of meanings based on their usefulness. Even in Computer Science, the artificial agent will make inferences on an abstraction, on a purpose-defined selection of classes, attributes and relations. An omniscient robot has no efficiency. Gilbert Harman[5] points out that, from a logical point of view, every belief implies infinitely many completely trivial consequences, which are of no interest to the purposes of an agent. It would be counterproductive for a finite rational subject to 'clutter' his mind with such useless beliefs, and it is equally disadvantageous to devote too many resources to making the robot reason without taking action[6]. How to choose what is trivial and what is not? The risk is to reason about systems with an explosion of ad hoc restrictions. It is as if there is a starting background, and, depending on the circumstance, we cut out different figures to focus on each time. One of the possible cutouts is that offered by culture.

Cultural ontology (we can call it that) offers subjects a cross-section of reality to execute their plans in agreement with other subjects. In this way, other individuals, sharing that common ground of representational primitives, attributes and relations, in short of presuppositions, will be able to anticipate each other's knowledge, making abductive, defectible reasoning and acting even in the presence of vague and ambiguous information, with limited computational resources. Why can we understand a *lapsus linguae*, knowing what the speaker would have meant beyond the string of sounds actually uttered? Because meaning does not depend simply on syntax and semantics, on what is said, but on inferential skills about the implicit, which are possible precisely because we share an external, factual world and the ontology co-created in communities. Thanks to this common ground, we can anticipate and carry out what in language pragmatics are called logical implicatures: inferences that human beings make from the unspoken based on the commonality of relevant domains, of conversational clues (implicit, such as body language or explicit) and accessibility to the minds of other speakers. That is why it is helpful to include a cultural ontology in an artificial social agent: it makes understanding and generalisation transparent without an explosion of trivial inferences.

According to Stalnaker, presuppositions constitute the domain of common knowledge and allow speakers to infer from the unspoken[7]. When we say that Aristotle was a philosopher, we assume, we take it for granted, that there was an individual called Aristotle. To be culturally competent means understanding each other's beliefs and presuppositions. We can access the ontologies of others since we are not totally dissimilar, and we can understand their point of view. In fact, there have never been any untranslatable cultures and languages, as Quine[8] had claimed in theoretical instances. That is because the meaning ascribed to the world is never simply a subjective projection, dependent on and constructed by the minds of individuals. The content of thoughts is causally linked to a world in common, founded on rules of correctness on which there is general agreement. The objective and substantive *relatum* contributes to linguistic normativity, i.e. the correct use of meaning in a given circumstance[4]. Intentional objects (the content of thought) is always actual (or possible) object about which speakers publicly reason. In ontology engineering, the standard agreement is also indispensable: it averts the construction of private languages in favour of actual co-agreement about meanings. In Wittgenstein's perspective[9], language is a form of life that adapts to a situation and evolves in an environment of human habits, symbols and beliefs. To realize conceptual flexibility[2], the ontology must be about an open, not closed world (OWL), with non-monotonic logics: probabilistic logics in dynamic domains where knowledge can be reasoned about and revised.

2.2. Meaning of Cultural Meanings and Epistemology

Gottlob Frege[10] distinguished, for each term, property and utterance, a sense and a reference. For proper names (Aristotle) and definite descriptions (Alexander the Great's master), the reference is the individual the term denotes; the sense is how it refers to. Saying "Alexander the Great's master" and "Plato's disciple" is analogous since the reference does not change: it remains Aristotle; what changes are the senses, that is, the criterion by which the philosopher is identified from those names: in one case I will observe Alexander the Great's relationships, in the other Plato's[11]. The same twofold way of understanding meaning is applied to utterances and predicates. For the latter, the reference is concepts. Frege defines them as functions, having for arguments the objects that fall under them and for values either true or false. The concept of "philosopher", for example, applies to Aristotle, Plato, Riccardo and Lorenza and returns the value True because the arguments are indeed those of the class: thus, Philosopher(x) = V if x is a philosopher[12]. Sense is how we apply this category: we can look for graduates in philosophical sciences or those who profess a rational doctrine. Concepts are not rigid but open to change and to the freedom of each individual to use them according to their different senses, thinking of them strategically on the basis of the function of truth that, from time to time, they may exercise in contexts. In short, asking about meaning cannot disregard the frame (context) in which it is placed for a set of speakers. Culture is one of the facilitators, one of the heuristics, one of the 'suppliers of meaning'. Of course, it can always be eliminated when tasks change their social purpose or in the face of changes within the culture itself. Before the Sophists, philosophy was not a job; with them, there was a cultural shift to be taken into account in interpreting the meaning of philosophy during the time. Culture becomes fundamental to social robots, in which conversational tasks and the implicit rules of kinaesthetic and proxemics, derive from culture, condition acceptance, pleasantness, and comfort.

