Complex Emotions Expression and Recognition for Paranoid Personality Disorder

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***Abstract*—This paper proposes a logical framework for the specification of some types of complex emotions related to Paranoid Personality Disorder (PPD) disease. The complex emotions we are targeting here are *despair* and *spite*. We propose a logic that allows to describe some of the psychological personality characteristics from the side view of emotion theory. It allows to express some emotions existing in Ortony, Clore and Collins theory (OCC theory) and Plutchik theories but yet formalized in logic. The logical model, that we build, can express and recognize the targeted complex emotions (i.e., *despair*, *spite*). This logical model coupled with an inference engine can help diagnosing whether a person is suffering from the emotional PPD disease.**

Keywords–Emotion; Paranoid Personality Disorder; Logic; Despair; Spite.

I. INTRODUCTION

Personality disorder diseases have gained increased importance in the society during the last years. These are common diseases to the extent that epidemiological organizations estimate that the percentage of such diseases among people living in the community is between 5% and 13%, the percentage increases to 30% and 40% for psychiatric outpatients and the percentage becomes even higher for psychiatric inpatients, with estimations between 40% to 50%. The percentage is estimated to be the highest among prisoners, between 50-78% [1].

This field is psychologically broadly covered in the literature. Peay [2] tackled the subject of the relation between law and such diseases. He submitted five key problems for the law in order to deal with people suffering from such diseases. Kemelgor *et al.* took the side of the workplace incivility and its relation with such diseases. They suggest that narcissistic traits are the modal descriptors for difficult employee, regardless of hierarchical role (boss, peer, subordinate) [3]. Wiederman *et al.* investigate the relation between such diseases and sexuality. They studied a group of people instead of individuals and tried to explain the group specifications which can be recognized by it. Their target was to shorten the treatment and understand individuals by examining their generalization [4]. Hazelden foundation published a study, related to addiction and its relation with such diseases, where people addicted to alcohol and drugs are suffering from co-occurring of the diseases [5].

Due to the lack of logic-based approaches related to Paranoid Personality Disorder (PPD), we decide to build a logical model that represents it, with emotional flavour. We propose a formalization of the psychological personality characteristics for PPD diseases where each characteristic is logically represented by its properties [6]. We focus on particular psychological states that are emotional states. We only consider the cognitive structure of emotion rather than emotion as a complex psychological phenomenon including cognitive and somatic aspects (i.e., feeling). The cognitive structure is a compound construction of noetic situations that is founded in someone mind when (he/she) is feeling some type of emotions [7].

In Section 2, we introduce the Paranoid Personality Disorder disease phenomenon, its definition and its reasons. In Section 3, a brief overview is given about emotion and how it can be classified depending on Plutchik's Theory. Complex emotions are then exposed tackling one of the most famous cognitive theory, which is the Ortony, Clore and Collins (OCC) theory. Finally, we address the subject of the facial evidences and its relation to emotions. In Section 4, we present our model to express and to recognize PPD diseases. In Section 5, we briefly discuss a possible implementation of the logical model allowing to decide whether an individual is suffering from such diseases via recognizing the two complex emotions (*despair*, *spite*). Section 6 concludes the paper.

II. PERSONALITY DISORDER

Personality refers to individual differences in a collection of characteristic patterns such as thinking, feeling and behaving or characteristics that humans developed as they grow. Although individuals suffering from a Personality Disorder (PD) have problems in their relations with other people, they tend to have a narrow minded view of the world and a compound of significant problems and limitations in relationships, social encounters, work [8]. A patient suffering from the PPD disease shares some common essential features such as: hold grudges and feels easily rejected and that, except himself, other people are sickening and suspicious [9].

In this paper, we use the work of Fawzi [10] related to PPD disease. It is approximated to be the single academic article published in Iraq that concludes its results from multinational prisoners and it is considered to be one of the rare studies in the Middle East, especially that most of the studies in these countries are theoretical and/or affected by political and religious influences. An individual that suffers from the PPD disease can be resumed as a person who [10]: possesses a sense of *despair* that justifies his aggression towards others, holds *spite* against those who disagreed with him in opinion or belief, is rigid in his cognitive approach as well as in dealing with conflicts, extrapolates, from the usual events, hidden threats and insults directed against him, and finally is preoccupied with unjustified doubts about his friends.

