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Designing Human-Computer Conversational Systems using Needs Hierarchy

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About Author

Souvick 'Vic' Ghosh is an Assistant Professor at the School of Information, SJSU. His scholarship involves the development of research models and methods that extend the traditional view of information seeking into voice-based and interactive environments. His work in these areas is informed by and contributes to the necessary research on Conversational Information Retrieval at the level of individuals interacting with a voice-based search system, and to the developments and innovations pertaining to such systems. It involves extensive use of techniques and approaches in Machine Learning, Natural Language Processing, Deep Neural Networks, and Human-Computer Interaction.

Before joining the doctoral school, Souvick completed his Bachelor's and Master's degree in Computer Science with a focus on Natural Language Processing and Machine Learning. In his work, Souvick loves using technology for social good.

Souvick has a strong teaching record at Rutgers School of Communication and Information, having taught multiple graduate-level and undergraduate-level courses, both online and on-campus, on Data Science, Programming, and Computer Science concepts.

Introduction

Research in conversational systems has gained massive popularity in recent years. While the commercial attraction of such systems could be attributed to novelty - you can talk to the system in natural language - conversational systems solve several problems in the medical domain and search space. Conversational systems allow a greater degree of multitasking as the user no longer needs to type in the queries. The voice-based support allows the user to "converse" with the system without having to look at the screen. Therefore, the use cases include situations where the user wants hands-free or eyes-free operation (Ghosh, 2020). Additionally, conversational systems are a solution to accessibility problems for people with disabilities (visual or manual impairment) (Ghosh, 2019; Guy, 2016; Frummet et al., 2019). These systems have also been used as open-domain conversational partners, and therefore, have found application in the mental health domain.

Commercial conversational agents are so ubiquitous that they are used in healthcare (Winata et al., 2017), education (Lee & Fu, 2019), elderly care (Kopp, Brandt, et al., 2018), customer service (Gnewuch et al., 2017), and information retrieval (Barko-Sherif et al., 2020). These systems are also known as intelligent personal assistants (IPA) or virtual assistants. Amazon's Alexa (https://developer.amazon.com/en-US/alexa), Google's Assistant (https://assistant.google.com/), Microsoft's Cortana (https://www.microsoft.com/en-us/cortana), and Apple's Siri (https://www.apple.com/siri/) are some of the more popular personal assistants available on the market.

The preference of users for humanoid systems has led to increasing research and development in making conversational systems more human-like in every way. The robotic voice has been replaced by human voices - male, female, and even celebrity (https://www.blog.google/products/assistant/new-voices-your-google-assistant-nine-countries/). Ongoing research is working towards making the agents more empathetic and affective, which requires research into user interfaces (which has to be more user friendly and accessible), natural language understanding (to improve the cognitive skills of the system), natural language generation (the system dialogues), and information retrieval (how much information to retrieve and how to present it). This interdisciplinary nature of conversational systems research makes it necessary to use techniques from Computer Science, Information Retrieval, Human-Computer Interaction, Psychology, and Cognitive Science. After all, since wheels have already been invented, it does not make sense to reinvent them for conversational systems.

Users interact with conversational systems with task fulfillment objectives. The user could have a specific task in mind, like operating the smart home appliance, or may want to engage in a casual conversation with the objective of minimizing boredom or isolation. Since the interactions between the conversational system and the user are governed by the success or failure of these tasks, it is important for the system to differentiate between tasks of varying importance. In this paper, we look into the framework of human needs to develop insights into how a conversational system should be operationalized to provide maximum satisfaction

to the user. For our analysis, we use the user-system interaction data collected as part of an experimental study.

The rest of this paper is organized as follows: First, we briefly discuss what conversational systems are and why it is important to explore the design aspects of such systems. Next, we look into the hierarchical framework of human needs and how they apply to conversational systems. In the following section, we explain user experiences with existing state-of-the-art conversational systems. Finally, we conclude the paper by highlighting the challenges and proposing how a needs framework could be used to improve future systems.

Conversational Search Systems

Conversational systems are characterized by the use of natural language dialogues between the user and the system, which could be in the form of text (e.g., chatbots) or audio (e.g., intelligent personal assistants). The back and forth dialogues could occur over multiple turns, and therefore, these systems are called "conversational."

