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Implementing WordNet Personality Adjectives as Influences on Rational Agents

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***Abstract*: In this paper we present a methodology dedicated to the computational implementation of personality traits in Conversational Agents. First, a significant set of personality-traits adjectives is registered from thesaurus sources. Then the lexical semantics related to personality-traits is extracted while using the WordNet database and it is given a formal representation in terms of so-called Behavioral Schemes. Finally, we propose a framework for the implementation of those schemes as influence operators controlling the decision process and the plan/action scheduling of a rational agent.**

***Keywords*:** Computational Personality, Rational Agents, WordNet Database, Behavioral Schemes**.**

I. Introduction

A. Rational and psychological agents

This study considers the particular context of conversational situations where three entities are in bilateral interaction: a human user (U), an assistant agent (A) and a computer system (S). In a typical UAS situation, the user performs some activity on/with the system; at times, the user can solicit the agent for general advice or for direct help upon the system or the task at hand. Actually, this definition, stemming from [1], encompasses a large class of conversational interactions ranging from situations where the user has the control upon the agent to opposite situations where the agent has a leading/intrusive role: Presenters, Helpers, Butlers, Friends, Companions, Teachers, Trainers and Coaches. An assistant agent, in the UAS situation, has two faces needing distinct capabilities:

— The control face, directed towards the system, and
— The dialogical face, directed towards the user.

Controlling a computer application requires both a symbolic model of the application and a rational reasoning capacity over that model [2]. In the following, we will refer to the control face of an agent as the **rational agent** in a way compliant with works in the two fields of Artificial Intelligence [3] and Multi-Agent [4].

Many agent cognitive architectures are based on practical reasoning, in the following of the SOAR and ACT-R frameworks [5][6] or more recently BDI-agents [7][8]. In Bratman's theory of practical reasoning [9], an agent's behavior is modeled by specifying *beliefs*, *goals* and *plans* and is effectively produced through the agent's deliberation cycle. These architectures have been quite successful at creating both autonomous and multi-agent systems capable of operating in computational contexts.

Dialoguing with the user requires three main elements: a) a conversational interface (often multimodal) [10][11]; b) a rational reasoning capacity able to process user's input to generate factual replies as output [12]; c) the expression of the agent's personality according to its actual role in one of the UAS situations listed above. In the following, we will refer to the agent's personality as the **behavioral agent**.

As agents are more and more in interaction with human users (both as autonomous conversational agents [1][13] or as part of mixed communities [14][15][16]), authors have claimed that agents should be not only competent (thanks to their symbolic reasoning capacities) but also psychologically relevant in order to increase: a) their acceptability factor [17], especially when they deal with people of the general public, b) the efficiency factor of the agent/human interactional process itself (e.g. comprehension and memory in teaching tasks [18][19]).

Moreover, since the notion of Believable Agents was introduced in the mid 80's [20][21] there has been various attempts at implementing psychological features into cognitive architectures. For example, the works of Rousseau and Hayes-Roth [22][23] have established a first ground by providing examples of how personality factors can be implemented into the cognitive architecture of artificial agents.

B. Personality traits

In the literature on Psychology, a particular interest has been given to the systematic description of the personality of a person through so-called personality dimensions. Although still subject to discussion, the use of personality traits to describe the psychology of an individual is widely spread. The most successful paradigm for the taxonomy of personality traits is the Five Factor Model (FFM), which is the outcome of convergent research from many authors in Psychology during the last twenty years. This paradigm has taken upon Cattell's classification, still prominent in the 80s, which was distinguishing 16 factors [24]. Cattell’s classification was supported by Eysenck's Personality Questionnaires (EPQ), which are questionnaires (generally with yes/no questions) used to assess the personality traits of a person [25][26].

Another approach to the taxonomy of traits is based on natural language and more precisely lexical resources [27], such as the glosses found in dictionaries. The lexical hypothesis states that most of socially relevant and salient personality characteristics have become encoded in the natural language [28]. The lexical approach has been promoted by Goldberg who claimed that “personality vocabulary provides an extensive, yet finite, set of attributes that people speaking a given language have found important and useful in their daily interactions” [29]. In 1990, Goldberg tried to define a small set of 475 common trait adjectives grouped into 131 categories of factors [30]. It issued in 1992 into a 50-item instrument using so-called `transparent format' [31], which finally contributed to the definition of the FFM. The FFM is based on five large classes of psychological traits (often named Big Five model or OCEAN), which are listed in the left part of Figure 1.