III. BASIC MATERIALS AND MOTIVATION

In this section, we expose briefly some basic and complex types of emotion, their relation with the cognitive theories and facial evidences, then we present the motivation and the objectives of our study.

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A. Emotions

As Becheiraz *et al.* [11] say "An emotion is an emotive reaction of a person to a perception". Basic emotions consist of a relatively small number of prototypes, for example: *sadness*, *fear*, etc. Basic emotions exist and can be identified easily. Complex emotions are emotions that occur as a result of a mixture or combinations of basic emotions [12]. When dealing with basic emotions, we are directed towards the idea that it happens automatically with a little cognitive processing. Complex emotions such as *despair* and *spite*, require more cognitive processing which reflects the agent's interaction and evaluation with some single event [13]. Plutchik [14] classified emotions using a wheel to illustrate some of the rules that shape the relationship among emotions. He identified eight primary emotions (*joy* vs. *sadness*, *trust* vs. *disgust*, *fear* vs. *anger*, *anticipation* vs. *surprise*). The wheel allows to blend multiple emotions to produce more complicated ones such as primary, secondary and tertiary dyads (i.e *love* is the blended emotion of *joy* and *trust*) [15].

B. Cognitive Theories

The basic notion of cognitive theories is that emotions are rational states that could be differentiated depending on cognitive analysis or suggestion components [16]. Depending on OCC Theory, emotions are triggered from the interaction of events (desirable/undesirable), actions (commendation/reproached) and objects. Each of the resulting twenty two emotions is a unique combination of these variables [17].

C. Facial Evidences

Ekman *et al.* [18] found some relationships between basic emotions such as: *happiness*, *surprise*, *fear*, *sadness* and *disgust* and evidences appearing on individuals faces affected by such emotions. The observation focused on the following face features: forehead, eyebrows, eyelids, cheeks, nose, lips and chin. Basic emotions could be blended together to produce new constructed facial evidences. However, when two emotions are blended together, not all the facial evidences of the basic emotions appear on the person's face.

D. Motivation and objectives

Based on the OCC theory and psychology literature, several studies tackle the subject of basic and complex emotions and build logical models of emotions. Guiraud *et al.* [19] propose a model that can recognize expressive speech acts, e.g., to apologize, to thank, to reproach, etc., based on emotions such as Rejoicing, Gratitude, Regret, etc. Lorini *et al.* [13] build a model for reasoning about counter-factual emotions such as regret, rejoicing, disappointment, elation. Steunebrink [17] formalize a psychological model for the twenty two types of emotions found in OCC theory such as love, hate, anger, gratitude, etc. Bonnefon *et al.* [16] build a logical framework for Trust-Related Emotions such as Joy/Distress, Hope/Fear, Satisfaction/Disappointment, Fear-confirmed/Relief and Gratitude/Anger. However, to our knowledge, none were concerned to address the logical formalization of any of the PPD diseases resulting emotions.

Moreover, we have chosen to illustrate the usefulness of our model through the implementation of a PPD disease diagnosis support system. This system is supplied with data related to the patient's knowledge such as his beliefs, goals, etc., and facial evidences of the latter. The choice of facial characteristics was guided by the richness of Ekman's work on this issue which provides a solid foundation on the relationship between basic emotions and facial evidences. We have placed this work in the context of the Plutchick's theory to express and recognize the facial evidences associated to complex emotions, if any. Thereby, our system implements the logical formalization of the two targeted complex emotions (i.e., *despair* and *spite*), gets input (patient data), and helps diagnose PPD diseases.

IV. Logical Formalisation for PPD diseases

In the model we aim to build, we suppose that an agent having a goal α or $(\neg\alpha)$ is responsible to feel some emotions towards that event (goal) [19].

