A Jungian based framework for Artificial Personality Synthesis

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ABSTRACT
The field of computational intelligence has enjoyed much success in developing a variety of algorithms that emulate human cognition. However, a framework to tie these algorithms together in a coherent manner to create a machines that possess the full spectrum of human-like personalities is still needed. To date, research on artificial personality synthesis has focused on using the Big Five model from the field of personality psychology. The overlooked Achilles heel of Big Five (BF) is that it is purely data-driven model, and thus offers only marginal guidance on how a machine with a personality might actually be created. In this work an alternative computational personality framework is presented based on the work of Carl Jung. There are two key insights that suggest a Jungian type-based framework is suitable for synthesizing an artificial personality. First, the cognitive functions which form the building blocks of the Jungian personality model can be mapped to classes of algorithms used to emulate cognition. Second, the Jungian framework suggests that at any given time humans are only using one of the cognitive functions. This suggests that a human personality could be emulated using a state machine with each state implemented using the appropriate class of algorithms.

CCS Concepts
• Human-centered computing→Interaction design theory, concepts and paradigms

Keywords
artificial personality synthesis; Carl Jung; affective computing.

1. INTRODUCTION
The advent of ubiquitous computing has increased interest in techniques for endowing a machine with a human-like personality. Vinciarelli [1] provides an overview of personality computing research which shows that since 2006 a marked increase in research papers with the word "personality," included in the title. Vinciarelli makes one particularly interesting statement with regards to the nature of the work that has been undertaken thus far, "Trait based models are widely accepted in the computing community as well. All of the works surveyed in this article adopt personality traits (the BF in 76 cases out of 81) and, to the best of our knowledge, no other theories were ever adopted in computing oriented research. On one hand, this barely reflects the dominant position of trait based models in personality psychology. On the other hand, trait-based models represent personality in terms of numerical values, a form particularly suitable for computer processing. [1]." This statement raises an interesting question. Why has computational personality research thus far restricted itself to exploring trait-based models of personality? Vinciarelli points out a number of competing personality models including: psychoanalytic, cognitive, and behaviorist and biological. Arguably, personality models such as the biological model may currently not be adequately understood to be implemented on a computer, and as Vinciarelli points out, the numerical nature of trait-based models may be amenable to computer implementation to a degree. However, the nature of the Jungian type-based model also lends itself to implementation on a computer, but to the best knowledge of the author has not been explored to date. This work will outline how Jungian psychological type theory can be used as guidance to synthesize an artificial personality.

This Jungian type-based framework possesses a number of attractive properties. First, a very large fraction of algorithms emulating cognitive processes can be utilized by the framework in a coherent manner. Second, the framework can arguably synthesize the full spectrum of human personalities. Third, Jungian-based personality theory is very popular among laypeople. Modern personality psychologists might argue that this is due to the cognitive bias known as the Barnum effect. From a Turing test perspective however this is irrelevant, and perhaps even an advantage because it would facilitate the illusion of a machine having a human-like personality For practical applications all that really matters is that the machine can convince a human that it has a personality.

2. THE JUNGIAN PERSONALITY TYPE MODEL
Carl Jung is probably most popularly known for introducing the concept of the "introvert," and "extrovert." Jung detailed his theory of psychological types in 1921 [2], [3]. Jung's model for personality is based on the idea of "cognitive functions." Jung identified two fundamentally different kinds of cognitive functions known as "perception," and "judgement. [4]" Perception describes how a person takes in information, and judgment pertains to decision-making. Jung then broke these classes down further. Jung asserted that perception came in two main forms: "sensation" and "intuition." Sensation is focused on physical reality:. It tends to focus on the present and past. Intuition is primarily focused on finding meaning, patterns, or possibilities in information.

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The tendency is to focus more on the future [5]. Likewise, Jung identified two forms of judgement which he referred to as "thinking," and "feeling." Thinking refers to decision-making processes that focus more on the application of basic truths/principles. It tends to impersonal in the sense that it resists allowing personal value judgements, or the value judgements of others influence decision making. Conversely, "Feeling," puts significant weight on values. These values can be either personal or shared by a community. It tends to prefer decisions that will result in harmony [6]. Jung then further refined his cognitive functions by asserting that each of the four functions has an introverted and extroverted orientation. An introverted orientation implies a tendency towards a person's interior world of thoughts, ideas, feelings and memories. An extroverted orientation focuses on people or experiences external to the self [4]. Jung's clinical observations and reflection ultimately resulted in a total of 8 cognitive functions. For completeness the eight cognitive functions are:

Extroverted Thinking	(Te)
Introverted Thinking	(Ti)
Extroverted Feeling	(Fe)
Introverted Feeling	(Fi)
Extroverted Sensing	(Se)
Introverted Sensing	(Si)
Extroverted Intuition	(Ne)
Introverted Intuition	(Ni)

For the sake of brevity, a full description of Carl Jung's 8 cognitive functions will not be provided in this document. Since Jung initially introduced the concept of cognitive functions, the language used to describe them has evolved as has an understanding of their nature. For the purpose of this work, the cognitive function descriptions provided in [4] will be used throughout this work.