The use of conversations in search has tremendous implications for the Information Science and Retrieval Community. If we are able to replicate the interactions between the librarian and the patron, then we could have an ideal search system. The users (information seekers) will no longer need to use keywords (or query terms) to express their information problem (Begany et al., 2015). The shorter queries – which are difficult to formulate and often not the right representation of information need – could also be replaced by long, natural language descriptions of the user's information need. A better understanding of the user's search context would also increase the relevance and usefulness of the retrieved information.

A conversational system may also be categorized based on the medium of interaction. While text-based systems are commonly referred to as chatbots, audio-based systems are called personal assistants. Some systems allow the use of multiple modalities – as in embodied conversational agents (ECA) (Bickmore & Cassell, 2005; Cassell et al., 2000) – where the agent may have a face or body in addition to the voice. Each of the above-mentioned categories has its own advantages and use cases. A voice-based conversational system is more useful for hands-free and multitasking situations. On the other hand, a chatbot is more suitable for extended dialogues, collaborative information seeking, and multimodal retrieval. An ECA is widely used in mental health domains as it can express emotions using facial expressions, gestures, and other non-verbal cues (McNeill, 2011) as is common in human-to-human conversations. The ubiquity of mobile devices has popularized the conversational systems for searching (Brandtzaeg & Fløstad, 2017; Mallios & Bourbakis, 2016), smart home operations, vacation planning (Shiga et al., 2017), tour guidance (Kopp, Gesellensetter, et al., 2005), flight booking services (Dubiel et al., 2018), or as conversational partners (Radziwill & Benton, 2017) in medical (Winata et al., 2017) and non-medical domains (Clavel & Callejas, 2015; Ring et al., 2013).

However, the existing conversational – and conversational search – systems are in a nascent stage. The developments, while novel, fail to achieve the standards of human-human conversations. Conversational systems have a wide application area and can massively improve user satisfaction if implemented properly. While computational development is a crucial part of system development, we must also

look into human psychology to gain insights on how such systems should be operationalized. Therefore, we look into the framework of human needs in the next section.

Framework of the Human Needs Hierarchy

The design and development of any human-computer interaction system should focus strongly on the end-users – what their needs are and how the system should be implemented to solve those needs. In 1943, Maslow (1943) proposed the hierarchy of needs which suggests that the survival of humans as a race and the levels of satisfaction are not random but dependent on how the human mind assigns importance to things around us.

Maslow's theory explains the reason behind human motivation. Let us imagine the life of a human being. When a baby is born, all it cares about are the fundamental items for survival – food, optimal temperature, and comfortable surroundings. Any harsh change in the environment is perceived as a threat to survival by the baby. As the baby grows to an infant and finally to an adult, it strives for growth and development. The fundamental needs are still important and prioritized, as they are keys to survival, but the individual pursues higher-order needs, which could be materialistic, egotistic, or philanthropic.

In Figure 1, we present the five-tiered structure of human needs as presented by Maslow. The pyramidal structure of the need hierarchy suggests that basic needs necessary for survival must be satisfied before the individual targets higher-order needs. If we move upwards from the bottom, the bottom two levels represent the basic needs for survival, followed by the two levels of psychological needs, and the top-level representing self-fulfillment. Let us now look into the five stages (and three new levels added later) in the need hierarchy in more detail.

- Physiological Needs:

  Survival and self-preservation are the greatest of all needs. Every human being needs air, food, water, sleep, and shelter to maintain and lead an optimal life.

- Safety Needs:

  The next level of need is the safety and security of self, followed by those who are closest to the individual. Human beings prefer a certain order and predictability in their environment which they can control. Unforeseen and dangerous situations – threats to life, health, economy, independence – jeopardize the basic living conditions and are, therefore, avoided by individuals.