Researchers used different types of logic to build models that serve their aims. We will rely on *df*STIT ("decidable and axiomatizable fragment of STIT") logic in order to overcome problems related to complex emotions representation. STIT ("Seeing to it that") logic [20] has emerged in the nineties as a tool in formal philosophy and recently was used in computer science thanks to its ease to express choices and possibilities of agents and group of agents. The language of STIT logic is built from a finite set of agents called $AGT = \{1, 2, ..., n\}$ and an infinite set of propositional variables called ATM. The well-formed formulas of STIT logic are:

$$\alpha ::= p|\neg\alpha|\alpha \wedge \alpha|[J]\alpha$$

where $p \in ATM$ and $J \subseteq AGT$. Unfortunately the version of STIT was recently proved to be undecidable and unaxiomatizable. Lorini *et al.* [13] proposed an extension to STIT, which is named *df*STIT and proved it decidable and axiomatizable. The *df*STIT was extended with knowledge modalities where modifications were operated to the syntax and semantics of STIT. This logic contains a vital chunk named STIT chunk, which deals with an agent and groups of agents. This chunk reflects the agent (group of agents) actions and concentrates on the effects of these actions. It also has the ability to express the confirmation from the viewpoint of the agent and the group of agents against an output. In Section IV-D, the STIT chunk will play an important role in constructing a cognitive structure to the *spite* emotion.

In the following, we give the syntax and semantics of our PPD logic (*PPDL*) allowing to formalize *despair* and *spite*.

A. Syntax

The ingredients of the *PPDL* syntax are: a finite non-empty set $AGT = \{a_1, a_2, ..., a_n\}$ of agents, a finite non-empty set $EVNT = \{ev_1, ev_2, ..., ev_k\}$ of atomic events, a non-empty set $ATP = \{m, n, ...\}$ of atomic propositions. The *PPDL* language is the set of formulas defined as follows:

$$Sl_{i,j} ::= p|Sl_{i,j} \wedge Sl_{i,j}|\neg Sl_{i,j}$$
$$\Omega ::= [J]Sl_{i,j}|\Omega \wedge \Omega$$
$$\alpha ::= p|Sl_{i,j}|\Omega|\neg\alpha|\alpha \wedge \alpha|Bel_i\alpha|Goal_i\alpha|Poss_iF\alpha|$$
$$Has_i\alpha| < \phi > \Omega$$

where α is an atomic event (goal), p ranges over ATP, J ranges over $2^{AGT}\backslash\{\phi\}$, (i, j) range over AGT.

The other Boolean classical constructions: $\wedge$(conjunction), $\vee$(disjunction), $\neg$(negation), $\rightarrow$(implication), $\leftrightarrow$(equivalence), $\perp$(contradiction), $\top$(tautology) are defined in a standard way.

Operators can be defined as unambiguous symbols that represent a collection of truth functions. They are as follows:

1) Operator ($\mathrm{Bel_i}\alpha$)*:* is used to represent a specific belief of agent *i* about the truthfulness of some event α. However this operator doesn't forcibly refer to the truthfulness of event in the real world. For example, "agent *i* believes that he is beautiful" but really he is not. This operator reads in the form of "agent *i* believes that α is true" [19].

2) Operator ($\mathrm{Goal_i}\alpha$)*:* is used to represent that a specific agent *i* goal is α. An agent must have a goal because of a standard compliance or it will deduce a goal from another agent goal. As an example of the standard compliance: "The hunger of agent *i* will oblige him to search for food. The hungry agent *i* forms a new goal represented by searching for food". The goal operator reads in a form "agent *i* wants α to be true" [19].

3) Operator ($\mathrm{Poss_i F}\alpha$)*:* is used to represent that a specific agent *i* thinks that α will be true in some possible world in the future. In other words, agent *i* thinks that there is at least one world, in which α will be true in all possible future worlds. Basically the $(Poss_i\alpha)$ is an abbreviation of $(\neg\mathrm{Bel_i}\neg\alpha)$ and reads in a form "agent *i* believes that there is a possibility in the future that α will be true" or "agent *i* doesn't believe that α will not be true" [16].

4) Operator ($\mathrm{Has_i}\alpha$)*:* is used to represent that a specific agent *i* has an event α. In other words, an event α is an exclusive ownership of an agent *i*. No other agent in AGT has the ownership of the event α. As an example if "agent *i* has a pen" then no other agent has the ownership of that pen. So, agent *i* has an exclusive ownership of it. Has can be defined as below:
$M, w \models Has_i\alpha$ iff $\forall v \in W, \forall i, j \in$ AGT,
$i \neq j \rightarrow M, v \models Has_i\alpha \wedge M, v \models \neg Has_j\alpha$.