In 1923, Katherine Briggs and her daughter Isabel Briggs Meyers were exposed to the newly available English translation of "Psychological Types" [7], [8] At the time Katherine was in the process of developing her own personality theory motivated partially by a desire to understand the personality of her son-in-law. Upon reading Jung's work they came to the conclusion that Jung's theory was superior to their own and so decided to adopt and refine the Jungian model. Over the next 20 years the mother-daughter team obsessively observed and documented human nature with regards to type. They eventually created a variation on Jung's system with an associated sorting instrument known as the Myers-Briggs Type Indicator (MBTI).

The evolution of Jung's psychological type proposed by Myers and Briggs had a few important characteristics that are worth mentioning. First, Myers and Briggs observed that all people used all of the cognitive functions. The dissimilarity between different types of people was the preference with which they used the cognitive functions. In this model each person uses the cognitive functions in a hierarchical manner with a dominant cognitive function, followed by an auxiliary, tertiary and inferior cognitive functions. Classically, Meyer & Briggs focused on the first four cognitive functions. Furthermore, Myers & Briggs introduced very specific constraints on the hierarchical order the cognitive functions were allowed to assume. One of the constraints Meyers & Briggs introduced was that the hierarchy of cognitive functions had to alternate between introverted and extroverted orientations. It is worth noting that the writing of Carl Jung can be interpreted to indicate a different scheme for ordering the cognitive functions, and competing ordering systems are in existence. For the sake of clarity, the author tends to prefer the ordering system outlined in [4]. However, with regards to artificial personality synthesis, the framework outlined in this work is flexible enough to be adapted to any desired cognitive function ordering scheme.

Ultimately, based on their imposed constraints on cognitive function order, Meyers & Briggs identified 16 unique personality types. These personality types were given four-letter labels. The first letter is either *E* or *I* to indicate an introverted or extraverted orientation of the dominant cognitive function. The second letter is either *S* or *N* to indicate the dominant perception preference of sensation or intuition respectively, the third label is *T* or *F* to indicate the preferred judging cognitive function of either thinking or feeling, and the last letter is either *J* or *P* to indicate whether or not the preferred perception function has an introverted orientation (*J*) or an extroverted orientation (*P*). An example of a personality label from the use of this model would be ENTJ. This would indicate a personality who's dominant function is extroverted thinking with introverted intuition as the auxiliary perceiving function. The constraints imposed by Meyers & Briggs on the cognitive function order would then further specify that the tertiary function is extroverted sensing and the inferior function is introverted feeling.

There is a very widely held misconception that each of the four letters indicates a dimension of personality, like that found in the Big-5 model. It cannot be stressed enough that the four letters used to provide a personality label are in no way representative of dimensions. It is more appropriate the think of each grouping of four letters as a label. The Jungian model is not based on the concept of dimensions in any way. It is based on the concept of cognitive functions and the hierarchical preference with which people with different types of personality use them. Another common misconception is that the Jungian/Meyers & Briggs model implies a binary distinction between -for instance- thinkers and feelers, or judgers and perceivers. The common criticism is that the model implies that a person solely uses only one class of cognitive function or the other. For example, that a person is either a thinker or a feeler. Once again this is not how the theory works. The theory indicates that all people have access to use all the cognitive functions. It is just that people have different orders of preference for different functions. Alternatively, Berens and Nardi [4] explain the preference in terms of energy expenditure. They describe the use of a given cognitive function as requiring the expenditure of more or less energy depending on a person's personality type. Thinking of cognitive function use in terms of energy usage is a very convenient way to guide the selection of cognitive function to use in a given situation because it interfaces well with computational thinking on cost functions in optimization as well as with results in psychology that suggest that self-regulation relies on glucose/energy levels [9].

3. A FRAMEWORK FOR MAPPING JUNGIAN COGNITIVE FUNCTIONS TO ALGORITHMS FOR EMULATING PERSONALITY

The proposed Jungian type-based framework for artificial personality synthesis is based on three key principles.