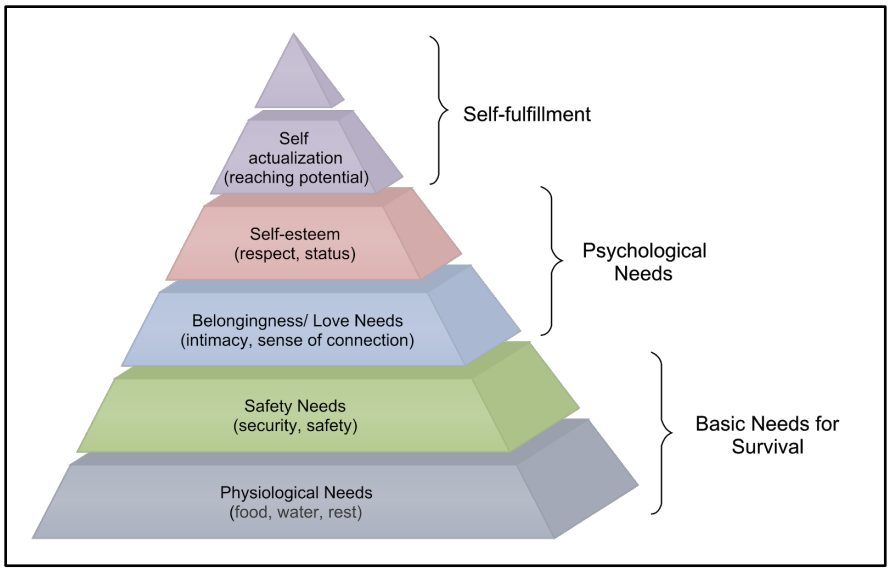

Figure 1. Human Needs Hierarchy (Maslow, 1943)

- Community and Belonging:

  Human beings are social animals. While individual survival is prioritized, humans value the sense of community and togetherness which they enjoy with their loved ones. The companionship offered by friends, family, and romantic partners is highly cherished as they help the individual avoid loneliness and depression. This level of need is required for psychological well-being as it allows humans to connect to something more than just themselves, which could be the social group they belong to, the organization they work for, or any other collective.

- Esteem Needs:

  The next level of psychological need relates to the esteem and feeling of self-worth for individuals. It is not enough to survive, but there exists an intense desire to be accepted by peers and social circles. Humans strive to earn respect from others (increase in popularity, fame, social recognition) and also self-respect (feeling of dignity, freedom, and competence). Social status is an important metric of self-worth in a community space which could be related to the economy, power, or achievements of an individual.

- Cognitive Needs:

  This level of need was later appended to the original five-tiered model. Cognitive needs allow humans to nurture their growth potential through the performance of cognitively challenging tasks.

- Aesthetic Needs:

Aesthetic needs were also added later to the hierarchical framework, as they represent an innate desire in humans to create and appreciate beauty.

- Self-Actualization:

  Self-actualization was the highest level in the five-tiered hierarchy and is related to self-fulfillment. The desire for growth and achieving true potential acts as a strong motivator in individuals. The needs could be short- or long- term and could include gaining skills and knowledge, fulfilling dreams, and pursuing happiness. Overall, it allows an individual to become a better human being based on the metrics they consider most important.

- Self-Transcendence:

  Self-transcendence has been added later to the needs hierarchy and involves spiritual needs. Just like an individual values the social circle they belong to (Community and Belonging Needs), there is also a deeper desire to be part of a larger universe or purpose. This greater purpose could be spiritual, religious, or scientific, but it goes beyond the needs of the self.

  In the words of Maslow:

  > It is quite true that man lives by bread alone — when there is no bread. But what happens to man's desires when there is plenty of bread and when his belly is chronically filled? At once other (and "higher") needs emerge and these, rather than physiological hungers, dominate the organism. And when these in turn are satisfied, again new (and still "higher") needs emerge and so on. This is what we mean by saying that the basic human needs are organized into a hierarchy of relative prepotency. (Maslow, 1943, p. 375)

The hierarchical framework is built on the premise that the primary needs must be satisfied before the individual strives for higher-order needs. Maslow's framework also connects human needs to motivation. Interestingly, for the basic needs, the higher the deficiency, the stronger the motivation. Lack of food, water, shelter, or safety acts as the strongest form of motivation. As these needs are met, the motivation keeps decreasing. However, the same is not true for higher-order growth needs (love, self-esteem, and self-actualization). As the growth needs are being met, the motivation increases as well.

