Knowledge representation and reasoning (KRR) is a subfield of artificial intelligence (AI) that is concerned with understanding, designing, and implementing ways of representing information in computers so that agents can use that information to reason and solve problems [3]. KRR is central to the entire field of AI [3]. The agents build primarily around this paradigm are often referred to as knowledge-based agents. The central component of a knowledge-based agent is its knowledge base, or KB [1]. A knowledge base is a set of sentences; each sentence is expressed in a knowledge representation language and represents some assertion about the world [1]. Deriving information that is implied by the information that is already present is a form of reasoning [3]. Decision procedures constitute another component of reasoning [9]. A challenge to work in KRR is its complexity; a “minimal” common-sense system must “know” something about cause-and-effect, time, purpose, locality, process, and types of knowledge. It also needs ways to acquire, represent, and use such knowledge [7].

Knowledge can be categorized in many ways. Two characterizations that will be significant to us are declarative/descriptive and procedural knowledge [3]. These types of knowledge can be encoded in many different forms, such as: frame networks, declarative languages (logics), imperative languages (Java, Python, etc.), semantic networks, product rules, neural networks, genetic algorithms, etc. [3]. Each of knowledge representation format has its advantages and disadvantages.

One of the more common methods of knowledge representation is logic. Logic was the dominant paradigm in AI before the 1990s, but it had some drawbacks due to it being deterministic and rule based [4]. Despite these drawbacks it is very expressive and compact [4]. There are several different types of logics, such as: propositional, first-order, second-order, modal, fuzzy etc. [5]. We shall only concern ourselves with propositional and first-order logic. The goals of logical languages are to represent and reason about knowledge in the real world [4], there is a direct relation between the goals of KRR and logical languages. In propositional logic there are propositional symbols and logical connectives (not, and, or, implication, bidirectional implication) [4]. A logical formula compactly represents a set of models where that formula is true [4]; for example, if we have propositional symbols P and Q, then P V Q represents all the worlds where P is true, or Q is true. In the logical paradigm, each sentence in a KB can be thought of as a logical formula that describes a set of models. ]. For logical inferencing using propositional logic our agent can use either modus ponens or resolution [6]. Modus Ponens is sound and complete for propositional logic with horn clause, and resolution is complete for propositional logic in general. Unfortunately, resolution has exponential time complexity while Modus Ponens is linear [6]. But unfortunately, propositional logic is limited in its expressiveness; as a result, first-order logic adds variables, functions, and quantification. First-order logic has two types of quantifiers, universal and existential. The universal quantifier argue that every member of a group meets a condition, and the existential quantifier argues at least one member of a group meets a condition. If we also impose the restriction that there is a one-to-one mapping from object to constant symbol in first-order logic, then the consequence is this idea of propositionalization where first-order logic is just syntactic sugar for propositional logic and as a result we can use any inference algorithm for propositional logic on first-order logic [6].

Logic as a form of knowledge representation may seem very attractive. But, in relation to these systems, some people believe in simple cases one can get such systems to "perform," but as we approach reality the obstacles become overwhelming. The problem of finding suitable axioms–the problem of "stating the facts" in terms of always-correct, logical, assumptions is very much harder than is generally believed [7]. Another formalism for representing knowledge is referred to as a frame. A frame is a data-structure for representing a stereotyped situation, like being in a certain kind of living room, or going to a child’s birthday party [7]. We can think of a frame as a network of nodes and relations [2]. Collections of related frames are linked together into frame-systems. The effects of important actions are mirrored by transformations between the frames of a system [7]. The "top levels" of a frame are fixed and represent things that are always true about the supposed situation. The lower levels have many terminals–"slots" that must be filled by specific instances or data. Each terminal can specify conditions its assignments must meet. (The assignments themselves are usually smaller "sub-frames.") Simple conditions are specified by markers that might require a terminal assignment to be a person, an object of sufficient value, or a pointer to a sub-frame of a certain type. More complex conditions can specify relations among the things assigned to several terminals [2, 7]. A frame's terminals are normally already filled with "default" assignments [7]. The frame system supports the so-called closed world inferring paradigm, where all facts that are presented in the system are true. If some fact is not presented, that means that it is untrue. It allows avoiding errors in inferring mechanism related to the knowledge representation format [2]. Other formats as, for example, ontology, may support the open-world paradigm, where all facts that are not presented may also be true [2].

A frame-based knowledge base is one of the typical models or a part of such models for knowledge representation in expert and decision- making systems [2]. For example, in [8] the authors developed a question answering (QA) system using a textual KB constructed from a biology textbook, and in [9] the authors developed an emergency management system using a KB constructed from domain expertise. In general, the design of a knowledge model is based on a sequence of refinement steps, starting from a general valid reasoning method capable of meeting the goals of the target application [9]. Some applications of frame-based systems are emergency systems, machine translation, biomedicine, health care, probabilistic dialog systems, banking expert systems, natural language processing, question answering, information extraction/retrieval, classification, machine learning, robotics [2].

Bibliography

[1] Russell, S. J., & Norvig, P. (2010). *Artificial Intelligence: A modern approach*. Prentice-Hall.

[2] Nazaruks, V., & Osis, J. (2017). A survey on domain knowledge representation with frames. *Proceedings of the 12th International Conference on Evaluation of Novel Approaches to Software Engineering*. https://doi.org/10.5220/0006388303460354

[3] Chaturvedi, V. (n.d.). *Understanding Artificial Intelligence and machine learning*. Udemy. Retrieved September 26, 2022, from https://www.udemy.com/course/understanding-artificial-intelligence-and-machine-learning/

[4] stanfordonline. (2020, December 17). *Logic 1 - propositional logic | Stanford CS221: Ai (Autumn 2019)*. YouTube. Retrieved September 26, 2022, from https://www.youtube.com/watch?v=xL0kNw5TudI

[5] YouTube. (2016, January 11). *An introduction to formal logics*. YouTube. Retrieved September 26, 2022, from https://www.youtube.com/watch?v=\_MhgsoPHvYo&list=PLJ5C\_6qdAvBG8HP77xIOVxH4Jzq3RQ9dI

[6] stanfordonline. (2020, December 17). *Logic 2 - first-order logic | Stanford CS221: Ai (Autumn 2019)*. YouTube. Retrieved September 26, 2022, from https://www.youtube.com/watch?v=\_Iz83hfkFds

[7] *A framework for representing knowledge Marvin Minsky mit-AI laboratory ...* (n.d.). Retrieved September 28, 2022, from https://courses.media.mit.edu/2004spring/mas966/Minsky%201974%20Framework%20for%20knowledge.pdf

[8] Inc., P. C. V., Clark, P., Inc., V., Inc., P. H. V., Harrison, P., Washington, N. B. U. of, Balasubramanian, N., Washington, U. of, Washington, O. E. U. of, Etzioni, O., & Metrics, O. M. V. A. (2012, June 1). *Constructing a textual KB from a biology textbook: Proceedings of the joint workshop on automatic knowledge base construction and web-scale knowledge extraction*. DL Hosted proceedings. Retrieved September 28, 2022, from https://dl.acm.org/doi/10.5555/2391200.2391214

[9] Hernández, Josefa & Serrano, Juan. (2001). Knowledge-based models for emergency management systems. Expert Systems with Applications. 20.