Artificial Psychosocial Framework for Affective Non-player Characters

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1 Introduction

A challenging task for video game designers is to make a realistic world for the player. One way to achieve a realistic world is to improve the human characteristics of a Non-Player Character (NPC). The 2018 AI Summit at GDC had a panel of video game designers discussing the necessary improvements for future NPCs [1]. The developers expressed several needs, and this paper addresses the following:

- AI that focuses on non-combat and allows NPCs to react to inputs at unpredictable moments.
- A system based on creditable research that covers the topic of human development.
- Working with NPCs that are not just good or bad but have varied characteristics.
- A framework implemented in a game engine that enables developers to balance values and create content.

Researchers in recent studies have advanced the understanding of NPC cognition by incorporating concepts from psychology [2]. In this paper, we define this new NPC class as an "Affective NPC" (ANPC). Bourgais et al. surveyed the progress in emotional modeling for social simulations to inform others of the potential architecture of ANPCs [2].

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A simple version of emotional modeling is reactive creation. The emotions felt by an ANPC are directly created by the perception of an event. The works from both Le et al. and Luo et al. demonstrate reactive creation for ANPCs in the context of an emergency evacuation of a building [3, 4]. If an ANPC perceives a threat, then its fear increases. As the fear increases and passes a threshold, then its behavior alters. The simplicity of this model allows for ease of implementation; however, this method does not rely on any emotional theory described in psychology [2].

A different approach to emotional modeling considers using fuzzy logic rules. Kazemifard et al. worked on COCOMO, a way to determine the cost of software development via simulating developers in a company [5]. The ANPCs (the developers) had pair values joy/distress and gratitude/anger with a value between 0 and 100, along with other metadata such as technical knowledge and level of soft skills. Fuzzy inference rules transform the values to calculate the emotional state, which, in turn, generates a mood for the ANPC. As the ANPC simulated the work and generated a mood, their behavior altered accordingly; for example, if an ANPC were in a good mood, they would work faster than one in a bad mood. Jones et al. also used fuzzy logic for emotional modeling but in the context of traffic simulation [6]. The calculation of fuzzy sets comes from the ANPCs perception of objects and events, such as their current speed, number of surrounding vehicles, and the percentage of trucks from the vehicles. From these perceptions, the desirability is calculated based on satisfying the ANPCs current goal, resulting in the ANPCs current emotional state. However, similar to reactive creation, fuzzy rules do not rely on any psychological theory about emotions [2].

Keeping psychological theories in mind, designers have integrated emotional behaviors for their ANPCs by using the "Cognitive Appraisal Theory" (CAT). From the works of Zoumpoulaki et al., ANPCs would calculate their emotions based on the appraisal of a situation, and in this case, are in the context of evacuations. The ANPC's appraisal of an event comes from the consequences of their current goal, modified by their personality. A 5-tuple vector represents the ANPC's emotional state, which holds a positive or negative value for each emotion. Multiplying the appraisal, personality, and current emotions, a final emotional intensity is calculated. The ANPC uses this emotional intensity to determine how to fulfill its current desire. Ochs et al. takes a step further and incorporates a social relationship for the ANPC with other ANPCs [7]. Ochs et al. implemented a complete version of the OCC model. However, the number of appraisals the designers have to assign, for every event, for each ANPC, will exponentially increase [2].

Lastly, designers are interested in the evolution of emotions over time. An ANPC starts with an initial emotional state, and the designers focus on the changes of emotions over time to observe how those changes affect their behavior. Faroqi and Mesgari evaluated ANPCs evacuating from an open square using different levels of an emotion [8]. Each ANPC had six transitions in fear, from calm to hysteria. Once an ANPC reached hysteria, they would run in random directions. NPCs were added to the simulation to calm the ANPC as well as inform them of an exit. Suvakov et al. proposed that emotions be generated on a two-dimensional plane to simulate the spread of an emotion in an online social network [9]. While ANPCs

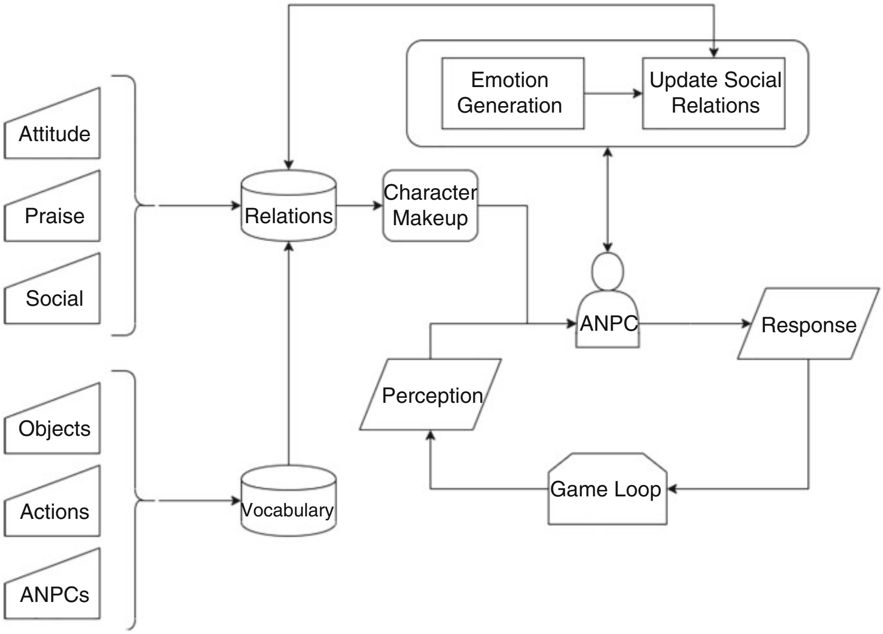

Fig. 1 Flow diagram of APF, starting from input data, representing an ANPC, a psychological evaluation, and then the continuation of the game loop

communicated through an online social network, variable valence and arousal were used with stochastic equations to model the evolution of their emotional state. This method makes a link to emotional generation and appraisal as well as the dynamic behavior using formal notation. The drawback from the evolutionary works is that the creation process is not fully explained, and would be much harder to implement into a system [2].