5) Operator ($< \phi > \Omega$)*:* is used to represent that "an event Ω is possibly True" [13].

6) Operator ($[\phi]Sl_{i,j}$)*:* $Sl_{i,j}$ represents the same level event, which means that two agents are at the same level in: Science, Finance, Social Position, etc. This operator is used to represent that "an event $Sl_{i,j}$ is necessarily true" [13].

7) Operator($< \phi > [J]Sl_{i,j}$)*:* is a mixture of the two preceding operators, which are the possibly and necessarily operators. It represents "agent *j* sees to it that $Sl_{i,j}$ is true" or "group *J* sees to it that $Sl_{i,j}$ is true" [13]. The composition $[J]Sl_{i,j}$ is basically written in the form $\neg[J]\neg Sl_{i,j}$ and it is abbreviated to the preceding form. The $[J]$ type operator is used to express the impression of *J* to an event. The *J* symbol will refer to one agent depending on the action responsibility that is related to that agent, while it is possible for the same symbol to refer to a group of agents. An agent or group of agents can express his/their opinion to the same level event (true or false) through the chunk sees to it that($STIT$). The operator ($[J]Sl_{i,j}$) is used instead of ($< \phi > [J]Sl_{i,j}$) to refer to the expression "sees to it that". When the case to consider is related to a group of agents in $[J]Sl_{i,j}$, *J* represents a group of agents and $Sl_{i,j}$ represents an event on which the group *J* must give their opinion. In more detail, the composition $[J]\alpha$ will refer to "group *J* sees to it that α is true no matter what the other agents in the set of agents except *J* to do". If the set *J* contains only one agent such as k, then the composition $[k]\alpha$ will refer to "agent *k* sees to it that α is true no matter what the other agents in the set of agents except *k* do".

Atoms: are tagging some states that share some specifications (goodness, same level, etc.) for a specific agent [13]. In our model we need the following atoms:

8) Atom($PSTV_i\alpha$)*:* is used to represent that an event α is a good thing to an agent *i*. We can say that this atom is used for tagging a positive event to a specific agent. Basically the $(PSTV_i\alpha)$ is an abbreviation of $([\phi]Pstv_i \rightarrow \alpha)$ and reads in a form "α is positive for agent *i* if and only if α is true in all positive states" [13].

9) Atom($Sl_{i,j}$)*:* is used to represent that two agents *i*, *j* are at the same level. The level $(Sl_{i,j})$ is an event which indicates that *i*, *j* are in the same scientific, finance, social position, ... levels. This atom is read in a form "agent i and j are at the same level".

B. Semantics

M= (*W*,*B*,*G*,*P*,*H*,*S*,*V*) represent PPDL semantic where:

1) W: is a nonempty set of possible worlds or states.

2) B: $AGT \rightarrow 2^{W\times W}$ maps every agent i $\in$ AGT to serial, transitive, euclidean relation B_i over W. It represents the semantic of the agent *i* belief chunk (Bel_i), which can be expressed as a set $B_i(w) = \{v|(w, v) \in B_i\}$. This set represents the worlds that an agent *i* thinks that it is possible at world *w*. The seriality of B_i means that an agent *i* has all the time harmonic beliefs, while the transitivity and euclideanity of B_i means that good and bad beliefs of an agent are introspective bound [19].

3) G: $AGT \rightarrow 2^{W\times W}$ maps every agent i $\in$ AGT to a serial relation G_i over *W*. It represents the semantic of the agent *i* goal chunk $(Goal_i)$, which can be expressed as a set $G_i(w) = \{v|(w, v) \in G_i\}$. This set represents the worlds that an agent *i* want, i.e., working towards achieving it. The seriality of G_i means that an agent *i* must all the time have at least one state that he is working to satisfy [19].

4) P: $AGT \rightarrow 2^{W\times W}$ maps every agent i $\in$ AGT to serial, transitive, euclidean relation P_i over *W*. It represents the semantic of the agent *i* possibility chunk $(Poss_i)$, expressed as a set $P_i(w) = \{v|(w, v) \in P_i\}$. Since the chunk $(Poss_i)$ is an abbreviation of $(\neg Bel_i\neg\alpha)$, the set P_i will gain the same relations: seriality, transitivity, euclideanity as in B_i [16].