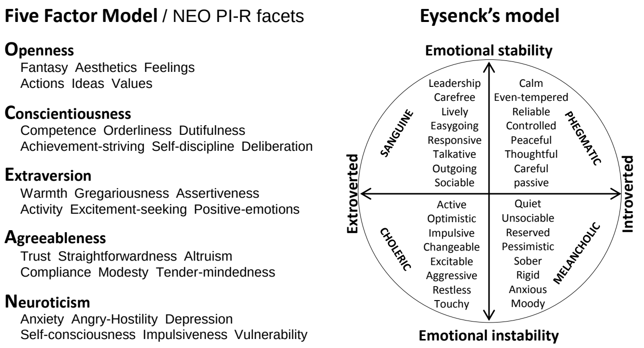


Figure 1. ─ Two personality traits taxonomies: left) Five Factor Model with 30 NEO PI-R facets; right) Eysenck's Two Factors model with 32 classes.

The FFM being a very generic classification, several authors have tried to refine this taxonomy by dividing the FFM classes into so-called *facets* [32][33][34]. John et al. [35] have shown that these facet lists have many similarities, although the number of facets can vary a lot. For example, one can compare the 30 facets of the so-called NEO PI-R proposition of Costa and McCrae [33] that span over the five classes of FFM listed in Figure 1-left, to the 32 classes of Eysenck's taxonomy [36] that span only over two of the FFM classes (E and N) listed in Figure 1-right.

C. Elicitation of personality traits

Starting from psychological studies, recent computational approaches on behavioral agents can be divided in two main fields:
a) The multimodal expression of the psychology using Embodied Conversational Agents (ECA) [13];
b) The proposition of formal causal models trying to emulate the evolution of the intensity of the psychological phenomena (typically, the OCC model [37]).

In both cases, basic psychological phenomena have been favored like the expression of Ekman's emotions with virtual characters [38] or the genesis of basic mental states through the classic notions of arousal, appraisal and coping. In turn, less work has been done on more complex phenomena such as high level mental states and personality traits (see Section 4 for a survey of such works related to computational implementation). This is the reason why we are interested in providing a rational agent with a computational implementation of a model of personality, which will be mainly based on the FFM personality traits. To achieve this, two main processes are defined, each one being divided in two sub-steps:

Process 1:
Elicitation of the basic constituents of a personality.

Three levels can be envisioned: emotions, traits and roles. In this study, we will focus on traits because they are intrinsic and stable (at least over a given conversational session). While the five factor model provides a popular approach to trait classification, this model is too general to exhibit the basic sought out constituents. Therefore we have to use the refined version of [32], which adds NEO PI-R facets, thus providing 30 bipolar classes. However, the FFM/NEO PI-R classes still remain very general and do not provide much source for computational implementation.

At this point, two possibilities can be envisioned:
1) Use items as found in questionnaires, e.g. we can consider the first three items from the 100 items EPQ questionnaire of Eysenck [25]:

- Do you have many different hobbies? Y/N
- Do you stop to think things before doing anything? Y/N
- Does your mood often go up and down? Y/N

2) Use glosses describing distinct senses of a word, as found in dictionaries (see an example in Section 2.2).

While these two sources are very promising for providing descriptions of actual human psychological behaviors (with the goal of computational implementation in perspective), the second approach was chosen for two reasons:
1) Dictionary glosses provide direct descriptions of senses related to adjectives, while questionnaire items are linked indirectly and a posteriori to the classes of a given taxonomy;
2) With new Natural Language computer based tools, it is possible to process systematically and automatically the required notions: Word-Sense-Gloss (WSG). This approach has two other advantages: a) it makes it possible to put WSG in relation with the whole language using the relational links in WordNet; and b) working at the sense level (WordNet synsets) facilitates cross-language span of the work. To do this, we rely on data offered by linguistic resources through the lexical semantics of thesaurus and databases such as WordNet [39].

To build a first set, we have followed a methodology in two steps, detailed in the section 2:

Step 1: Gathering a set of personality-trait adjectives from thesaurus sources, available on the Internet;

Step 2: Associating lexical semantics to these adjectives, using their senses and glosses from the WordNet base.

Process 2:
Definition of a computational framework for the implementation of basic constituents.

Again, we have followed a methodology in two steps, which are detailed in the section 3:

Step 1: Associating with the senses (related to personality traits) a formal description called a Behavioral Scheme. Given an agent A with a set of capacities (*i.e.* a set $\mathbb{A}$ of atomic actions $\alpha_i \in \mathbb{A}$ that the agent can perform upon the system), a Behavioral Scheme $\sigma \in \mathbb{S}$ is defined as a symbolic representation of the attitude of the agent with regard to its capacities. This is presented in sections 3.1 and 3.2.