This paper presents the "Artificial Psychosocial Framework" (APF), an extension of the work proposed by Ochs et al. [7], which based their work on the CAT. Having APF based on the CAT allows developers to focus on creating content for the ANPC, such as dialog or voice-overs. Developers would assign values to the ANPC to represent their feelings towards other game objects, interactions, or other ANPCs. APF extends the works of Ochs et al. by utilizing an ambivalent hierarchy of emotions, classification in vector space, and intended for game engine integration. In psychology, ambivalence is the phenomenon of an individual feeling both positive and negative emotions at the same time. Hierarchical refers to the conditions that the actions experienced can alter the character's mood, emotions, and feelings. The classification allows designers to have a reference point to interpret the set of values when used in each model. Lastly, APF is implemented as a library so that developers can integrate the framework into their existing game engine as a plug-in (Fig. 1).

2 Overview

The principle of APF is on the psychological theory of the CAT. A cognitive appraisal states that a person evaluates a situation based on their criteria [2]. Consequently, due to personal criteria, individuals can experience a similar situation with different emotions, resulting in different actions. From this foundation, APF chains together psychological models to generate different states.

APF uses two popular psychological models, along with a third supplemental model. First, is the Big Five personality traits model: "Openness, Consciousness, Extroversion, Agreeableness, and Neuroticism" (OCEAN). Second, is emotion representation by the "Ortony, Clore, and Collins" (OCC) model. There is a third model used to represent social relations, which is from the works of Ochs et al. It Uses a 4-tuple to represent the "Liking, Dominance, Solidarity, and Familiarity" (LDSF) model [7].

Vectors are used to decompose each model, i.e., the OCEAN personality model is a 5-tuple vector where each element is in the range [0.0, 1.0]. The benefits of using a vector are that one can apply equations to manipulate the values and provides an ease of implementation into a program. The drawback is that the vector represents some point in n-dimensional Euclidean space that, at first glance, does not have contextual meaning. Thus, using named reference points, APF uses Multidimensional Scaling (MDS) to classify the point of interest. The classification gives meaning to the point and offers a better understanding of its interpretation.

Lastly, APF takes a step further from previous emotional agent frameworks for its development as a library. Previously, these frameworks were implemented as custom applications to solve theoretical problems. APF is a plug-in that works with commercial engines, such as the Unreal Engine, or proprietary engines. APF can work in tandem with other AI techniques, such as Fuzzy Logic, Behavior Trees, and Goal-Oriented Action Planning. Utilizing APF with AI allows developers to work on decision making from a different perspective and focus on emotion-centric gameplay.

3 Background Information

In psychology, a concept called Psychosocial focuses on the individual's psyche and their interactions with their social environment. The concept primarily focuses on how individuals conduct themselves based on the influences of relationships with other people, places, experiences, and themselves [10]. Maintaining these relationships will have varying repercussions and will inevitably come back around to the individual. Nearly all of us want to have a safe environment, but there are multiple variables to determine safety [11]. Do we have a sense of control in our lives, can we build a meaningful connection with others, do we feel safe from harm's way, or support ourselves or those closest to us? Answering these questions will require an understanding of valence.

Valence is defined as an affective quality that is expressed on a scale of attractiveness to aversion towards an event, object, or situation [12]. The amount of valence generated from a stimulus is subjective. Hence, when different people face the same situation, they can feel different emotions, which leads to performing different actions. For example, when given a photo of an individual and a few seconds to determine whether to talk to that individual or not, the decision is influenced by the valence generated from the appearance of the person in the photograph. APF attempts to quantify valence and is used as the base unit to calculate the emotions generated from a stimulus. Additionally, ambivalence is another term analogous to valence but infers conflicting emotions generated by a stimulus. Ambivalence causes individuals to have mixed feelings towards something, such as a love/hate relationship with someone. Having the base unit defined, we can now describe the evolutionary proses it goes through to generate an emotion, known as the “Cognitive Appraisal Theory” (CAT).

A cognitive appraisal is a subjective interpretation made from a person towards a stimulus in the environment [13]. The subjectivity is explicitly the valence emotion that the person has associated with the stimulus. Cognitive appraisal allows for a person’s emotional state to be directly linked to the situation, rather than their physical response. Additionally, the connection between emotional state and situations allows an individual to respond to the situation, rather than instinctively react.

Stepping outside of Psychology and into Data Science, there is a technique called Multidimensional Scaling (MDS). MDS is a cluster analysis method that reduces the dimensions of a complex dataset. Complexity is explicitly referring to the data being represented as a four or higher-dimensional vector. The reduction in dimensions allows for the vector to be drawn onto a 2D or 3D graph, making the data easier to interpret and determine common groups. Using a vector allows for ease of manipulation with formal equations. One of the benefits and drawbacks of working with vectors is that we have an ample n-dimensional Euclidean space to manipulate the values. To a designer, there is no context in representing a point in this space. APF uses MDS to give the designer meta-information about the dynamic vectors used. It does this by using reference points authored by the designer. The reference points represent the center of a hypervolume. Within that hypervolume, other potential points are closely related to the reference point. Because the reference point and the generated point are so close to each other, APF labels the generated point with the same name as the reference point. Additionally, this process also allows designers to reverse engineer a vector, rather than to handwrite them. Designers can choose a reference point that feels right for their ANPC. Once selected, APF uses that point, but random offsets each axis by a small amount. The slight randomization allows the designers to continue to work with their creativity, rather than interrupt their thought process to think about mathematics.

4 A Priori Setup

For APF to work, there needs to be a set of vocabulary known to the system. The vocabulary is made up of all the living, nonliving, and potential actions to perform in the virtual world. Following the concept of Psychosocial, the vocabulary needs to have relationships with each other. The relationship depicts the valence an ANPC has with a vocabulary. Thus, a subset of these relationships, along with a personality, are the characteristics that make up an ANPC.

Defining the vocabulary describes what inhabits the virtual world and what the inhabitants can do. Three main sets make up the vocabulary: Objects, Actions, and ANPCs. Objects are things that have no cognition and are props used by the player and an ANPC. These include, but are not limited to, cars, work tools, chairs, and laptops. For APF to know what an object is, it just needs to be represented by a name. Actions are all the things that both the player and an ANPC can do within the virtual world. These include, but are not limited to, commuting, hacking, complementing, and bartering. For APF to know what an Action is, it must be represented as a name and an effect onto the virtual world. The effect is a value from 0.0 to 1.0, where 0.0 is a negative outcome of the action for the ANPC who experiences it, while 1.0 is a positive outcome. The last set is the ANPCs, and these are all the characters that will inhabit the virtual world. For APF to know what an ANPC is, it is represented with their name and personality. The personality is represented by a vector, where each dimension is a trait. Each trait is between the value of 0.0 and 1.0, where 0.0 means the opposite of the trait, and 1.0 is fully resembling that trait.