Finally, the reference of the propositions is the truth value: two statements like '2+2 = 4' and 'The capital of Spain is Madrid' have the same reference (they are both true). What changes is the sense, that is, the thought they communicate. Wittgenstein expressed it as the criterion of truth, the knowledge of how the world should be for that statement to be either true or false. For Frege, anti- psychologist, the sense is not a mental entity; otherwise, it would be too aleatory, dependent on the different mental configurations of subjects (connections, hormones) and private. On the contrary, senses (as has been said for ontologies) must be guarantors of the situated use of language as a social phenomenon. They must be intersubjectively shareable.

The semantics expressed by Frege is complicated when epistemic, deontic verbs and alethic expressions appear in the utterances. In these cases, where the contexts are opaque or indirect, the principle of compositionality and substitutivity fail.

Principle of Compositionality: In a language, the meaning of a complex expression is a function of its parts' meaning and syntax. It means that if one replaces parts in an utterance with others having the same reference (synonyms with synonyms), the truth value does not change. For so-called propositional attitude utterances, this does not apply. Let us take α: In Genoa pesto is made with garlic, and $\alpha2$: In Paolo Villaggio's hometown pesto is made with garlic. α has the same truth value as $\alpha2$. Now we add a doxastic operator (Kα): substitutivity no longer holds. In these cases, the reference is not the object but the belief. e: "Anna knows that $\alpha2$" may not be true because she may not know where Paolo Villaggio was born. In these cases, the reference is

the sense, the cognitive path, the method for defining the truth conditions.

2.3. Epistemology

Only on the basis of meta-reasoning around what one knows is it possible to plan queries in memory and action plans with which to retrieve missing knowledge from the world. This is why it becomes crucial that epistemic logic is also dynamic: a family of modal logics obtained from a given logical language with the addition of one or more modal operators describing model-transforming actions[13]. To formalise culture and thus common knowledge and multi-agent logic, extensional and first-order logic are not sufficient, as they cannot evaluate on mode verbs and do not capture vagueness and uncertainty. The agent often has to deal with uncertain evaluations, which depend on ignorance. In such cases, reference is made to probability applied to belief. If the concept is vague, on the other hand, it means that no clear line can be established between entities that fall within the class extension and those excluded: all canids divided from the other individuals of the animal kingdom is not the same as carving out the set of all Italians who share Italianness. However, if one does not know the preference of a single individual, it becomes rational and justified to use visual and conversational cues and presuppositions, including those of a dominant culture.

3. Logic of Cultural Belief and Ignorance

The meaning of an utterance specifies the connection between a proposition and the world, actual or possible. The term Possible World belongs to Leibniz's philosophical system, through which he resolved the meaning of 'necessary' and 'contingent', respectively 'true in all possible worlds' or 'true only in some'. Based on this reasoning, Saul Kripke[14] proposed a semantics for modal contexts. True or false, for utterances with attitude verbs, are to be evaluated on possible worlds, on alternative situations to the actual, complete and non-contradictory world.

Carnap[15] defined reference as extension and sense as intension. To understand the intension of α is to be able to distinguish the situations that make α true[11]. Thus if α means 'the cat is on the table', to understand its meaning is to observe in the world whether a table exists and whether a cat is actually on it. Enunciations such as 'Lorenza knows that α' or 'Lorenza believes that α' behave in a non-truth-functional way, i.e. their truth and falsity are not determined by the truth value of the constituent utterances alone; it cannot be characterised by the truth table of logic. Lorenza can believe a falsehood: Bα is true even if α is F. Lorenza is not at home and can believe that the cat is on the table because it usually is, except that time because the cat ran away. The same applies to the situation in which Joe Bloggs is at Lucca Comics and Games, I can believe he is at the fair because he is a nerd, but I can imagine situations in which he is only among the stands as a chaperone and therefore does not belong to the dominant culture at all. In these cases, the robot should know that it does not know whether Joe Bloggs is Nerd or not, but it knows that in all possible worlds, Joe Bloggs knows that he is either Nerd or not Nerd. The robot can choose if it is more probable he is a nerd, but it knows it remains a belief that should be confirmed.