1. Algorithms that have been developed to emulate cognition (e.g. Principle Components Analysis [10], Artificial Neural Networks, Linear Classifiers, etc.) can be mapped to the cognitive functions that make up the building blocks of the Jungian personality model. These algorithms can be used to implement the cognitive functions.
2. Human personality is inherently serial in nature. Human personality arises from the limitation that humans can only use one cognitive function at any given time. Or at least the human ability to use more than one function at a time appears to be severely limited.
3. The Jungian type-based personality framework allows for the possibility of an individual agent to use any of the 8 cognitive functions at any given time, however, personality emerges from a hierarchical preference for certain cognitive functions over others. The order and magnitude of preference can be selected based on models such as the Myer & Briggs cognitive function orders [4]. They could also possibly be learned from data, or could even be chosen arbitrarily. Initially the authors suggest using the Myers & Briggs cognitive function orders as guidance.

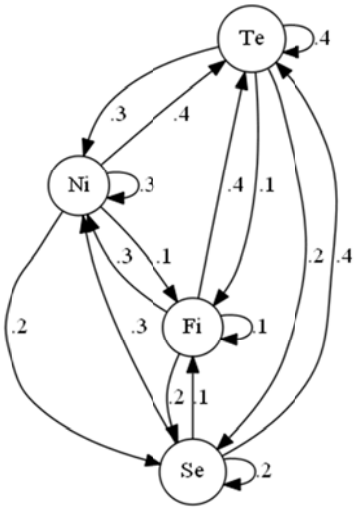

Figure 1 A Markov chain representative of an ENTJ. Cognitive function preference order: Te – Ni – Se – Fi.

Figure 1 shows an implementation of the Jungian type-based personality framework in the form of a Markov chain. The states of the Markov chain are occupied by cognitive functions. The values associated with the edges provide a probability that the artificial personality will transition to each of the alternative cognitive functions. In the case of a machine with an ENTJ personality, a proclivity will exist for the machine to remain in an extroverted thinking (Te) state with occasional transitioning to the intuitive intuition state. It is less common for the ENTJ machine to use extraverted sensing (Se) and it rarely if ever transitions to the introverted feeling (Fi) state. Personality is emulated by executing the algorithms that correspond to the current cognitive function.

It is worth noting that alternatives to the Markov chain representation could be envisioned. For instance, instead of probabilities, the proclivity to transition to another cognitive function could be couched in terms of energy costs associated with the use of a cognitive function for a given personality type as discussed in [4]. Also, please note that only 4 cognitive functions are shown in Figure 1. For completeness all 8 cognitive functions could be included. Only the first 4 functions were used as is specified by the classic Myers and Briggs framework for the sake of clarity. Lower order functions were not included. In initial implementations of this framework it might be preferable to only use the first 2 highest preference cognitive functions for the sake of simplicity. The reason being that the first two cognitive functions are all that is needed to distinguish one personality type from the other 16. Furthermore Jungians tend to believe the first two are the most important.

In order to implement the Jungian type-based personality framework, it is necessary to map algorithms that emulate cognitive processes to the cognitive functions. Table 1. provides a listing of the 8 cognitive functions, a short description of each of the cognitive functions, and a list of possible algorithms that could be used to emulate the cognitive function. This list is by no means exhaustive, and revisions are expected as artificial personality research progresses. The descriptions provided in Table 1. borrow heavily from [4] in order to maintain some uniformity in descriptions.

Table 1: Cognitive functions and associated algorithmic candidates for implementation.

Cognitive Function	Description [4],	Candidate Algorithms
Extroverted Thinking (Te)	Organizing people and things to work efficiently and productively. Organizes the environment and ideas.	• Partially Observable Markov Decision Process • A* • Optimization routines • Linear Programming
Introverted Thinking (Ti)	An internal sense of the essential qualities of something. Noticing the fine distinctions that make it what it is, internal reasoning process of deriving subcategories of sub-classes and sub-principles of general principles.	• Principle Components Analysis • Independent Components Analysis • Sparse Dictionary Learning • Auto Associative Neural Networks