Step 2: Defining so-called Behavioral Heuristics $H\sigma_i$ implementing the schemes σ_i. In section 3.3, we present the principle of the Rational and Behavioral (R&B) agents, stating that $H\sigma_i$ are implemented in terms of influence operator controlling and/or altering the rational process of the agent.

II. Personality Adjectives

A. Resources for personality-trait adjectives

The process of gathering a set of personality adjectives $p_i \in \mathbb{P}$ has been carried out to determine the most popular p_i in order to exhibit the most socio-cognitively salient σ_i. As a second order requirement, we also wanted a significant (but not necessarily exhaustive) coverage of the p_i. This is the reason why, to collect the so-called $\mathbb{C}$p corpus, we relied on 10 different Internet sources explicitly claiming to provide "lists of adjectives describing personality traits" (the sources are summarized in Table 1).

We have identified the most significant pi by sorting the corpus according to the frequency of appearance of each pi in the selected sources (the theoretical maximum score is hence 10), as illustrated in Table 2.

B. Working with lexical semantic

In Table 2, adjectives are given as lemmas. Generally, to a lemma are associated several lexical semantics senses/meanings (noted /thesense/). The first way to assess the various meanings of a lemma is to consult a dictionary like for example the online version of the Merriam-Webster dictionary (MW) that gives the following description of the lemma 'friendly' with four main senses (the first one having three variants):

friend·ly \ˈfren(d)-lē\ Function: *adjective* Inflected Form(s): friend·li·er; friend·li·est Date: before 12th century

1 : of, relating to, or befitting a friend: as **a:** showing kindly interest and goodwill **b:** not hostile <a friendly merger offer>; *also* **:** involving or coming from actions of one's own forces <friendly fire>
c: CHEERFUL, COMFORTING <the friendly glow of the fire>
2 : serving a beneficial or helpful purpose
3 : easy to use or understand <friendly computer software> — often used in combination <a reader-*friendly* layout>
4 : COMPATIBLE, ACCOMMODATING <environmentally friendly packaging> — often used in combination <a kid-*friendly* restaurant>

synonyms see AMICABLE — friend·li·ly \ˈfren(d)-lə-lē\ *adverb* — friend·li·ness *noun*

A more automated way to associate senses to lemma relies on the use of a lexical database like WordNet (WN). In WordNet, the senses are called synsets and a gloss, optionally with usage examples, is given for each synset. Moreover, as in the MW, lexical relations (antonym, synonym, etc.) are provided. In Table 3, we give the WN entries (without lexical relations) of adjectives with frequency 9 or 8 in Table 2.

If we consider the lemma 'friendly', MW and WN descriptions are not exactly the same but they share the personality-trait related senses: 1 = /pally/, 1a = /favorable/. This provides evidence that one can rely on MW and WN for a good coverage of the required senses. More important, the overall observation of the glosses related to personality description in MW and WN shows that the descriptions are generally given in terms of:

a) The *manner* a subject performs actions or activities e.g. /alert/ = "quick and energetic"

b) The *attitude* of a subject interacting with others, e.g. /favorable/ = "inclined to help or support"

This is the reason why we propose in the next section a symbolic representation of the senses related to personality description in terms of so-called **Behavioral Schemes** that capture subjects' manners and attitudes.

III. Implementation

A. Formal notations for behavioral schemes

From the examination of the relevant WN synsets (i.e. only those related to personality description) of the 25 most frequent adjectives in Table 2, it is possible to establish that their glosses can generally be expressed as a Behavioral Scheme of the form:

$$\sigma \equiv F(Pi(a), \ldots) \text{ or } \sigma \equiv F(Pi(Pj(a), \ldots))$$

Where:
— **F** (performative): denotes a pair of notions (a positive one and its antonym) about a disjunction of P_i.

Examples:

TEND (*resp.* AVOID)
the subject tends to do or like (resp. avoid) $P_i(a)$;

POSSESS (*resp.* LACKOF)
the subject has (resp. lacks) the feature(s) $P_i(a)$.

— **P** (predicate): denotes notions related to manner and attitudes of subject *x* about the entity a (optionally involving another subject *y*).