The concept of "Being nerdy" can also be expressed as a widespread belief through epistemic

logic. It is formalised as $[B*]F$, i.e. it is common knowledge in group B that F is true. Conventions and social norms are when everyone knows that everyone knows.

It is necessary to introduce more formalism. Saul Kripke[14], building on the pioneering work of Hintikka[16], developed a semantics for epistemic logic. Here, truth is assessed on possible situations compatible with the subject's beliefs and the facts of the current world. One cannot know that Lucca Comics is a sausage festival because it is false; one can, however, believe that it is the sausage festival, the belief being less strong. For the logic of knowing, too, we have to introduce a language L, consisting of propositional letters $(p,q,r...)$, true-functional connectives $(\wedge, \rightarrow, \neg)$, quantifiers $(\forall, \exists)$, with the addition of the operators K (knowing) and B (believing). So if α is a formula, Kα and Bα are also formulas - in a natural language, they stand for "It is known that α" and "It is believed that α". In these contexts, K and B are evaluated as true or false on an epistemic model that formally is triplet $M = (W, \phi, R)$. W are the possible worlds, ϕ is the interpretation function that, for each possible world, assigns a truth value to each primitive formula of the language. In short, for each possible world $w \in W$ and for each primitive formula p, $\phi[w,p] \in \{v,f\} : \phi[w,p] = v$ if p is true in the world w, and $\phi[w,p] = f$ if p is false in the world w. ϕ assigns one and only one value to each primitive formula; every possible world w is therefore consistent (it cannot happen that a formula is simultaneously true and false in w) and complete (every primitive formula has a truth value in w). On the other hand, R is a binary accessibility relation between the worlds of w that allows us to draw inferences and associate truth values for each belief[12].

If Cultural Competence is knowing how to put oneself in others' shoes and in one's own, accessing the body of knowledge to act accordingly is that relation of accessibility between worlds $R(w, w^1)$. Based on the type of relationship, we have different systems. The simplest is defined as T, whereby, in addition to the propositional axioms, the distributive axiom $K(\alpha \rightarrow \beta) \rightarrow (K\alpha \rightarrow K\beta)$ and the axiom of truth: $K\alpha \rightarrow \alpha$. Modus ponens and necessity also apply. In T, to know that Joe Bloggs is Nerd, Joe Bloggs must be Nerd in all possible worlds, and therefore it is important that the relation is reflexive: that is, that in w (current world), w itself is accessed. In the S4 system, R is reflexive and transitive. So if w accesses w^1 and w^1 accesses w^2, then w accesses w^2. It means that if I know that Joe Bloggs is Nerd, I know that I know. This is the principle of positive introspection. S5, in addition to the previous axioms, includes negative introspection $\neg K\alpha \rightarrow K\neg K\alpha$: if I do not know about Joe Bloggs, I know that I do not know. The accessibility relation is Euclidean: hence reflexive, symmetrical and transitive. In this case, all worlds are interconnected and see each other. In order to act in a planned manner, based on the need to gain more knowledge or to change one's own and others' beliefs, it is important that the accessibility relation is like this one in S5. Such a system can be called Socratic: as the philosopher reminds us, only when one knows not to know, they put themselves in a position to fill the lack by seeking. Here, then, are the actions by which epistemic logic becomes dynamic. We will have actions (including linguistic acts, orders, for example) with which to modify the world: world-altering actions; actions that modify the knowledge of others, announcement actions; actions to refine one's own knowledge (questions, at the level of linguistic acts), and we call them sensing actions[17].

Clearly, if I am at Lucca Comics and Games and Joe Bloggs approaches with a Monkey Island shirt, the probability that he is there by chance is very low. We can think of Possible Worlds as worlds in which a formula is more or less likely, based on knowledge and initial state. So the

frequency of α is not random.