With the vocabulary defined, the connections are left to form the web of relationships. The entire set of relationships forms the psychosocial aspects of the ANPCs. A single relationship represents a cognitive appraisal of an ANPC. A relationship can be one of the three types: Attitude, Praise, or Social.

An Attitude relation is between an ANPC and an Entity. Specifically, the relationship is between an ANPC and an Object or another ANPC. An Attitude relation represents the ANPC's thoughts towards the game object or the other ANPC. The value can be calculated automatically for the other ANPC via the social relation's liking trait; however, the attitude value represents the original biased thought of the ANPC. The valiance from the Attitude is between 0.0 and 1.0, where 0.0 means the ANPC vehemently hates the entity, while 1.0 means an uncontrollable love towards the entity.

A Praise relation is between an ANPC and an action. A Praise relation represents the ANPC's beliefs against the action. The action can be as general as "arguing" or "hugging." Taking into consideration of satisfying a goal, an option that the ANPC can pick is "killing." However, the developers should consider specifying the action so that the ANPC can view it in different situations, for instance, "killing_for_money" with low praise versus "killing_to_save_human_life" with high praise. The valiance is between 0.0 and 1.0, where 0.0 means the ANPC views the action as something that goes against their moral belief, and 1.0 is praiseworthy.

The difference between the effect of an action and the praise of action is the objective and subjective point of view. The effect represents the general outlook of undergoing the action, either being painful or pleasurable. The praise is the ANPC's perception of the action, either being reprehensible or admirable. The distinction allows ANPCs to express their biases for action while also experiencing the consequence of the action.

Social relations are the connections between ANPCs. A social relation describes how an ANPC should present themselves and how they should treat the other ANPC. However, these kinds of relations are more complicated than the previous and will need more information than a single value. The social relationship follows the same model as Ochs et al., using the LDSF model [7]. A 4-tuple vector represents the LDSF model. Each trait is between the range [0.0, 1.0], where 0.0 is the opposite trait, and 1.0 is the full trait. Liking is the degree of affinity towards another ANPC. Dominance is the power that an ANPC can exert onto another ANPC. Solidarity is the degree of "like-mindedness" or having similar behavior dispositions with another ANPC. Furthermore, Familiarity is characterizing the type, private or public, and the amount of information comfortably exchanged between the two ANPCs.

5 Character Makeup

With the vocabulary defined, APF now has enough information to create instances of the ANPCs. Instancing an ANPC is different from instancing a game object or action. The ANPC file is treated as the unique cast of actors, meaning each line in the file is a different character in the virtual world. The game objects and actions files are the definitions to make as many copies as the designer needs, meaning if the designer needs nine copies of baseball bats, then only the line that defines a baseball bat is read nine times. To instantiate an ANPC, APF goes down the list of ANPCs to gather their metadata first and then find the corresponding relations to populate the ANPC. From the list of ANPCs, we set their names and their personalities.

APF uses the OCEAN model to represent the personality of the ANPC. The OCEAN model is a 5-tuple vector where each element is in the range [0.0, 1.0]. For example, with the Openness trait, 0.0 means the ANPC is non-curious and less intellectually driven, while 1.0 means the ANPC is inquisitive and is insatiable in their quest to know more. Stated earlier, MDS is used to give designers additional information about the vector. APF is given 32 reference points, which are mapped from the OCEAN model to the Myers-Briggs Personality Types (MBPT) model [14]. Some of the names are "Turbulent Architect," "Assertive Mediator," and "Turbulent Executive," just to name a few [15]. The mapping turns the 5-tuple personality vector into a label to quickly understand it is contextual meaning. Understand that the mapping that was selected was by designer choice. If there is another list of personality reference points and is mapped from the OCEAN model to the designer's convention, APF will use those labels and hypervolumes instead.

Additionally, if APF parses a valid label of a reference point in the ANPC set, rather than a vector, then the reference point will be used and will be randomly offset.

The relations are all that is left to instantiate an ANPC. The Attitude and Praise relations are assigned to their ANPC accordingly. If an ANPC is missing a relationship with a game object or an action, APF assigns the valence of that relationship to neutral, 0.5. These values are not dynamic and will stay the same throughout the entire playthrough. The social relation is assigned to the ANPCs, but because they are vectors, MDS can be used. Like personalities, a list of reference points is used to label the vector. The names used are “Parent-Child,” “Child-Parent,” “Boss-Worker,” and “Stranger.” Notice how these labels are pairs of titles. The first title is how the source ANPC is presenting themselves, and the second title is how they are treating the other ANPC. The exception to this rule is stranger, which acts as the default social relation for any missing pairs. Like the other reference points, these are designer specific. A different list of reference points mapped to the LDSF model can be used to better suit the context. Additionally, if a label is parsed, rather than a vector, then the random offset is applied to the relation and is set

6 Psychological Evaluation

At this point, the virtual world is defined and populated. ANPCs are walking around the virtual world and interacting with game objects and other ANPCs. For an ANPC to evaluate their psychological state, they first need to have some means of perception. In APF, the perception is the same event handling from Ochs et al., which uses a Sowa graph [7, 16]. The representation of an event is a 4-tuple node (Agent, Action, Patient, Certainty). The Agent is the source of the event and can be either an ANPC acting, an unknown ANPC, or no ANPC. Action is the performance that is taken place during the event. The Patient is an entity, either a game object or another ANPC. The Certainty is used to represent either seeing the action in person, 1.0, hearing about the action 0.0–1.0, or confirming that the action did not happen 0.0.

When an ANPC registers an event, it goes through a psychological evaluation. The first step in the evaluation is determining the emotional state of the ANPC. APF uses a modified OCC model to evaluate the emotion an ANPC felt caused by the event. The modified version is based on the works of Steunebrink et al. and their revised version of the original OCC model. Their revised version kept the emotions as pairs, hate/love, approving/disapproving, fear/hope, and so on. The pair representation meant that the value would be from a range $[-1.0, 1.0]$. For example, using hate/love, a -1.0 means a feeling of hatred, and 1.0 means a feeling of love. An issue that arises from this representation is when we update the emotional history of an ANPC.

