

A Demonstration of Possibilistic Hierarchical Task Networks for Believable Agent Behavior

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Abstract

Believable human non-player characters (NPCs) are inherent to immersive gameplay yet developing them remains a common challenge. When the success of many modern games relies on using bots in online services to replace real players, it's vital for the bots to seem like they make decisions like real people. This paper explains the inspirations for, ideas behind, and base functionality of a demo made to build a foundation for future work that aims to establish a framework for developing believably human NPCs. This demo simply aims to show that possibility theory can work with hierarchical task networks (HTNs) by using custom utility functions. This reliance on utility functions also means that this work provides developers who use behavior selection systems that can use utility functions to decide between branches, a clear example of how to adopt possibilistic logic in their own work. Most importantly, since this logic is simplistic, it can be easily adopted by both hobbyists and experts.

Introduction

Goal systems consist of networks of goals associated with their means of attainment as well as alternate goals and consist of cognitive and motivational properties. Cognitively, the structure and links between goals and means is vital, while motivationally it's the "principle of subjective utility", which decides what's best to pursue (Kruglanski 2002).

With the understanding that goal systems rely on link design between sub-goals and means, and a decision-making principle, the goal of this work is to show that possibility theory can work with hierarchical task networks (HTNs) for non-player character (NPC) goal planning in video games (and sims). This demo only provides a base for later evaluating the assumption that this combination results in NPCs that goal plan in a natural or human-like way, which is based on the understanding that goal systems are an acceptable portrayal of human goals, HTNs offer a natural structure for planning (or goal) systems, and the possibility for achieving

a sub-goal by current means can be used as a human-like "principle of subjective utility".

HTNs are a planning architecture for NPC behavior selection that allows NPCs to decompose high level tasks into lists of actionable atomic tasks that represent possible plans. It's also been mentioned that this process of "breaking down a high-level task into smaller ones is a very natural way of solving many sorts of problems (Humphreys 2013)." HTNs have been used in games such as Horizon Zero Dawn, Kill Zone, and Total War (Emir 2019).

Possibility theory was introduced as a conceptual solution to the challenge of understanding information that applications like uncertain decision-making face, and that "much of the information on which human decisions are based is possibilistic rather than probabilistic in nature (L.A. Zadeh 1977)." Based on "the notion of possibility for a real-world event [being] context dependent", the degree of possibility for a real-world event is defined by a function that combines the probabilities that the prerequisites for the event to occur will be satisfied and/or the constraints that would stop the event will not be, through the use of possibilistic logic where the logical "and" and "or" operators represent the min and max mathematical operations, respectively (Schwartz 2016). So, if event, E, requires Event X (E_X) "and" Event Y (E_Y), then the possibilistic function for E ($Poss(E)$) is:

$$Poss(E) = \min(Prob(E_X), Prob(E_Y))$$

Utility-based AI agents choose the highest utility behavior after calculating a score for each action an agent can take (Graham 2013). A utility function for reloading is a negatively sloping line where the utility (y-axis) of reloading is based on the current ammo (x-axis). Utility AI is used here to evaluate utility functions based on possibilities for the optional actions since the priority order evaluation done by HTNs by default removes the ability to score options.

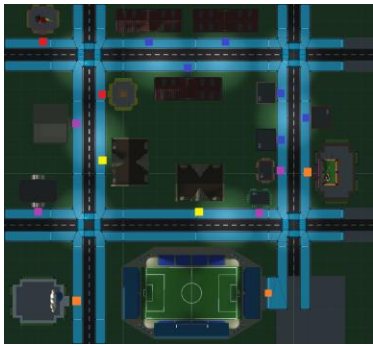


Figure 1: Map of city with highlighted Navigation mesh and PoI).

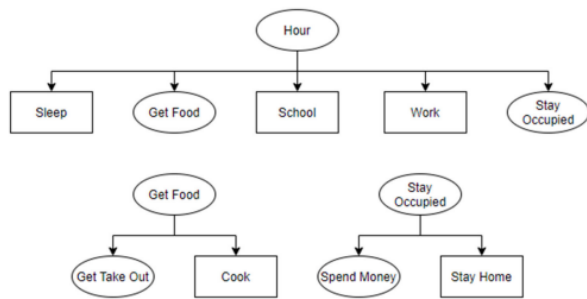


Figure 2: HTN for each student in the sim (Warnick 2022).

Demo Explanation

Human NPCs are common to city sims, so I made a city sim demo of a small college town with various points of interest (PoI) such as homes (blue), restaurants (red), school locations (yellow), work locations (pink) and free time activities (orange) (Figure 1), where each student is defined by variables such as money, job, home, school class, hunger, schedules, and operates on the HTN in Figure 2. This demo was made to establish that possibility theory can work with HTNs, not to assess NPC believability or develop gameplay.