5) H: $AGT \rightarrow 2^{W\times W}$ maps every agent *i* $\in$ AGT to a serial relation H_i over W. It represents the semantic of the agent *i* has chunk (Has_i), which can be expressed as a set $H_i(w) = \{v|(w, v) \in H_i\}$ that represents the worlds where an agent *i* has an ownership. The seriality of H_i means that an agent *i* must all the time have at least one state that he/she has the ownership.

6) S: $2^{AGT} \rightarrow 2^{W\times W}$ maps a set of agents $J \in 2^{AGT}$ to equivalence relation S_J over *W*. It represents the semantic of the "sees to it that" chunk $([J])$. In *S* the relation on W is a function from W to 2^W, such that for every $J \in 2^{AGT}$, the

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set can be expressed as $S_J(w) = \{v \in W | w S_J v\}$. This set represents the worlds that a set of agents *J* seeing to them that an event is true. S_J is an equivalence relation over W such that this set must satisfy the following bonds [13]:

- $S_J \subseteq S_\phi$;
- $S_J = \cap_{j \in J} S_{\{j\}}$;
- $\forall w \in W, \forall (w_j)_{j \in AGT} \in S_\phi(w)^n, \cap_{j \in AGT} S_{\{j\}}(w_j) \neq \phi$;
- $S_{AGT} = id_W$

where S_ϕ is the relation over all possible outcomes: if $w S_\phi v$ then v is a possible outcome at the current world w.

7) V: $ATM \rightarrow 2^W$ is a valuation function. This set represents the worlds that an agent i wants/works to achieve.

C. A formalization of Disappointment Emotion: Despair

Despair is a complex emotion. This emotion type represents "total loss of hope, which may be passive or may be derive one to furious efforts" [21]. A person feeling with *despair* will not tend to have any hope. He believes that there is nothing he can do to change the situation that causes him to feel *despair* [22]. Relating to the first characteristic, Fawzi says [10] about patients who suffer from the PPD disease, that they are "Possessed by a sense of *despair*, which paid them to aggression on others". Depending on Plutchik's theory, the *despair* is a secondary dyad, which is constructed from the two basic emotions *fear* and *sadness*:

$$Despair = Fear + Sadness \tag{1}$$

Fear makes the agent displeased about the prospect of an undesirable event [17]. Depending on the preceding definition, it can be recognized that *fear* is constructed from two components, which are: agent *i* does not desire an event α to be true, and, in a specific time in the future, agent *i* believes that α may be true. The first component can be understood as, at this moment, the agent *i* does not desire an event α to be true. This understanding could be formalized by: $Goal_i \neg\alpha$. The second component can be interpreted as the agent *i* believes that, in the future, in some way or another, α will be true. Said otherwise, agent *i* believes that α will be true in some possible moment in the future: $Poss_i F\alpha$ where $F\alpha$ means that somewhere, in the future, α will be true . According to the preceding analysis, the epistemic framework for *fear* can be built as [16]:

Definition 1 (*Fear*)

$$Fear_i\alpha = Goal_i\neg\alpha \wedge Poss_i F\alpha \tag{2}$$

Sadness is one of the basic emotions, and it is the result of the person perception of the truthfulness of some event and what he aims to do. In other words, an agent *i* will feel Joy if he knows that some event α is true, agent *i* must believe that α is true and agent *i* goal is α. Relating to *sadness*, if the agent *i* realizes that α is true but his goal is $\neg\alpha$ then he feels *sad* about the fact that α is true. According to the preceding analysis, the epistemic framework for *sadness* can be built as [19]:

Definition 2 $(Sadness)$

$$Sadness_i\alpha = Goal_i\neg\alpha \wedge Bel_i\alpha \tag{3}$$

Depending on Plutchick's definition of *Despair* and definitions 1 and 2, the cognitive structure that recognizes the *despair* is:

Definition 3 $(Despair)$

$$Despair_i\alpha = [Goal_i\neg\alpha \wedge Poss_i F\alpha] \wedge [Goal_i\neg\alpha \wedge Bel_i\alpha] \tag{4}$$