Let us say that an ANPC was to undergo a practical joke. When the joke is initiated, the ANPC will be distressed from what happened. Once the ANPC realizes

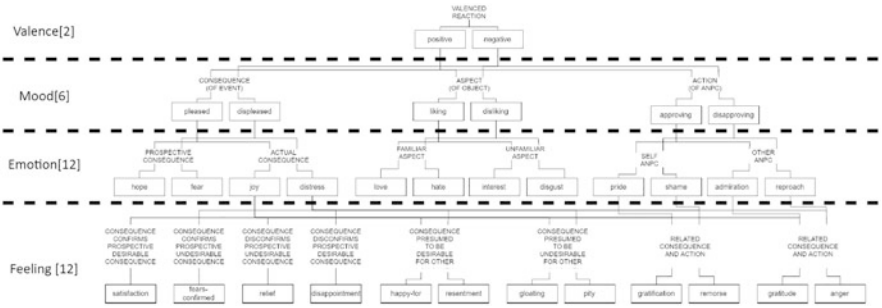

Fig. 2 Modified OCC model based on the works of Steunebrink et al. [17] taking into account ambivalence and psychological ideology with the hierarchical nature

the joke, the ANPC should be joyful. In the revised version, the emotions of distress and joy are paired together. The pairing means that the emotional value can be from $[-1.0, 1.0]$, as well as the emotional history for the ANPC. Let us say that the ANPC hated the joke's start so that they would generate an emotion of hatred of -1.0. However, once they realized it was a joke, and they liked the joke, they would generate an emotion of joy of 1.0. When updating the emotional state, we would simply add the current state to the emotional history and add the new emotional value to the current state. Now, the ANPC has gone from really hating the joke, -1.0, to being neutral about the joke, 0.0. The current emotional state does not correctly reflect the amount of joy that the ANPC generated. Furthermore, we lose the opportunity to track how angry the ANPC is since the start of the joke. With the modified version, we track both hatred and joy separately. This separation allows for ambivalence, the state of having mixed emotions. Going through the scenario again, the ANPC will generate hatred from the start of the joke and store it accordingly. When the ANPC generates joy, hatred is not modified, but instead continues to decay over time. Joy is stored accordingly, and now we make a simple comparison of which emotion has a higher value.

In the work of Steunebrink et al., they mentioned that the original model had a hierarchical property. They wanted to preserve this property, but as an inheritance hierarchy for object-oriented programmers [17]. In doing so, we can represent each height of the hierarchy as a different idea from psychology. From Fig. 2, we can split the modified model into four sections and denote them as follows:

(1) From the CAT, we have a valence, our positive or negative input value. Valence is the subjective spectrum of positive to negative evaluation of an experience an individual may have had [12].
(2) Mood, an affective state heavily influenced by the environment, physiology, and mental state of the individual. Moods can last minutes, hours, or even days [12].
(3) The basic emotions, the chemical release in response to our interpretation of a specific situation. It takes our brains a quarter of a second to identify the trigger, and another to produce the chemical [12].

(4) Feelings, what we analyze after experiencing the generated emotion, which can last longer than an emotion [18].

Using the modified OCC model is similar to using the previous versions. The model starts with a valence; this is the summation of all the relations involved and is bounded between 0.0 and 1.0 for both the positive and negative valences experienced. Next, the mood queries the Sowa node for the action performed, the ANPC acting, and the affected object. The valences from the relative relations of the ANPC are used to calculate the new mood. When calculating the new emotion, queries are made to the Sowa node, the social relation, and the values from the new mood. Lastly are the feelings; however, due to time constraints, this section was not fully implemented in APF.

Going through the OCC model, the personality of the ANPC is also taken into consideration when generating an emotion. An ANPC with a high Neurotic trait will increase negative emotions, such as disapproving, disliking, reproach, and distress. An ANPC with a high Extraversion trait will increase positive emotions, such as liking, pleased, love, and hope. An ANPC with a high Agreeableness trait will positively influence the consequence subtree and action subtree. An ANPC with a high Openness trait will have a positive influence on the aspect and action subtree. An ANPC with a high Conscientiousness will have a positive influence on the consequence subtree.

Using the terms from the Sowa node, when generating the new emotion from the event, if an Agent ANPC was involved in the event, then the social relation from the Patient ANPC to the Agent ANPC is updated. Note that the social relation from the Patient ANPC to the Agent ANPC is not the same as the Agent ANPC to the Patient ANPC. Thus the social relation has a non-commutative property. From Fig. 3, any positive emotions will positively influence the liking trait, while negative emotions will negatively influence the trait. In Fig. 4, certain positive emotions will cause the dominance trait to increase, while certain negative emotions will decrease it. However, if the Agent ANPC reacts to the Patient ANPC and expresses negative emotions, this will increase the Patient ANPC's dominance trait. From Fig. 5, if the Agent ANPC generates the same emotion as the patient ANPC, then the solidarity trait is increased. If they are not the same, then the solidarity trait decreases. However, negative emotions from the consequence subtree and the action

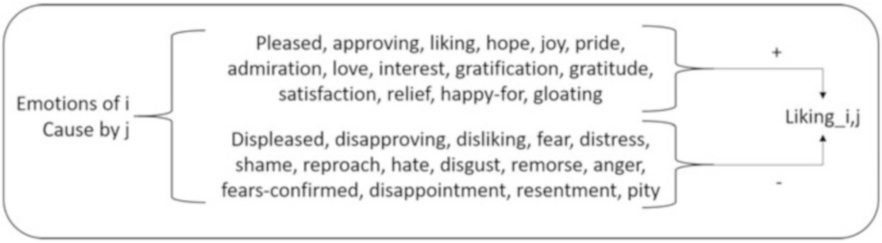
Emotions of i
Cause by j
Pleased, approving, liking, hope, joy, pride, admiration, love, interest, gratification, gratitude, satisfaction, relief, happy-for, gloating
Displeased, disapproving, disliking, fear, distress, shame, reproach, hate, disgust, remorse, anger, fears-confirmed, disappointment, resentment, pity
+
-
Liking_i,j