Extroverted Feeling (Fe)	The desire to connect/disconnect with others. Causes response to expressed or unexpressed needs of others. Takes on the feelings of others – Empathy	• Use own embodiment as analog computation based on perception of external affect • Artificial Neural Networks • Resources allocated weighted towards communications/collaboration with other agents (human, machine and otherwise) • State of health evaluation of other agents • Cost functions for optimization designed in such a way that rewards associated with group success outweigh individual rewards associated with individual success • Analysis of how actions will affect group well-being
Introverted Feelings (Fi)	A filter for information that matches what is valued, wanted, or worth believing in. Continual assessment of a given situations with respect to individual values.	• Artificial Neural Networks • Techniques for state of health monitoring of self. • Cost functions for optimization designed in such a way that individual rewards for individual success outweigh group rewards associated with group success • Analysis of how actions will affect individual well-being
Extroverted Sensing (Se)	Use of the concrete senses to become aware of the physical world in detail. An impulse to act on information in order to get immediate results. Active seeking of information until sources of input are exhausted or attention is captured by	• Active learning • Active SLAM • Online Learning • Search based on maximum information gain • PID control
	alternative subject.	
Introverted Sensing (Si)	Storing experiences and information and comparing/contrasting the current situation with similar prior experiences. The similarities/differences are registered as important input.	• Supervised learning • Support Vector Machine Classification • Matched filtering • Narrowband filtering • Autocorrelation • Cross correlation
Extraverted Intuition (Ne)	Cross-contextual, divergent thinking. Generates and explores a host of possible interpretations from a single idea. The ability to entertain a variety of disparate ideas, beliefs and meanings simultaneously while maintaining the possibility that they are all true. Seeing things "as if."	• Search Engines (web) • Compressive Sampling • Random Walk • Genetic Algorithms
Introverted Intuition (Ni)	Lays out how the future might unfold based on unseen trends and signs. Can involve working out complex concepts or systems of thinking or conceiving of symbolic or novel ways to understand things that are universal.	• Simulation/Prediction • Design of Experiment • Autocomplete • System ID • Interpolation/Extrapolation • Bayesian Inference

The introverted and extroverted feeling judging functions merit additional discussion. The feeling judging functions are often associated with emotional response. The author currently likes to think of emotional decision-making in general to be similar to an artificial neural network in the sense that an artificial neural network can often take many complicated inputs and learn relationships between the inputs that can be used to quickly make decisions, however it is not always clear how exactly those decisions are made. The author also prefers to think of the emotional cognitive

functions as being partially the results of an embodied intelligence. Feeling judgements can be thought of as using the body as an analog computer to perform simulations and make decisions. Work by Nummenmaa [10] on mapping the sensation of emotions felt in the human body lends some support for this perspective.

As an example of the application of the framework, a machine endowed with an ENTJ personality using the Markov chain in Figure 1, we might employ the A* algorithm to perform the dominant extroverted thinking (Te) cognitive function to form a plan to move through an environment. After the plans are generated they might be analyzed in the introverted intuition (Ni) state using an appropriate simulation that corresponds to the environment and task of interest. If the simulation verifies that the plan is acceptable the plan may be executed by the extroverted Sensing function. In many cases the machine may totally ignore the introverted feeling state and proceed directly to execution, but when it does go into the introverted feeling state it may use a neural network trained to look out for the machine's own well-being to decide whether or not to actually execute the task based on whether or not the machine "feels," it will advance the machine's self-interests.

It is also worth noting that creating the ability to endow robots with personalities may also have application in human machine teaming applications. Much as diversity in teams of humans tends to lead to better results [4], endowing teams of robots with different personalities may also lead to more robust robotic teaming. For example, a team consisting of humans could be augmented with machines endowed with personalities different from the existing team members in order to enhance the overall team diversity. Teams consisting only of robots could be designed in such a way that individual team members are endowed with complimentary personalities, thus enhancing the overall robustness and performance of the machine team.