The former description of *Despair* in equation (4) could be minimized to be as we can see in equation (5) since the chunck Bel_i means that $agent_i$ believes that α is always true. While the chunck $Poss_i F\alpha$ means that $agent_i$ believes that, in the future, α may or may not be true:

$$Despair_i\alpha = Goal_i\neg\alpha \wedge Bel_i\alpha \tag{5}$$

Depending on equation (5), the two emotions, which are *despair* and *sadness*, will represent the same emotion. This is a contradiction since the *despair* emotion has a different meaning and effect to the person than the *sadness* emotion. In order to differentiate between them, we searched the literature of psychology and found that Boeree [23] defined the *despair* as "*despair* is sorrow arising from the idea of a past or future object from which cause for doubting is removed. *Despair* happens when *fear* overwhelms *hope*". Johnson *et al.* [24] claimed that the *despair* is a complex emotion and defined it as "intense *sadness* and lack of *hope* as a result of inability to achieve goals". So the *despair* is hopeless while *sadness* is close to Sorrow and can be hopeful. The *despair* will be:

$$Despair = Fear + Sadness + Hopeless \tag{6}$$

Hopeless indicates that there is no possibility in the future to achieve agent *i* goal [23]. In other words, an agent *i* will feel hopeless, when some event happened and that event is the inverse of (his/her) goal and there are no possibility in the future for agent *i* goal to be achieving.

$$Despair_i\alpha = [Goal_i\neg\alpha \wedge Poss_i F\alpha] \wedge [Goal_i\neg\alpha \wedge Bel_i\alpha] \wedge [Goal_i\neg\alpha \wedge \neg Poss_i F\neg\alpha] \tag{7}$$

Depending on equation (5), the equation (7) will be:

$$Despair_i\alpha = [Goal_i\neg\alpha \wedge Bel_i\alpha] \wedge [Goal_i\neg\alpha \wedge \neg Poss_i F\neg\alpha]$$

which could be minimized to equation (8) by removing the redundancy of the chunk $Goal_i\neg\alpha$:

$$Despair_i\alpha = [Bel_i\alpha \wedge Goal_i\neg\alpha \wedge \neg Poss_i F\neg\alpha] \tag{8}$$

So equation (8) will represent the cognitive structure of the *Despair* emotion.

Example 1.
An employee named Tom works in a famous company. He knows somehow that he will be fired from the job, represented by Bel_{Tom}(fired). Tom's aim is not to be fired, represented by $Goal_{Tom}\neg$(fired). Tom realizes that there is no possibility in the future to be not fired represented by $\neg Poss_{Tom} F\neg$(fired). Tom will feel *despair* as we can see below:

$$Despair_{Tom}(\text{fired}) = [Bel_{Tom}(\text{fired}) \wedge Goal_{Tom}\neg(\text{fired}) \wedge \neg Poss_{Tom} F\neg(\text{fired})]$$

In order to improve the accuracy of complex emotion detection, we will cover some facial evidences related to such detection. Facial evidences coupled to *despair* emotion factors will be provided to the knowledge base of the system, allowing

to improve the decision process to be taken by the inference engine. Equation 6 shows that *despair* is composed of three different emotions: *fear*, *sad* and *hopeless*. The first two are basic emotions and have special facial evidences for each. Unfortunately, this is not the case for the *hopeless* emotion. The facial evidences for *fear* are: Eye Brows are raised and drawn together, Upper Eye lid are raised and lower eyelid is tensed, Lips are either tensed slightly and drawn back or stretched and drawn back, Eyes are opened and tense, Mouth opens, Forehead wrinkles drawn to the center while the facial evidences for *sad* are: Inner corners of eyebrows are raised and may be drawn together, Skin below the eyebrow is triangulated with inner corner up, Upper lid inner corner is raised, Corners of the lips are drawn or lip is trembling. When the *fear* and *sad* are blended, not all the facial evidences for each are collected together, instead some evidences of each appears. The blending of *fear* and *sad* will produce the facial evidences: Inner corners of eyebrows are raised and may be drawn together, Upper lid inner corner is raised, Mouth opens by which it is regarded as facial evidences for *despair* emotion [18].

D. A formalization of Resentment Emotion: Spite

The *spite* emotion has been neglected by psychologists in their studies and research. The neglecting case of that emotion type reached the degree that there is no single article published on this topic in journals of psychology, social personality or clinical psychology. The evolutionary biologists Marcus *et al.* [25] defined *spite* as "behaviors that have negative consequences for both the actor and the recipient". *Spite* is a complex emotion and could be classified as an extreme passive type of emotion. The agent who feels it oscillates between harsh agent, sly agent, devastating agent, petty agent and seemingly unharmed agent.