Fig. 3 Updating the liking trait from the LDSF model

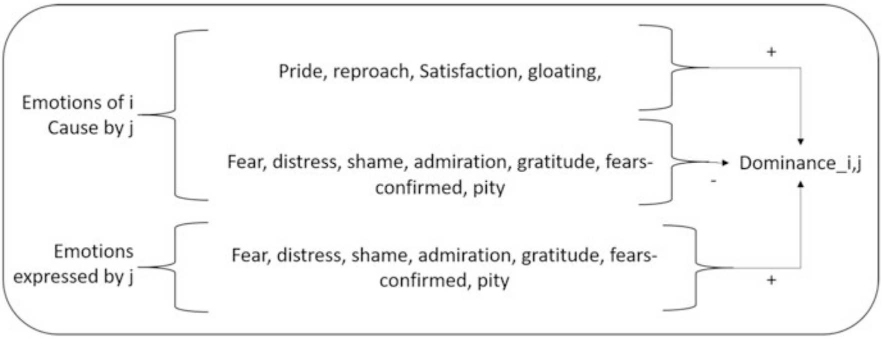
Emotions of i
Cause by j
Pride, reproach, Satisfaction, gloating,
+
Fear, distress, shame, admiration, gratitude, fears-confirmed, pity
-
Dominance_i,j
Emotions expressed by j
Fear, distress, shame, admiration, gratitude, fears-confirmed, pity
+

Fig. 4 Updating the dominance trait from the LDSF model

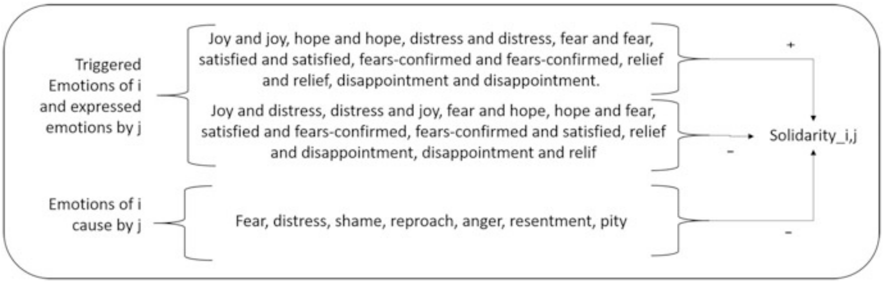
Triggered Emotions of i and expressed emotions by j
Joy and joy, hope and hope, distress and distress, fear and fear, satisfied and satisfied, fears-confirmed and fears-confirmed, relief and relief, disappointment and disappointment.
+
Joy and distress, distress and joy, fear and hope, hope and fear, satisfied and fears-confirmed, fears-confirmed and satisfied, relief and disappointment, disappointment and relif
-
Solidarity_i,j
Emotions of i cause by j
Fear, distress, shame, reproach, anger, resentment, pity
-

Fig. 5 Updating the solidarity trait from the LDSF model

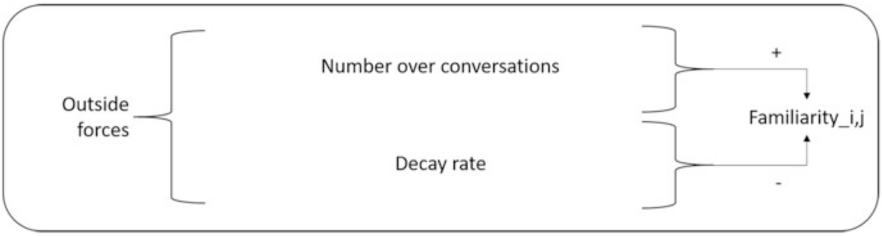

Fig. 6 Updating the familiarity trait from the LDSF model

subtree will negatively influence the solidarity trait. Lastly, Fig. 6 shows that over time, the more interaction an ANPC has with another ANPC, the Familiarity trait will increase; otherwise, it will decrease slowly over time.

7 Formal Grammar

The purpose of this section is to understand the general structure of each model used in APF. An ANPC is continually changing, so referring to it is relative to a time t. The moment an ANPC is created is defined by $t = 0$. For this section, let us refer to one ANPC at a given moment as i_t, that is from the set of all ANPCs in our world, I. From the works of Eggs et al., personality, mood, and emotional state form the PME model [19]. We are extending their work by adding valence, attitude relations, praise relations, and social relations. Personality, attitude relations, and praise relations are constant and initialized at $t = 0$. The valence, mood, emotional state, and social relation are dynamic and initialize to 0 at $t = 0$. Thus we define i_t as a 7-tuple $(m, A_i, P_i, \gamma_t, \pi_t, \xi_t, S_{i_t})$ where m is the personality, A_i is the subset of attitude relations for an ANPC i, P_i is the subset of praise relations for an ANPC i, γ_t is the valence at time t, π_t is the mood at time t, ξ_t is the emotional state at time t, and S_{i_t} is the subset of social relations for ANPC i at time t.

There exist several personality models, each consisting of a set of dimensions, where each dimension correlates to a specific attribute towards the makeup. In APF, the personality model used is the OCEAN model, which has five dimensions. Generalizing the theory, we assume that a personality has n-dimensions, where values represent each dimension in the interval [0.0, 1.0]. A value of 0.0 is the lack of that dimension in the personality, while a value of 1.0 is the greatest presence of that dimension in the personality. The following vector can represent the personality m of an individual:

$$m^T = [\mu_1, \mu_2, \mu_3, \ldots, \mu_n], \forall x \in [1, n] : \mu_x \in [0.0, 1.0] \qquad (1)$$

As we mentioned earlier, we must define a priori to the game a vocabulary, the set of game objects, O, the set of ANPCs, I, and the set of actions, C. The set of vocabs is $Voc = O \cup I \cup C$. Object $o \in O$ is a game object that has no cognition, versus an ANPC that can. An ANPC $i \in I$ is the non-player character that simulates human affects. Action $c \in C$, are couples $(name, effect)$, where $name$ uniquely identifies the action, and $effect$ denotes the effect of the action onto an ANPC ranging from [0.0, 1.0]. 0.0 means a negative impact on the ANPC, and 1.0 a positive impact. Additionally, let us define E to be the set of entities within the game. The entire set of entities is from both sets of objects, O, and ANPCs, I, thus $E = O \cup I$. A single entity, $e \in E$, can either be an object or an ANPC.