Researchers have wondered if the framework of the needs is indeed hierarchical. Do human beings pursue the lower-order needs exclusively until they are satisfied? What triggers the desire for higher-order needs? Well, it depends on the individual and the socio-cultural environment they are in. The top of the hierarchy is difficult but aspired, but they are rarely pursued unless the basic needs are satisfied. While there is no fixed threshold that motivates the individual to move to a higher need, there should be no deficiency in the previous level. Exceptions are common, especially for high achievers, who often ignore the basic needs for growth, fame, and self-esteem. For others, we could observe a back and forth movement between the different needs over the life of the individual. For example,

an individual may be poor but healthy and could be motivated by financial gains (safety needs over physiological). Next, they meet their romantic partner and move to the higher need level (love needs). They start a family and realize that they need to be stronger financially to support their family. Therefore, they will focus on a lower need again. They may also focus on esteem needs and self-actualization parallelly. However, as the individual gets older, they may develop health complications and the physiological needs might become more important. After a balance has been reached, humans push for needs that are either more important to them or the ones which are more likely to decline in the near future. That is why an older person has greater physiological needs whereas a young adult prioritizes love and esteem needs. Therefore, unlike a hierarchical pyramidal structure, the framework may have multiple and different degrees of overlap.

Experiences with Voice-based Conversational Systems

An artificially intelligent conversational system should behave in a way like any human would, framing the responses and assigning urgency based on the framework of needs. For example, the user may be desperate when they are facing threats to their physiological needs (a user looking for food stamps or homeless shelters) and safety needs (requesting an ambulance, emergency care, suicide support, or law enforcement). Searching for a restaurant or hotel is also similar but not as severe as the previous examples. The system should immediately call for human assistance (law enforcement, social services) or return the information urgently. Any delay in providing information could adversely affect the user experience. For higher-order needs – where the limit of fault tolerance is also higher – the system should attempt to tune the response to provide maximum satisfaction to the user. For example, if the user is feeling lonely, the system could play the role of a listener and be empathetic (thereby addressing psychological needs). Also, the system should always take the blame for any unsuccessful interactions. The esteem needs of the user are violated if the system holds the user accountable for the failure. If the user feels incompetent or offended by the system, there is a strong likelihood that they will never use the system in the future.

We looked at some hypothetical situations involving different levels of needs and observed the system responses. Let us look at some examples.

- Example 1 (Violation of Safety Needs):

  John feels there is someone trying to break into his house. He asks the voice-based assistant to call the cops, but the assistant fails to recognize his voice. John uses his phone to call instead.

- Example 2 (Violation of Physiological Needs):

  Lily is hungry and wants to order food delivery which would take the shortest amount of time to deliver. She asks the conversational assistant to find the restaurant, but the assistant responds with a long list of restaurants to choose from. Lily finds the list hard to navigate and decides to order online from her laptop.

- Example 3 (Violation of Esteem Needs):

Stuart starts talking to his voice-based personal assistant about his health condition. Stuart decides to explain his situation in more detail, but the system cuts him off midway and starts providing irrelevant information. Stuart is upset and decides to stop talking to the system.

- Example 4 (Violation of Esteem Needs):

  Shruti is a non-native English speaker and has an accent. She wants to operate her smart home devices using a voice-based assistant, but every time she issues a command, the system responds by saying that it was unable to understand what she said. Shruti feels upset that the system response was a criticism of her English pronunciation.

The above examples may be hypothetical, but there are several situations in which our interaction experiences with the conversational system are unsatisfactory and problematic. If the system's actions are in direct violation of human needs, the users tend to discard the system and never use them in the future.

Conclusion

In this paper, we looked at the design and functionality of conversational search systems using the framework of human needs, originally proposed by Maslow. Since human-computer interactions are goal-oriented and related to task fulfillment, it is important to consider the relative importance of the tasks. The user may perform a wide range of functions using voice-based assistants or chatbots. This includes (but need not be limited to) searching for information online, managing smart home devices, writing notes and emails, calling and messaging contacts, or placing an online order. Casual chitchats are common, too, and these are motivated by the users' desire for companionship. The role of the interface is crucial, as it decides the success or failure of the system.

By using the framework of human needs, the system designers can leverage the unconscious and subconscious preferences – or aversion – of the human mind towards different actions performed by the system. Each of the user-system interactions can be tied to different levels of need in the need hierarchy. Therefore, the system's actions – the style of response, the vocabulary used, and the overall urgency – can either satisfy or threaten the needs. The existing state-of-the-art conversational systems do not satisfy the primary or basic human needs. Once the novelty wears off, the purchasing decision made by the customer will be contingent on the fulfillment of the needs. Therefore, in our work, we highlight how the commercial success of the system and customer satisfaction can be enhanced by applying the framework of the human needs for system design and development.

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