Examples:

INTENT
x intends to perform a in the near future;

ADOPT
x adopts a as a goal for the near future;

Source	Word count
1. http://personal.georgiasouthern.edu/~jbjoy/Adjectives.html	315
2. http://www.keepandshare.com/doc/view.php?u=12894	182
3. http://www.esldesk.com/vocabulary/adjectives.htm (general adjectives)	733
4. http://www.lingolex.com/personalidad.htm	52
5. http://www.lesn.appstate.edu/fryeem/RE4030/character_trait_descriptive_adje.htm	183
6. http://www.mckinnonsc.vic.edu.au/la/lote/german/materials/describe/pers-adj.htm#top	363
7. http://www.learnenglish.de/grammar/adjectivepersonality.htm#positive merged with: http://www.examples-help.org.uk/parts-of-speech/personality-adjectives.htm	277
8. http://jobmob.co.il/blog/positive-personality-adjectives/ (biased by 'positiveness')	130
9. http://www.nonstopenglish.com/exercise.asp?exid=440	20
10. http://www.scribd.com/doc/2212798/Adjective-List	80
TOTAL	**2335**
TOTAL of union (words different)	**1303**

Table 1. Sources of personality adjectives. Source 3 is quite large because we extended the coverage of Cp with one source of more general adjectives; Source 7 is a merged list of two close-related sources.

Adjectives	Freq.
—	10
friendly	9
lively, kind, helpful, ambitious	8
proud, excited, energetic, cheerful, calm, warm, talented, silly, quiet, lazy, happy, gentle, generous, funny, clumsy	7
successful, pleasant, nervous, eager, determined, courageous, cooperative, brave, tough, sensitive, mature, good, faithful, enthusiastic, crazy, bright, bad	6
wonderful, witty, thoughtful, selfish, nice, modern, lucky, jealous, fantastic, fair, exuberant, charming, zany, wise, unusual, trustworthy, sincere, shy, sad, romantic, responsible, placid, loyal, loving, jolly, dull, careless, arrogant, anxious	5
timid, aggressive, willing, upbeat, reflective, likeable, knowledgeable, industrious, impartial, efficient, dynamic, discreet, cultured, cowardly, alert, vivacious, uptight, upset, tense, splendid, relieved, perfect, obedient, naughty, lovely, joyous, hungry, hilarious, glorious, fine, evil, encouraging, enchanting, embarrassed, elated, delightful, comfortable, cautious, zealous, worried, wasteful, tricky, tender, stubborn, strange, stingy, slow, scary, receptive, protective, patient, passionate, outgoing, nasty, modest, jittery, ignorant, humorous, horrible, healthy, grumpy, curious, cruel, confused, careful, athletic, angry, adaptable	4
frank, thrifty, punctual, passive, considerate, confident, adventurous, sensible, self-confident, reliable, mean, honest, hard-working, conceited, weak, wary, vigorous, unbiased, tight, succinct, stimulating, steadfast, skillful, selective, seemly, sedate, ruthless, righteous, rhetorical, resolute, quarrelsome, productive, possessive, plucky, plausible, peaceful, painstaking, noisy, naive, materialistic, malicious, level, instinctive, honorable, harmonious, grouchy, greedy, flippant, finicky, fearless, fabulous, exclusive, excellent, entertaining, endurable, eminent, disagreeable, diligent, detailed, decorous, decisive, debonair, dazzling, dashing, credible, coherent, capable, boundless, boring, apathetic, aloof, alluring, abrupt, wild, wicked, weary, testy, smiling, rich, repulsive, obnoxious, mysterious, lonely, hurt, helpless, envious, depressed, defiant, dangerous, creepy, combative, clever, bored, annoying, annoyed, amused, agreeable, young, tolerant, tired, tall, sympathetic, superficial, strong, spiteful, sloppy, simple, short, shallow, serious, self-conscious, secretive, rude, religious, realistic, prickly, pathetic, opinionated, open-minded, open, natural, narrow-minded, musical, itchy, intelligent, great, gifted, frail, forgetful, foolish, elegant, educated, dramatic, domineering, dizzy, daring, creative, cool, cold, childlike, boorish, black, better, beautiful	3
… (abridged)	2
… (abridged)	1

Table 2. Most occurring adjectives in the Cp corpus.

Freq	Adjective	Synsets	Gloss (non personality related synsets are in *small italic*)
9	friendly	/pally/	characteristic of or befitting a friend
		/allied/	*belonging to your own country's forces or those of an ally*
		/easy/	*easy to understand or use*
		/favorable/	inclined to help or support; not antagonistic or hostile
8	lively	/vital/	full of spirit
		/eventful/	*filled with events or activity*
		/frothy/	full of life and energy
		/Springy/	*elastic; rebounds readily*
		/alert/	quick and energetic
		/racy/	full of zest or vigor
8	kind	/tolerant/	tolerant and forgiving under provocation
		/genial/	agreeable, conducive to comfort
		/openhearted/	having or showing a tender and considerate and helpful nature; (…)
8	helpful	/helpful/	providing assistance or *serving a useful function*
8	ambitious	/pushy/	having a strong desire for success or achievement
		/challenging/	*requiring full use of your abilities or resources*

Table 3. WordNet synsets associated with the 5 most frequent pi in the Cp corpus.