Figure 2 includes compound tasks (round) that are achieved through sub-tasks and primitive tasks (square) that are steps agents can take directly. The “Hour” and “Get Food” tasks are decided by precondition checks, but the “Stay Occupied” decision is made under uncertainty. This uncertain decision uses a utility selector to evaluate the utility functions for each optional free time activity, with the options for this demo being between staying home, going bowling, to a sports bar, or to a local sports game.

Defining the heuristic for such utility functions maybe unclear but one can model the context for the possibility of a student enjoying each optional activity so that possibilistic

functions can be used instead. Let’s assume that if the student has the time and money to afford an activity, then the student’s enjoyment of an activity, or *the possibility of a student choosing an activity*, is based on if they prefer the activity enough to deal with its customer traffic. Using,

$P_1 = \text{sufficient time}, P_2 = \text{sufficient money}$

$C_1 = \text{high customer volume at activity}$

$P_3 = \text{personal preference for activity}$

the contextual construct for the general event of a student choosing an activity, E_A , can be represented by:

$C_A = (P_1 \wedge P_2 \wedge (\neg C_1 \vee P_3))$

Then, the formalizations in (Schwartz 2016) leaves the possibilistic function for a student choosing an activity as:

$\text{Poss}(E_A) = v(C_A)$

$v(C_A) = \min(v(P_1), v(P_2), \max(v(\neg C_1), v(P_3)))$

$v(C_A) = \min(\text{Prob}(P_1), \text{Prob}(P_2), \max((1 - \text{Prob}(C_1)), \text{Prob}(P_3)))$

where the $\text{Prob}(P_1)$ and $\text{Prob}(P_2)$ are absolute (0.0 or 1.0) and treated as precondition checks, $\text{Prob}(C_1)$ is a variable respective to each option used to represent their customer traffic, and $\text{Prob}(P_3)$ is the students preference for the optional activity. With no traffic or costs at home, the utility function for evaluating choosing home is just $\text{Prob}(P_3)$.

Two domains were made for the demo using Fluid HTN (Trefall 2021). One had students decide how to stay occupied based on their time and money, and another relied on a utility selector based on the possibilistic utility functions above. They both were made to help show how possibilistic HTNs can create varied behaviors, with the possibilistic utility function design. Most students would head straight to an activity when they could, but a few would go home first and then to an activity later, which was due to the students reevaluating the possibilistic functions with the updated customer traffic as it decreased through the night.

Conclusion

The first takeaway is that possibility theory can successfully work with HTNs by using possibilistic utility functions. The second takeaway builds from this work’s dependence on utility functions and it’s that possibilistic logic can be used in any system that uses a utility selector in decision making.

In conclusion, this demo serves as a proof-of-concept foundation for later evaluating the assumption that NPC decision making driven by possibilistic logic being used with HTNs is more natural or human-like. But in a broader sense, even without deeper evaluation, this work is a clear example for future developers to account for future event context and possibilistic logic in their own behavior selection systems.

References

- Graham, D. R. 2019. An Introduction to Utility Theory. In *Game AI Pro*, edited by Steve Rabin, 14. Boca Raton: CRC Press. doi.org/10.1201/9780429055058-6
- Humphreys, T. 2019. Exploring HTN Planners through Example. In *Game AI Pro 360*, edited by Steve Rabin, 103–22. Boca Raton: CRC Press. doi.org/10.1201/9780429055058-9
- Kruglanski, A. W.; Shah, J. Y.; Fishbach, A.; Friedman, R.; Chun, W. Y.; Sleeth-Keppler, D. 2002. A theory of goal systems. In *Advances in Experimental Social Psychology*, edited by Mark P. Zanna, 331-78. San Diego: Academic Press. doi.org/10.1016/S0065-2601(02)80008-9
- Schwartz, D. G. 2016. On the Possibility of an Event. In *Proceedings of the 2016 International Conference on Artificial Intelligence*. Las Vegas, Nevada.
- Schwartz, D. G. 2017. A Theory of Event Possibility with Application to Vehicle Waypoint Navigation. In *Proceedings of the North American Fuzzy Information Processing Society Annual Conference 2017*. doi.org/10.1007/978-3-319-67137-6_38
- Pál Trefall. 2021. Fluid HTN. <https://github.com/ptrefall/fluid-hierarchical-task-network>. Accessed: 2022-05-01.
- Warnick, B. 2022. Possibilistic Hierarchical Task Networks. Master Thesis, Department of Computer Science, Florida State University, Tallahassee, Florida.
- Zadeh, L. A. 1978. Fuzzy sets as a basis for a theory of possibility. *Fuzzy Sets and System* (1): 3-28. doi.org/10.1016/S0165-0114(99)80004-9.