With the vocabulary and entity set, we can define the set of Attitudes and Praises. The set of attitudes is the combination of all ANPCs with all entities. An attitude also is denoted from the range [0.0, 1.0], where 0.0 means the ANPC vehemently hates the entity, while 1.0 means an uncontrollable love towards the entity. The set of praises is the combination of all ANPCs with all actions. Praise is denoted from the range [0.0, 1.0], where 0.0 means the agent views the action as something that goes against their moral belief, and 1.0 as praiseworthy. So the formal notation of the set of attitudes, A, and the set of praises, P, is as follows:

$$A = I \times E = (i, e) \rightarrow [0.0, 1.0] : i \in I, e \in E = (O \cup I) \tag{2}$$

$$P = I \times C = (i, c) \rightarrow [0.0, 1.0] : i \in I, c \in C \tag{3}$$

$$A_i \subseteq A \text{ and } P_i \subseteq P \tag{4}$$

Valence is the bias experience an ANPC feels. In APF, valence is a tuple for positive and negative experience coming from the attitude and praise. In general, this can be a list of physical or mental values that the individual enjoys or dislikes based on a specific moment. We define the valence γ_t as a k-dimensional vector, where values represent all k valence intensities in the interval [0.0, 1.0]. The value 0.0 corresponds to the absence of the valence, while 1.0 is the maximum intensity. The vector is given as follows:

$$\gamma_t^T = \begin{cases} [\eta_1, \ldots, \eta_k], \forall x \in [1, k] \ : \eta_x \in [0.0, 1.0], & \text{if } t \geq 0 \\ 0, & \text{if } t = 0 \end{cases} \tag{5}$$

Furthermore, we define the valence history Γ_t that contains all valances until γ_t, thus:

$$\Gamma_t = \langle \gamma_1, \gamma_2, \gamma_3, \ldots, \gamma_t \rangle \tag{6}$$

The mood is an affective state of the ANPC. In APF, the mood is defined by a 6-tuple vector, (pleased, displeased, approving, disapproving, liking, disliking). The mood could also be represented as either good or bad, similar to valence. We define a mood π_t as an h-dimensional vector, where values represent all h mood intensities in the interval [0.0, 1.0]. The value 0.0 corresponds to the absence of the mood, while 1.0 is the maximum intensity. The vector is given as follows:

$$\pi_t^T = \begin{cases} [\nu_1, \ldots, \nu_h], \forall x \in [1, h] \ : \nu_x \in [0.0, 1.0], & \text{if } t \geq 0 \\ 0, & \text{if } t = 0 \end{cases} \tag{7}$$

Similarly, we define the mood history Π_t that contains all moods until π_t, thus:

$$\Pi_t = \langle \pi_1, \pi_2, \pi_3, \ldots, \pi_t \rangle \tag{8}$$

The emotional state is the biological state of the ANPC. In APF, the emotional state is defined by a 12-tuple vector, (hope, fear, joy, distress, pride, shame, admiration, reproach, love, hate, interest, disgust). The six basic emotions are these same values, however, as pairs, and from a range of -1 to 1. We define an emotional state ξ_t as a y-dimensional vector, where values represent all y emotional intensities in the interval [0.0, 1.0]. The value 0.0 corresponds to the absence of the emotion, while 1.0 is the maximum intensity. The vector is given as follows:

$$\xi_t^T = \begin{cases} [\epsilon_1, \ldots, \epsilon_y], \forall x \in [1, y] \ : \epsilon_x \in [0.0, 1.0], & \text{if } t \geq 0 \\ 0, & \text{if } t = 0 \end{cases} \tag{9}$$

Similarly, we define the emotional state history Ξ_t that contains all emotional states until ξ_t, thus:

$$\Xi_t = \langle \xi_1, \xi_2, \xi_3, \ldots, \xi_t \rangle \tag{10}$$

The formal model of social relations continues its representation from the works of Pecune et al. [20]. Social relations are a 4-tuple vector (Liking, Dominance, Solidarity, Familiarity), represented as s_{i_t} for the social relations of ANPC i, towards a different ANPC at time t. $s_{i_t} \in S_{i_t}$, is the set of Social relations for ANPC i, at time t. We can also define the social relation history Θ_t, that contains all social relations until S_{i_t} for an ANPC, thus:

$$\Theta_t = \langle S_{i_1}, S_{i_2}, S_{i_3}, \ldots, S_{i_t} \rangle \tag{11}$$

As the ANPC perceives the world, events are registered based on the actions performed onto entities. APF calculates the valence based on the Sowa node describes in section VI and following the OCC model. We define this information as a *desired change in valence intensity* for each valiant, defined by a value in the interval [0.0, 1.0]. The valiant information vector V (or valance influence) holds the desired change of intensity for each of the k valances after evaluation in the first height of the OCC model:

$$V^T = [\eta_1, \eta_2, \eta_3, \ldots, \eta_k], \forall x \in [1, k] : \eta_x \in [0.0, 1.0] \tag{12}$$

The valence can then be updated using a function $D(m, \Gamma_t, V)$. This function calculates the change in valence, based on the personality, m, the valence history, Γ_t, and the valence influence, V. To represent internal valence changes to the ANPC, such as the decay rate or balancing modifications, is given as $F(m, \Gamma_t)$. Given these two functions, the new valence γ_{t+1} can be calculated as follows:

$$\gamma_{t+1} = \gamma_t + D(m, \Gamma_t, V) + F(m, \Gamma_t) \tag{13}$$

Given the new valence and the event, the mood is updated. The mood influence vector M holds the desired change of intensity for each of the h moods in the second height of the OCC model:

$$M^T = [\nu 1, \nu_2, \nu_3, \ldots, \nu_h], \forall x \in [1, h] : \nu_x \in [0.0, 1.0] \tag{14}$$

The mood is updated using a function $G(m, \Pi_t, \Gamma_{t+1}, M)$. This function calculates the change in mood, based on the personality, m, the mood history, Π_t, the new valence history, Γ_{t+1}, and the mood influence M. Additionally, to represent internal mood changes, either decay rate or balancing modifications, to the ANPC is given as $H(m, \Pi_t, \Gamma_{t+1})$. Given these two functions, the new mood π_{t+1} can be calculated as follows:

$$\pi_{t+1} = \pi_t + G(m, \Pi_t, \Gamma_{t+1}, M) + H(m, \Pi_t, \Gamma_{t+1}) \tag{15}$$