Finally, regarding epistemic logic, it is important to overcome the problem of logical omniscience. Intensional logic tends to idealise agents. As specified above, human beings deal with vague concepts and uncertain knowledge: they are anything but omniscient. Several syntactic and semantic attempts have been proposed with incomplete and inconsistent worlds or with implicit formulas (omniscience being the p's that one could only know) and explicit formulas (the p's that one knows)[12]. Instead, Fagin and Halpern[18]propose introducing an awareness function, which specifies that an epistemic subject may not be aware of the meaning of certain primitive formulae. Intuitively, the purpose of such functions (Ai) is to 'carve out' partial situations within possible worlds that correspond to different actors' points of view. It is clear that this assumption is very similar to the one proposed in this paper.

4. Guidelines for Incorporating Cultural Competence in Artificial Agents

Based on what has been defined in the previous paragraphs, to programme a robot through an epistemic and dynamic logic, we propose a planning such as PDDL, in versions such as PPDDL1.0, which menages probabilistic effects and rewards. In this way, the artificial agent can modify the plan initially chosen on the basis of the feedback received and thus customise the choice in the light of new information obtained through world-altering, sensing and announcement actions[17]. Customisation and dynamic change prevent cultural biases from being perpetuated: culture remains a more likely adaptation shortcut, a principle of economy, to which, however, not all cases will necessarily fall since, also thanks to the S5 accessibility relation, the agent is aware of those worlds in which the plan is not true (with what likelihood) and is aware of not knowing certain data so that it can ask for them. Moreover, to avoid the combinatorial explosion of trivial plans and inferences defined by very low probabilities, it is important to add a threshold below which the planner does not evaluate sequences of actions. The threshold allows us to handle the logical omniscience, obviating engineering limitations of computational power. PDDL has already been used to model the Theory of Mind and epistemic logic[17]. For example, Chang and Soo[19] show how the narrative of Shakespeare's Othello emerges in the interaction between social agents endowed with personal, social and objective motives and the ability to perceive the environment, read the minds, and modify their beliefs, so the preferred plan. As suggested in this paper, the proposed social planning involves the automatic reading and translation of an OWL world into PDDL. Other proposals come from Bolander et al.[20]. They have defined a formalisation for evaluating knowledge, facts, and false beliefs on possible worlds, which change dynamically.

Another way to implement these assumptions is to use hybrid architectures such as ACT-R. Here, each "if... then... rule" in the procedural buffer is associated with a certain utility value according to the goal, so plans and concepts selection from the declarative module change strategically as the motivation change (see conceptual flexibility). In our case, the heuristics and meanings provided by a certain culture will be activated in circumstances of social utility. In addition, being a hybrid cognitive architecture (both symbolic and connectionist), ACT-R can modify weights based on external rewards or punishments, integrating new information into the

chunk in memory and creating new ones; this again avoids biases. Leslie and Polizzi[21] developed a model for selecting plausible beliefs within a set of other beliefs. This selector has been implemented in ACT-R[22]. We think that it can be declined on the basis of cultural ontologies and the probability and salience of the agents' possible worlds, with negative introspection S5. So if the robot does not know α, it knows that it does not know, but it also knows that it believes α with a higher probability than other possible worlds. It is an epistemological justification to try the more likely plan, with the possibility of dynamically modifying it if new facts emerge.

5. Conclusion

Culture conditions what is known and the value order: what comes before and after by taxonomy and moral importance. In short, it is relevant to consider modal contexts for an ontology of a social robot. The situation becomes more complicated if one considers that culture, precisely in the light of its mutability in time and space, is one of humans' many possible dynamic choices. To formalise such a system, first-order and monotonic logic is not sufficient. We should include notions of probability and queries that select subsets (also cultural) of knowledge from the semantic network based on contextual clues. On the basis of a Euclidean S5 accessibility relation, the artificial agent simulates empathy and meta-cognition, with which it enacts justified action plans that conform with the ontology and its awareness. The world in which the culturally competent robot operates is open and dynamic. Cultural ontology is one of the many possible strategies to manage the complexity of meanings placed in the world. The selection is not arbitrary: it is based on the consensus over time given by entire communities. It is a strategy to shorten the time it takes for the mind to adapt to a world and vice versa, thus enabling inferences despite indecision.

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