SUGGEST
x suggests *y* that action a should be a good thing to do;
TELL
x tells *y* fact a.

Moreover, predicates can wrap a second order predicate P_j such as to express a modality.

Examples:

ISQUICK(P_j(a))
x is quick when doing P_j(a).

— **a** (argument): denotes any entity that can be the object of a predicate.

Examples:

Operation
any action in the system;
help-action
x acts on the system on behalf of *y*;
help-information
x provides *y* with a help information;
comfort
x expresses "words of comfort" to *y*;
void/any
are the empty argument and anything argument.

It is also useful to predefine basic schemes occurring frequently in glosses. Basic schemes are noted as uppercase symbols defined with the following syntax:

BASICSCHEME = F(Pi("a")).

For example, here is the description of some basic schemes (some are used in examples of section 3.2)

```
HELPFUL       = TEND[INTENT["help-action"]   ∨
                      SUGGEST["action"] ∨ TELL["help-information"]]
COMFORTING  = TEND[EXPRESS["comfort"]]
PAIR            = TEND[FEEL["same-rank"]]
JOYFUL         = TEND[FEEL["joy"]]
TOLERANT      = AVOID[REACTTO["provocation"]]
ENERGETIC     = POSSESS[PHYSICAL["energy"]]
SILLY            = LACKOF[ISSERIOUS["void"]]  // empty argument
```

B. Annotation of personality adjectives

Personality adjectives can be manually annotated by associating to each of their relevant WN synsets a set of elements, composed of schemes of the form F(P(...)) or of basic schemes symbols. For example, the annotation of adjectives 'friendly', 'lazy' and 'lively' is as follows:

```
friendly = {
   /pally/        =              // use of predefined basic schemes
{HELPFUL,COMFORTING,TOLERANT,PAIR},
   /favorable/  = {HELPFUL}
 }

lazy = {
  /workshy/    =  AVOID[EXECUTE["action"], ISHARD["action"]]
                       // first scheme form
  /slow/        = TEND[ISSLOW[EXECUTE["action"]]]
                       // second scheme form (predicate wrapping)
 }

lively = {
 /frothy/   =  {"ENERGETIC"},
  /alert/    = TEND[ISQUICK[REACTTO["event"]]],
  /racy/    = TEND[ISQUICK[EXECUTE["action"]]]
                // antonym of /slow/ = ISSLOW[EXECUTE["action"]]
 }
```

From the annotation of the 25 first adjectives of Table 2, a list of 57 synsets has been exhibited and then submitted to the definition process described above, thus producing 39 distinct behavioral schemes. This enabled a first assessment of the distribution of the entities involved in the behavioral schemes.

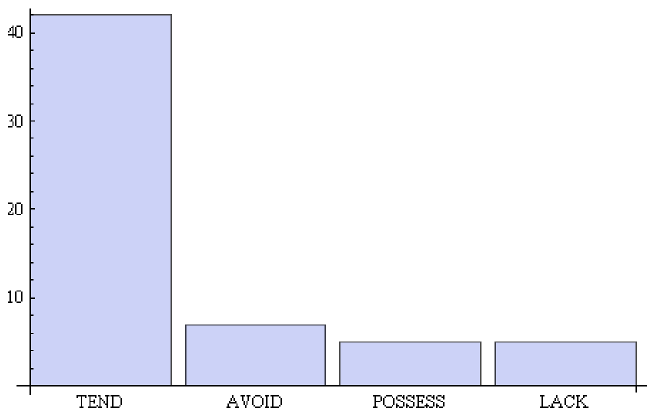


Figure 2.a — Frequency of the 4 main performatives of behavioral schemes for 25 most frequent adjectives.

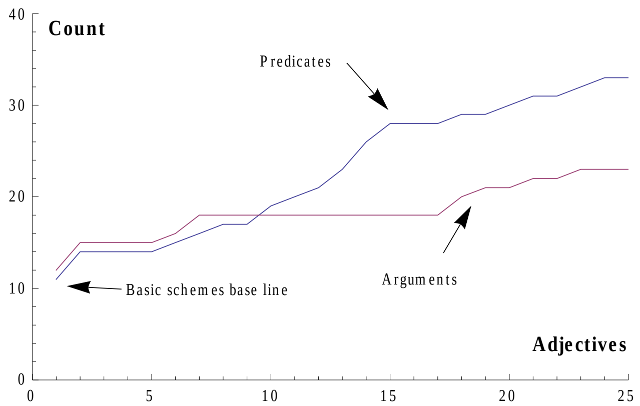


Figure 2.b — Evolution of the number of predicates and arguments used while annotating the adjectives, for the behavioral schemes of the 25 most frequent adjectives.