According to Florey [26], *spite* is a negative, harmful feeling, which incites irrational actions. It arises when one believes that someone else exists on an even status as one's self, but has something which one does not, and because of the belief that both individuals are on the same level, one feels that they are being wronged. The two individuals, however, do not exist on the same level, and if they did, then the spiteful one would have legitimate means of achieving the desired object, and therefore, has no reason to feel spiteful". Relating to the second characteristic, Fawzi [10] said of a patient suffering from PPD disease that the patient "Holds *spite* against those who disagreed with him in opinion or belief". By using our logic, we can build a formula to recognize the *spite* emotion:

Definition 4 $(Spite)$

$$Spite_{i,j}(\alpha, Sl_{i,j}) = Bel_i \neg Has_i PSTV_i \alpha \wedge Bel_i Has_j PSTV_i \alpha \wedge Bel_i \alpha \wedge Bel_i Sl_{i,j} \wedge \neg[J] Sl_{i,j} \quad (9)$$

So equation (9) will represent the cognitive structure of *spite* emotion, where the first chunk of it represents that agent *i* will feel *spite* against agent *j* in the existence of two atomic events α and $Sl_{i,j}$. The *spite* will be achieved under the presence of several factors: agent *i* believes that he does not have a positive (good) event, which is α, agent *i* believes that agent *j* has a positive event, which is α, agent *i* believes that α is true, agent *i* believes that he and agent *j* are at the same level such as $Sl_{i,j}$ is true, and the group of agents *J* sees to it that the same level event $Sl_{i,j}$ is false.

Example 2.
Consider two neighbours Joe and Max: Joe is an employee in a small company with a simple salary while Max is a sales manager in a big company with a huge salary. Max bought an expensive new car and Joe knows it somehow, represented by Bel_{Joe}(car), so he believes that Max has the ownership of a positive event, which is represented by $Bel_{Joe} Has_{Max} PSTV_{Joe}$(car), but Joe did not buy an expensive new car, represented by $Bel_{Joe} \neg Has_{Joe} PSTV_{Joe}$(car). Joe believes that he and Max are at the same level, represented by $Bel_{Joe}(Sl_{Joe,Max})$. The belief of Joe came from the view point that he and Max are employees and did not take into consideration other differences. The same level event means that agents Joe and Max are of the same level in science degree, community position, financial position, etc. We assume having a group *J* of persons, which are the friends of Joe and Max, represented by the group (Tom, Tony, Ted). The composition $[J]\alpha$ can be expressed depending on a form of group (Tom, Tony, Ted) sees to it that an event Joe and Max are at the same level is true, no matter what the other agents in the set of agents except Tom, Tony, Ted do. In reality the group *J*, represented by Tom, Tony, Ted did not see that Joe and Max are at the same level. Joe will feel *spite* when the preceding events are satisfied:

$$Spite_{Joe,Max}(\text{car}, Sl_{Joe,Max}) = Bel_{Joe} Has_{Max} PSTV_{Joe}(\text{car}) \wedge Bel_{Joe} \neg Has_{Joe} PSTV_{Joe}(\text{car}) \wedge Bel_{Joe}(\text{car}) \wedge Bel_{Joe}(Sl_{Joe,Max}) \wedge \neg[\text{Tom,Tony,Ted}]\text{sees to it that}(Sl_{Joe,Max})$$

Unfortunately, there are no facial evidences relating to *spite* since this type of emotions isn't constructed from basic emotions that we can blend.

V. LOGICAL MODEL IMPLEMENTATION

The proposed system has the ability to differentiate the *despair* and *spite* emotions, which are constructed from (Input, Inference Engine, Knowledge Base and Output) as we can see in Figure 1. The Input of the system is data ranging between facial evidences and the factors of the targeted emotions of the agent. The inference engine will compare the system input to the knowledge base in order to differentiate the two targeted complex emotions. Relating to *despair* emotion, the stored data in the knowledge base are facial evidences and emotion factors while the data for *spite* are only emotion ones. The system output is to differentiate complex emotions such as *despair* and *spite*. Depending on this differentiation, we can diagnose if the agent suffers from PPD disease.