Lastly, we update the emotion. The emotion influence vector J holds the desired change of intensity for each of the y emotions in the third height of the OCC model:

$$J^T = [\epsilon_1, \epsilon_2, \epsilon_3, \ldots, \epsilon_y], \forall x \in [1, y] : \epsilon_x \in [0.0, 1.0] \tag{16}$$

The emotion is updated using a function $K(m, \Xi_t, \Pi_{t+1}, \Gamma_{t+1}, J)$. This function calculates the change in emotion, based on the personality, m, the emotional state history, Ξ_t, the new mood history, Π_{t+1}, the new valence history, Γ_{t+1}, and the emotion influence J. Additionally, to represent internal emotional state changes, such as decay rate and balancing modifications, to the ANPC is given as $L(m, \Xi_t, \Pi_{t+1}, \Gamma_{t+1})$. Given these two functions, the new emotional state ξ_{t+1} can be calculated as follows:

$$\xi_{t+1} \quad = \quad \xi_t \ + \ K(m, \Xi_t, \Pi_{t+1}, \Gamma_{t+1}, J) \ + \ L(m, \Xi_t, \Pi_{t+1}, \Gamma_{t+1}) \tag{17}$$

The social relations are updated similarly to the works of Ochs et al. [7]

8 Implementation

Running the APF library, we construct a scenario with two ANPCs with different personalities. In this scenario, we use the context of the 1960 comic book "Dennis the Menace." Dennis is a young, 6-year-old boy who is trying to learn about the world. Dennis's parents, the Mitchells, and his neighbors, the Wilsons, are his role models that try and steer Dennis to the right path. For this scenario, the player plays as Mr. Wilson, and the ANPC is Dennis.

We can understand the ANPCs' social relationships by graphing their emotional state. As time passes, actions are performed by the player, and the ANPC reacts to the action. In Fig. 7, there are six graphs with three different examinations over time for both experiments. The first set of graphs is the ANPC's emotional state history, plotting the twelve emotions the ANPC can generate. The second set of graphs shows the social relationship history from Dennis to Mr. Wilson. The social relationship is based on the emotional state at that time, and the graph plots the four dimensions of a social relationship. For clarity, only liking and dominance from the social relationship are plotted. The third graph is using MDS to show the certainty of classifying the current relationship.

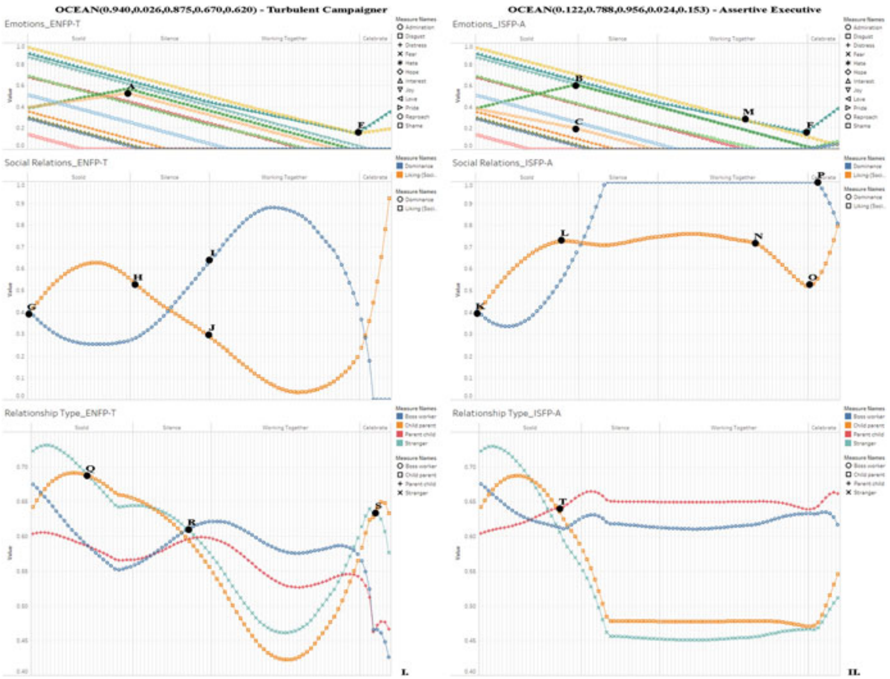

Fig. 7 Two experiments running APF with a Dennis the Menace setting, testing the heterogeneity of two ANPCs undergoing the same scenario, one Dennis with a turbulent Campaigner personality and the other Dennis with an assertive executive personality

The abscissa for all graphs is the time passing and the name of the action performed by the player. The ordinate for each graph ranges from 0.0 to 1.0. The first set of graphs, the emotional state history, tells the amount of an emotion felt by the ANPC at that time. The second graph, the social relationship history, tells the amount of a trait visible by their relationship. The third set of graphs, the relationship type, is a percentage of similarity between the reference points of social relationships and the current social relationship between Dennis and Mr. Wilson. In other words, the social relation with the highest value is considered to be the current relationship.

The scenario plays out as follows: Mr. Wilson catches Dennis uprooting one of his turnips. Mr. Wilson scolds Dennis for picking his crop too early and tells him to wait as he grabs some tools. Mr. Wilson comes back and works with Dennis to plant new turnips. Once they finished, they both celebrate that the garden is back to normal.

With this scenario, we can change Dennis's personality to see how he will react to Mr. Wilson. To represent Dennis's personality, APF was given 32 reference points to map the OCEAN personality to the Myers-Briggs Type Indicator [14]. In the first experiment, Dennis has a Turbulent Campaigner (ENFP-T) personality. In the second experiment, Dennis has the Assertive Executive (ESTJ-A) personality.

In the emotional history graph, there are distinct differences between the Campaigner Dennis and Executive Dennis. As the Campaigner is experiencing the Scolding from Mr. Wilson, he generates emotions of hate and fear, Point A. The Executive, on the other hand, only generates hatred, point B, and does not fear Mr. Wilson, point C. The reason for this is because of the Neurotic trait of their personality. The Campaigner's Neurotic level is at 0.620, giving him qualities of anxiousness and prone to negative emotions. The Executive's Neurotic level is much lower, at 0.153, giving him qualities of being calm and even-tempered. Both the Campaigner and the Executive generated hatred because of their Extraverted trait, 0.875, and 0.956, respectively, giving the Dennises the qualities of being sociable and assertive. At point E, the Campaigner is generating love and enjoyment when they are celebrating with Mr. Wilson. The Executive, however, only generates love and not enjoyment at point F. The lack of enjoyment is because of the Openness trait. For the Campaigner, Openness is at 0.940, giving him qualities of curiosity and having a wide range of interests. For the Executive, Openness is at 0.122, giving him qualities of being practical and conventional.