Consequently, the following observations can be made:

1) Figure 2.a shows that the positive pole of the TEND operator is widely used to express personality traits; the POSSESS-LACK operator associated with features is much less used. Consequently, the proposed F operators have proved sufficient to express the 57 synsets associated with the 25 annotated adjectives.

2) Figure 2.b shows that arguments are quite stable whereas the predicates are not yet in a log distribution with 25 adjectives: hence we can consider that we have a good coverage for the arguments but the coverage of the predicates is not yet complete.

Predicates	Arguments	Freq.
–	void	20
–	action	9
INTENT, FEEL	help-action	8
SUGGEST, TELL, EXPRESS	help-information	7
–	–	6
–	–	5
REACTTO, ISPLEASANT	comfort, provocation, joy, event	4
DESIRE, PHYSICAL, SHARE	same□rank, energy	3
OVERESTIMATE, OBEY, ISQUICK, ISEFFICIENT, EXE□UTE, ISELEGANT, ISTENSE	success, positive-probability, command, goal, resources, joke	2
ADOPT, BUILD, ISDIGNIFIED, STRONG, ISWORKINGHARDON, ISAGITATED, TEND, ISSERIOUS, ISFOOLISH, ISSHOWY, ISOBTRUSIVE, ISACTIVE, ISSLOW, ISHARD, ISOK, EXPECT	plan, self-worth, emotion, thrilled, information, action-result, anxiety	1

Table 4. Frequency of the 33 predicates and 23 arguments used in behavioral schemes of the 25 most frequent adjectives.

3) Table 4 reveals that the most frequent predicates are either intrinsic (INTENT, FEEL, DESIRE) or interpersonal (SUGGEST, TELL, EXPRESS), and that frequent arguments (not void) are actions or about actions, then about interaction (comfort, provocation).

C. *Behavioral scheme implementation*

In [40] we have proposed a framework dedicated to the study of artificial agents that exhibits both rational and behavioral reasoning (i.e. symbolic reasoning about psychological phenomena): the R&B framework. The R&B framework primarily focuses on the implementation of psychological behaviors in terms of influence operators controlling and/or altering the rational decision process of the agent.

Formally, the rational process of the agent is based on the execution of plans involving atomic actions $\alpha_i \in A$ corresponding to the capacities of the agent (i.e. what the agent can perform, at a given moment, upon the system). Plans are built from several αi combined with compound operators (seq, alt, par, case, etc.) controlling the procedural scheduling of the plan. Moreover, declarative (sub)-plans are composed of four sets:

<goals-set, preferred-actions-set, optional-actions-set, default-actions-set>.

In the following example of a plan description, we use the four compound operators:

Name	Symb.	Semantics (informal)
seq	;	$\alpha_1;\alpha 2$ Done(α_1) is a precondition. to start execution of action α_2
alt	|	$\alpha_1 \vert \alpha 2$ Chooses randomly either α_1 or α_2 and executes it
par	||	$(\alpha_1 \Vert \alpha_2) = (\alpha_1;\alpha_2) \vert (\alpha_1;\alpha_2)$ Chooses one of the sequences and executes it
case	→	$guard_1 \rightarrow \alpha_1$ $guard_1$ is an explicit precondition that must be True for α_1 to get executed. If several guards are True, then one is randomly chosen and executed

Example of plan:
We give a formal example of a simple plan p, first in textual form:

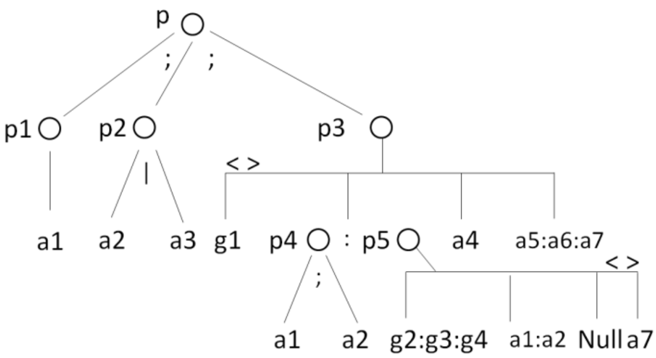
Definition statements of plan p:

```
p  = p1;p2;p3          // sequence of  sub plans p1, p2, p3
p1 = a1                // a sub plan can be a terminal action
p2 = a2|a3             // random choice between elements a2, a3
p3 = <g1,  p4:p5, a4, a5:a6:a7>     //  declarative plan
p4 = a1;a2
p5 = <g2:g3:g4,  a1:a2,   Null,   a7>
```