4. ADDRESSING SOME CONCERNS WITH THE JUNGIAN MODEL

Since the MBTI was developed more than 10,000 companies, 2500 colleges/universities and 200 U.S. government agencies have used the test [11]. It is estimated that more the 50 million people have used the instrument since 1962. Jungian personality theory has had a great influence on corporate America as well as popular culture. For instance, Carl Jung popularized the terms introvert and extrovert. Despite the popularity of Jungian personality theory in industry and among laypeople, academia tends to discount it. One common criticism against the MBTI is that it lacks test-retest reliability [12]. The current perspective of the author is that this criticism is probably valid. At this time the instrument itself appears to have problems. The reason for the lack of reliability with the current instruments may be that the instrument is based on the analysis of a self-report inventory. This type of instrument may be suitable if a Cartesian model of personality is used, but the Jungian model is better described as a dynamic system. Ultimately enhanced versions of projective tests such as those suggested by Ottley [13], and Brown's [14] work may be better able to characterize human personality. Another common criticism is that some Jungian advocates made the claim that MBTI score distributions assumed bimodal distributions, thus lending support to the misunderstanding of Jungian theory that people fell into one of two groups with respect to each letter in the Meyers-Briggs labels. Some research suggests this bimodal distribution was an artifact of the analysis techniques used [15]. The problem with the original argument was that it was not necessarily respecting the Jungian model as a dynamic system and was making the assumption that the Jungian model could be represented with a four dimensional Cartesian coordinate system. It is not clear what type of distribution a personality consisting of cognitive functions as building blocks should generate when evaluated using a self-report inventory. A central limit theorem argument could be made to suggest it come out as a Gaussian, but to really make a definitive statement a more rigorous analysis should be undertaken. Ultimately when synthesizing an artificial personality, the most important criteria for most applications is that the personality be convincing to humans. As long as the machine can pass a Turing-like test it is probably an acceptable solution. The fact that the Jungian model is so widely popular suggests that it may have a low barrier to acceptance among the majority of the population.

5. JUSTIFICATION FROM A NEUROSCIENCE PERSPECTIVE

A number of interesting results have come out of the psychology and neuroscience communities that lends some support for the idea of using the Jungian type model as outlined in this work. The idea that humans can effectively only use one cognitive function at a time gains support from the results of Watson [16] that suggest 98% of humans are incapable of multitasking. Jack's analysis of fMRI measurements of the human brain suggested that there are physiological constraints on our ability to simultaneously engage two distinct cognitive modes. In this case they found humans could not attend to tasks that require social cognition and physical reasoning simultaneously [17]. Grondin (2015) [18] found neuroanatomical differences between Agentic (achievement-oriented) and Affiliative (sociable) extroverts. From a Jungian perspective the concept of an agentic extroverts corresponds very well with personality types with a dominant extroverted thinking preference (ENTJ, ESTJ) and affiliative extroverts correspond strongly with personality types with a dominant extroverted feeling preference (ENFJ, ESFJ).

6. CONCLUSIONS

Personality from a Jungian perspective can be thought of as a zero sum game. Humans only have limited cognitive resources, and our personality is based on how we tend to choose to use those resources. This proposed framework is particularly attractive because it uses established algorithms as building blocks for personality. Because the building blocks are algorithms, and in some cases learning algorithms, the machine is ultimately able to learn and adapt to experiences. The personality framework provides a genotype so to speak but the ultimate phenotype of the machine depends on the experiences it encounters throughout its span of existence. This framework allows for great diversity in resulting perceived personality phenotype.

An interesting implication of the Jungian type-based personality framework is that it might help in the development of robust, high-performance human-machine teams consisting of members with diverse personalities. Observations on the personality diversity of teams and their

performance suggest that teams consisting of members with diverse personalities tend to perform better [19]. A team consisting of humans could be augmented by machines endowed with personalities that enhance the team's overall personality diversity. Alternatively, teams consisting solely of machines could consist of members who provide each other with different perspectives of the world they are interacting with.

Experience has shown that data science problems often benefit from the use of a combination of many heterogeneous models. The Netflix prize provides a good example of showing the advantages associated with simply combining different approaches [20]. However contemporary computational personality research is dangerously homogeneous in the sense that all computational personality research is currently using a trait-based paradigm [1]. The field would benefit from competing models and approaches. Furthermore, from an engineering/Turing test perspective it really does not matter whether or not the approach used to generate an artificial personality accurately models what is occurring in the human mind. It is only necessary to convince the person interacting with it that it is a human-like personality. In fact, the widespread popularity of Meyer's Briggs in business settings and with the general public suggests that an artificial personality based on the Jungian model may perform well with respect to convincing other people of the machine's personality.

Artificial personality synthesis is at a similar point in development as the airplane was at the time of the Wright Brothers. You do not need to understand how a bird flies in order to build a transatlantic aircraft, and you do not need to understand how the human mind works in order to build a machine that has a recognizable personality. Finally, it is interesting to note that while the Jungian perspective on artificial personality synthesis presented here is very different from the mainstream views on the topic that center on the use of Big-5 theory, this paradigm is not any more controversial than the Freudian paradigm advocated for by Marvin Minsky [21]. The Jungian paradigm presented in this work is worth consideration in future artificial personality synthesis. It is attractive in the sense that it can leverage a variety of existing algorithms to implement the personality. It also has the property that an artificial personality made with this framework should exhibit the full range of human personality as described by Jung.

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