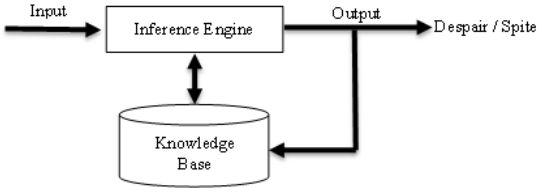

Figure 1. implementation system structure

As an example, consider two students Ed and Sam. Ed is dismissed from the university. Ed's friend Sam has a girlfriend. Let us start by analyzing the event: Ed is dismissed from the university. Ed knows somehow that he is dismissed from the

university, represented by Bel_{Ed}(dismiss study). Ed's goal is not to be dismissed from his university, represented by $Goal_{Ed}\neg$(dismiss study). Ed realizes that there is no possibility in the future to be not dismissed from his university, which is represented by $\neg Poss_{Ed}F\neg$(dismiss study). The system can conclude that Ed feels *despair* when the preceding events are satisfied as we can see below:

$$Despair_{Ed}(\text{dismiss study}) = Bel_{Ed}(\text{dismiss study}) \wedge$$
$$Goal_{Ed}\neg(\text{dismiss study}) \wedge \neg Poss_{Ed}F\neg(\text{dismiss study})$$

When Ed face shows some evidences such as: inner corners of eyebrows are raised, upper lid inner corner is raised, the system cannot conclude that Ed feels *despair* since one of the facial evidences ("Mouth opens") is unavailable. Despite this problem, the system enables to diagnose that the agent feels *despair* from the existence of the emotion factors.
Now, let us consider the event: Ed's friend Sam has a girlfriend. Sam is an attractive person while Ed is not. Ed knows somehow that Sam has the ownership of a positive event (having a girlfriend), represented by $Bel_{Ed}Has_{Sam}PSTV_{Ed}$(gf) but Ed did not have a girlfriend, which is represented by $Bel_{Ed}\neg Has_{Ed}PSTV_{Ed}$(gf). Ed knows that Sam has a girlfriend, which is represented by Bel_{Ed}(gf), which means that Ed believes that an event of "have a girlfriend" is true. Ed believes that he and Sam are at the same level relating to attractiveness, which is represented by $Bel_{Ed}(Sl_{Ed,Sam})$. The belief of Ed came from the view point that he and Sam are beautiful and did not take into consideration the other differences. We assume having a group *J* of persons who know both Ed and Sam that is represented by the set (John, Joe, Jack). The composition $[J]\alpha$ can be expressed in a form "group (John, Joe, Jack) sees to it that an event (Ed and Sam are at the same level) is true no matter what the other agents in the set of agents except (John, Joe, Jack) do". In reality the group *J* did not see that Ed and Sam are at the same level, which is represented by Ed and Sam are at the same level. The system can conclude that Ed feels *spite* when the preceding events are satisfied as we can see below:

$$Spite_{Ed,Sam}(\text{gf}, Sl_{Ed,Sam}) = Bel_{Ed}Has_{Sam}PSTV_{Ed}(\text{gf}) \wedge$$
$$Bel_{Ed}\neg Has_{Ed}PSTV_{Ed}(\text{gf}) \wedge Bel_{Ed}(\text{gf}) \wedge Bel_{Ed}(Sl_{Ed,Sam})$$
$$\wedge \neg[\text{John, Joe, Jack}]seestoitthat(Sl_{Ed,Sam})$$

VI. Conclusion

In this paper, we presented a logic named PPDL that allows us to formalize and to reason about two complex emotions that are *despair* and *spite*. Unfortunately the OCC and Plutchik's Theories could not cover the emotional states of psychological personality's characteristics for the PPD disease. We overcome this problem by going deep in the psychology literatures and searching for discreet representation to reach to the unified formalization for the disease. Such formalization aims to capture the logical structure underlying a chosen psychological model of emotion; the resulting logical specification of emotions can then be used to reason about properties of emotions in a formal manner, thus gaining more insight into the workings of human emotions. By the unified formalization, we reach the goal of representing and recognizing the PPD disease by building a logical model with emotional flavour.

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