In the later we have:

g2:g3:g4	is the goal set
a1:a2	is the preferred set
Null	is the optional set
A7	is the default set

Plan p can also be expressed in a tree form, as follows:



D. *Influence operators*

We call influence operators heuristics used in the implementation of the behavioral schemes, in terms of their influence over the execution of the rational plan (such as defined in Section 3.2). Influence operators act as meta-heuristics in the execution of plans. In the R&B framework, two main classes of influence operators are defined:

1) Preference operators: Typical preferences preserve the rational process of the agent, that is one cannot distinguish the formal effects (in terms of logical post-conditions) of a plan on which a preference operator has been applied. Preferences operators can be divided in two main categories:

a) Choice: they enable the agent to choose between equal (in terms of post conditions) alternatives occurring either during the procedural scheduling (e.g. in par and alt operators) or in a declarative plan (e.g. between actions of preferred-actions-set, optional-actions-set or default-actions-set);

b) Modal: they control the way an action is performed, not its formal result (e.g. the speed of a walk from location a to b).

2) Desire operators: they enable the agent to express its intimate mental states, in a more drastic way, by altering the plans (e.g. by adding/deleting actions and/or sub plans) thus possibly leading to non-rational behaviors. They are not discussed in this paper.

Example: Implementation of influences associated with personality-trait adjective ‘lazy’.

Suppose we want to implement a “lazy agent” in terms of preference operators controlling the scheduling process of a plan like p as defined above. As seen in Section 3.2, lemma ‘lazy’ is associated with two synsets /workshy/ and /slow/ that can be implemented with two heuristics:

$H_{/workshy/}$ = AVOID[EXECUTE["action"], ISHARD[“action”]]

A policy can be proposed respectively for each element of this scheme, EXECUTE and ISHARD, which are in disjunction:
1) Never execute optional actions (*e.g.* do not execute action a4 in sub plan p3);
2) Suppose there exists a ranking operator that can sort actions {a1, .., a7} while using a measure function:

$$\mu_{hard\text{-}easy}: a_i \rightarrow [-1., 1.]$$

It is then possible to choose the best ranked action whenever rationally equivalent actions are executable (say, in alt or par constructs *e.g.* a2|a3 or in declarative parts, *e.g.* p4:p5 or a5:a6:a7).

$H_{/slow/}$ = TEND[ISSLOW[EXECUTE["action"]]]

In this scheme, ISSLOW is a modal operator that influences the manner an action is executed. Suppose that **some actions a_i of plan p have an extra parameter** $\phi \in [0.,1.]$ for speed control. Then each time an a_i action is scheduled, $H_{/slow/}$ sets $a_i.\phi$ to value 0.2 for example.

E. Implementation

We have developed a software toolkit, called DIVA for the implementation of Embodied Conversational Assistant Agents on the Internet where agents are personified by graphic characters animated on the client page that interact in a multimodal way (linguistic, gestural, …) with users. The DIVA software and documentation is accessible and downloadable freely[1].

Independently, a first version of the R&B framework has been implemented in Mathematica from Wolfram Research. The R&B toolkit and its tutorial can be accessed and downloaded freely on the R&B project Web page[2].

Moreover, the processing of the personality adjectives described in this paper freely accessible and downloadable as XML resource files, on the R&B project Web page[3]. It contains our classification, in the FFM/NEO PI-R taxonomy, of the WordNet glosses of the 1055 most salient personality adjectives taken from the sources defined in Table 1.

[1] http://www.limsi.fr/~jps/online/diva/divahome/
[2] http://www.limsi.fr/~jps/research/rnb/rnb.htm
[3] http://www.limsi.fr/~jps/research/rnb/toolkit/taxo-glosses/taxo.htm

IV. Related Work

A. Traits in agent cognitive architectures

Recent work on implementation of psychological phenomena with BDI agents has been successfully carried out in the Multi-agent community: for example, CoJACK [41][42] extends the multi-agent creation platform JACK [43] (which implements the BDI theory [8]) with a layer that intends to simulate physiological human constraints. For example, the duration taken for cognition, working memory limitations (*e.g.* ‘losing a belief’ if the activation is low or ‘forgetting the next step’ of a procedure), fuzzy retrieval of beliefs, limited focus of attention or the use of moderators to alter cognition. There are two main differences with our work:
a) CoJACK targets a class of human behaviors not related to personality traits but to physiological human constraints that are closer to reasoning over agent's capacities than to agent's psychology (the applicative field is close to that of the PMFserv framework mentioned below;
b) CoJACK directly implements a small set of predefined constraints whereas our approach is capable of handling a large class of influences operators.