In the social relations history graph, we see how the Dennises view Mr. Wilson based on how Mr. Wilson treats Dennis. With the Campaigner, Denis at first likes Mr. Wilson at point G because he started with an abundance of joy. However, since the Campaigner is generating fear and hatred up to point A, the liking starts to decrease. With the hatred increasing, the dominance increases as well. When Mr. Wilson leaves to grab his tools at point H, there are more negative emotions generating than positive, and so the liking for Mr. Wilson continues to drop. While Mr. Wilson is looking for his tools, fear is decreasing, so the dominance continues to rise. When they start working on the garden at point I, there is an inflection point for dominance because of the decrease in pride and reproach. At point J, there is another inflection point for liking because of the increase in love and a decrease in hatred and reproach. Finally, since the Campaigner generated emotions of love and enjoyment, liking rises.

Looking at the social relations history graph for the Executive Dennis, there is still an increase in liking at point K because of the abundance of joy. However, because fear was not generated, the liking flat lines at point L before the scolding finishes. Similarly, because of the decrease of fear and an increase in hatred, dominance rises much quicker. During the silence, the dominance maxes out while the liking continues to flatline because a relatively equal amount of positive and negative emotions are decreasing. While they are working together, joy decreases a little faster than love, making them intersect at point M. The intersection influences the liking at point N so much that it starts to decrease. Once the garden is done, and they are celebrating, the Executive is generating love, admiration, and hope at point F. The generation of positive emotions increases liking at point O, but because of the increase in admiration, there is a decrease in dominance at point P.

In the last set of graphs, the relation type shows how the Dennises are associating themselves and how they would treat Mr. Wilson. The Campaigner, in the beginning, views Mr. Wilson as a stranger. At point Q, during the scolding, the Campaigner believes he is a child and should treat Mr. Wilson as a parent. At point R during the silence, the Campaigner presents himself as a boss and treats Mr. Wilson as a worker. The reason the Campaigner chose the boss-worker relation is because of the enormous gap between the liking and dominance from the social relation. The boss-worker relation gives the feeling that the Campaigner is impatient and wants to start working without Mr. Wilson. It is not until they celebrate does the Campaigner presents himself as a child, and Mr. Wilson as a parent once more at point S.

For the Executive, we start the same with a stranger, and then the child-parent relation similar to the Campaigner. The difference shows at point T when the Executive presents himself as a parent and treats Mr. Wilson as a child. The Parent-Child relation was chosen because of the smaller gap between the liking and dominance from the social relation. The Executive continues with the Parent-Child relation for the remainder of the scenario. The Parent-Child relation gives the feeling that the Executive wants to take responsibility but is forced to work with an overdramatic person.

9 Conclusion

The "Artificial Psychosocial Framework" (APF) is an emotional modeling tool to help create "Affective Non-Player Characters" (ANPC) in-game engines. The principle of APF is the CAT and is supported by psychological models to generate emotions and social relations with other ANPCs. Developing ANPCs will help create realistic virtual worlds and allow for the conception of further emotion-centric gameplay for designers. APF was created as a library for developers to use as a plug-in for any game engine. From Fig. 8, one can see an example of how a developer can use APF with the visual programming tool, blueprints, from the Unreal Engine.

Future works include optimizations to allow for thousands or millions of ANPCs within a virtual world. In this case, one file of valence values would represent a colony. One can also use a random number offset to modify the ANPCs' valences within the said colony. Balancing is necessary for each game to determine the correlations between personality vs. emotion, personality vs. social relation, and emotion vs. social relations. APF allows for social relations to update over time. One can consider updating the other relations, Attitude and Praise, to allow for dynamic opinions.

After integrating APF into a game engine, we can consider unique gameplay features. Like Valve's zombie apocalypse title, "Left 4 Dead," their AI director guides the gameplay based on the players' dread [21]. APF would monitor ANPCs' emotions, and either changes the virtual world, using a director or arbiter system, or influence NPCs' decisions, such as animal or zombie. From the works of Brinke et al. with their project, "The Virtual Storyteller," we can use their idea of out-of-character knowledge with in-character knowledge to influence ANPC choices [22]. An ANPC would select actions that result in an intended reaction from another

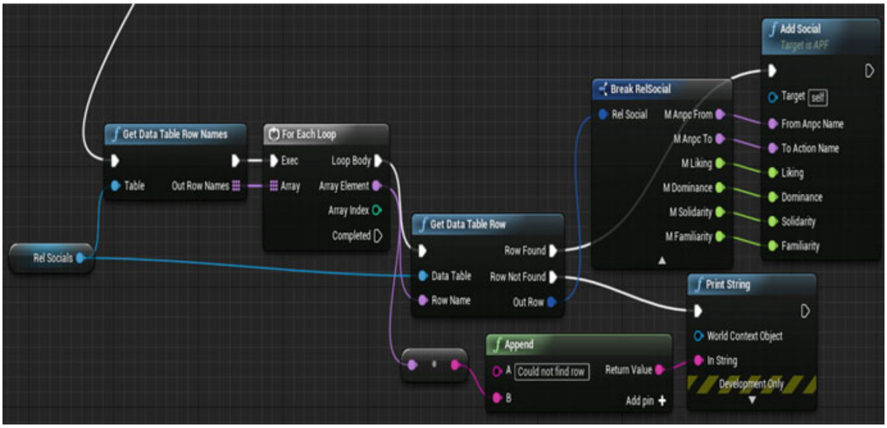

Fig. 8 And example blueprint that uses the APF plug-in to import the social relations

ANPC, leading to exciting scenarios. Alternatively, APF can enhance the tension of 11 Bit studio's title "This War of Mine," where the player has to consider the ANPC's opinions and well-being before sending them off to complete a moral dilemma [23]. Integrating APF into a game engine will allow for novel game mechanics that focus on human emotions and social relationships.

To access the Library and data presented in the paper, please visit https://gitlab.com/humin-game-lab/artificial-psychosocial-framework.

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