Recently, Allbeck and Kress-Gazit [44] have proposed a framework where complex instructions can be given by the user, especially by using natural language to control the agent. In that case, the agent is a robot (hence a single agent) acting in a complex environment. The user's instructions constrain the execution of the agent's plan. This work is focused on dynamic actions and planning for robots. The constraints applied to the actions and plans are: a) provided by an external source (a human user) and b) are different from our influence operators in nature (preference/alteration), although in some cases their impact over the actions and plans can be similar (*e.g.* prohibiting an action, changing the actions execution order, etc.).

B. Traits in intelligent virtual agents

The works of Rousseau and Hayes-Roth, mentioned in section 1.1., stated the principle that personality traits actually express themselves as influences on actions and plans. Another major contribution is the idea that personality traits can be associated with intensity factors so that a computational planning engine can take them into account. Here, we generalize this approach with systematization in terms of influence operators and with the proposition of a generic framework (R&B).

Rizzo et al. [45] prove that goals and plans can be used to represent a character's personality in an efficient way, by attributing specific behaviors to the pursuit of each goal. Personality traits are used to choose between the multiple goals of a BDI agent (i.e. traits influence Desires). Once chosen, the goals are planned and executed whereas in our case, traits operate on already planned goals (*i.e.* traits influence Intentions).

Malatesta et al. [46] use traits to create different expressions of behaviors, especially by influencing the appraisal part of the OCC theory [37]. Their work focuses on how agents evaluate results of their actions and of external events, not on the way they perform a task. Nonetheless the idea that traits can differentiate agents' behaviors underlies this work.

The PMFserv framework [47] is dedicated to the creation of culturally credible agents by using performance *moderators functions* (PMFs). The authors claim that "*its principal feature is a model of decision-making based on emotional subjective utility constrained by stress and physiology*". This work was partly based on Gillis and Hursh's work [48]. They have introduced the notion of *Behavior Moderators*. Like CoJACK, they focus on a differentiation based on the physical capacities of the agents, as their aim is to simulate crowd behavior in military forces.

Finally, we can cite an excerpt from Paiva et al. [49] claiming that it is necessary to create individual agents through personality traits because "*in the era of globalization, concepts such as individualization and personalization become more and more important in virtual systems. The FFM can be a basis for the creation of distinguishable personalities by using the personality traits to automatically influence cognitive processes: appraisal, planning, coping and bodily expression*" Moreover they claim that there is a need for an emotion model that can easily represent emotions in a *systematic* way.

C. WordNet and affects

Recent work has also been achieved on lexical semantics associated with affective computing: for example, WordNet-Affect [50][51] aims at building affective lexical resources, derived from the WordNet base, that are dedicated to affective computing research; this work focuses on Natural Language Processing tools for general text filtering [52] rather than on the extraction of personality traits.

This is the reason why, relying also on the WordNet base we were interested in selecting first from thesaurus sources (cf. section 2.1) the most prominent adjectives and their related synsets. In doing so, we are closer to the research in psychology related to personality adjectives like Anderson's [53], Alicke's [54] or Craig's [55] but with a computational aim in our case.

V. Conclusion

In this paper, we have presented a methodology dedicated to the computational implementation of personality traits in rational agents, especially assistant agents that work in UAS situation and have to interact with people of the general public.

Our approach is based on the idea that dictionary thesaurus can provide entities (Word-Sense-Gloss associated with personality adjectives) where the glosses exhibit examples of actual psychological behaviors, which in turn can be considered as a source of influence operators (meta-heuristics modifying the actual execution of plans and actions of rational agents).

To achieve that, first, a significant set of personality-traits adjectives was registered. Then the lexical semantics related to personality-traits was extracted while using the WordNet database and it is given a formal representation in terms of so-called Behavioral Schemes. Finally, we proposed a generic framework for the future implementation of those schemes.

Next work will consist in the definition of a more complete set of heuristics for the already exhibited Behavioral Schemes. Meanwhile, using subsets of the Behavioral Schemes, it should be possible to put them to test on the DIVA toolkit. This toolkit will be used for experiments with human subjects in order to measure the extent and the precision of their actual perception of the Behavioral Schemes when they influence the rational process of the assistant agent

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