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Verification Analysis of an Agent Based Model in Behaviour Change Process

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***Abstract*— This paper describes the verification analysis for agent formal model of behaviour change process. The verification analysis was based on two widely used approaches in agent formal evaluation namely mathematical and automated analysis. The mathematical analysis made use of stability equilibria point while the automated, made use of Temporal Trace Language (TTL). The results obtained verify the formal model validity.**

***Index Terms*— agent model, verification analysis, behaviour change, psychological reactance**

I. INTRODUCTION

Modelling as a field has kept up playing remarkable roles in the area of system development. This concept contributes to the ability to understand the approach with which things function and the importance to the efficient and effective design, operation and evaluation of new systems and products. The results obtained from modelling gives important information for actions and decisions in quite a number of behaviour of the developing system. Computational modelling verification on the other hand is a process that aids ensuring the correctness and reliability of the simulations and models. There exist two verification approaches to confirm accuracy of models which are mathematical verification and automated verification [1], [2], [3].

Mathematical verification most times take the form of a partial differential equation (PDE), geometry, constitutive equations, boundary and initial conditions, required to display and describe the relevant system mathematically. Using mathematical analysis, the stable point is determined which defines the existence or possibility of obtaining the equilibrium of the system. This said equilibrium describes the situation where the stable situation has been attained and the corresponding equilibrium conditions gives further verification instances. There is a possibility of explaining these equilibrium conditions from prior knowledge of the problem or theory being modelled. Also, the fact that a reasonable equilibrium exists, shows how correct the model under consideration is. Although if a differential equation describes the dynamic of the system, then by setting all derivatives to be equal to zero, an estimation of the equilibrium can be derived. Note that, an equilibrium condition will be considered as being stable if the system maintains its level of stability even after being acted upon by a small disturbance.

On the other hand, automated verification involves the evaluation of model properties against its specifications. There are two widely used approaches for automated verification which includes model checking and logical proof procedures. Using the approach of model checking, a justification of the entailment relations is made through verifying the properties on the set of all theoretical traces possible which will be gotten by executing the model. Also, verification based on logic is done by assigning case in point to the variants of modal temporal logic. For this purpose, Temporal Trace Language (TTL) is used. Hence, this paper made used of these two approaches in the verification of the agent model of behaviour change processes.

II. AGENT COMPUTATIONAL MODELLING

The main aim of computational modelling which is also known as formal model is to create a representation of the system-in-context that approximates the underlying process of the phenomenon and behaviour of a real-life system. Formal models are more advantageous over verbal (non-formal) theories because they are more precise, transparent, and internally consistent approach for theorizing. In agent intervention research, formal model is used to explicitly comprehend how agent achieves successful behavioural change process. Agent researchers computerized existing psychology theories of behaviour change and psychological reactance to comprehend agent's behavioural factor interactions. Thus, this verification study employed agent formal model presented in study [4].

The agent model has been previously discussed in a study titled designing a BDI agent model of behavioural change process [4]. The model is based on existing psychology theories that describe factors of behavioural change. It is an integrated model based on the following theories and model namely Relapse Prevention Model (RPM), Trans-Theoretical Model (TM), Self-Efficacy Theory (SET), Self-Regulation Theory (SRT), Theory of Reasoned Action (TRA), Theory of Planned Behaviour (TPB) and Health Belief Model (HBM).

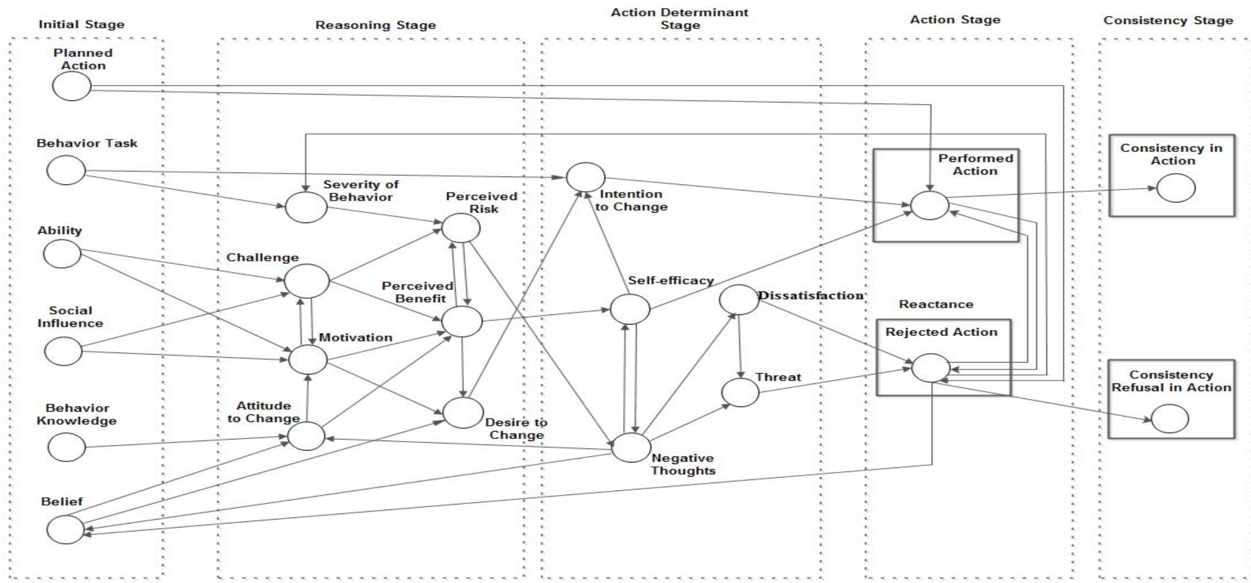

Fig. 1 The Model of Behaviour Change Process

TABLE 1: STATE VARIABLES OF THE MODEL

Concept	Formalization
Ability	*Ab*
Behaviour Knowledge	*Bk*
Behaviour Task	*Ba*
Social Influence	*Si*
Attitude to Change	*Ac*
Challenge	*Cg*
Motivation	*Mv*
Perceived Risk	*Pr*
Perceived Benefit	*Pb*
Threat	*Hr*
Intention to Change	*Ic*
Dissatisfaction	*Df*
Negative Thoughts	*Ng*
Self-efficacy	*Se*
Severity of Behaviour	*Sb*
Performed Action	*Pc*
Planned Action	*Pa*
Belief	*Bf*
Desire to Change	*Dc*
Consistency in Action	*Ca*
Action Reject	*Ar*
Consistency Refusal in Action	*Cr*

These existing psychology theories can be divided into two main groups namely: Social Cognition Models and Stage Models [5]. Based on these theories Fig. 1 depicts the interaction of agent's factors that produce behaviour change.

The structural relationships and factors interaction in the model is shown with arrows denoting causal dependencies of interplaying factors. Table 1 denotes the model concept formalization while the formalization nodes were designed using parameters ranging from 0.1-0.3 as low values, 0.4-0.6 as average values and 0.7-0.9 as high values. Based on the concept of the model, severity of behaviour (*Sb*) is the strictness of the consequences of behaviour. The designed model depicted that it is high when both behaviour task (Ba) and action reject (*Ar*) are high which was formalized as shown in equation (1). This same procedure was used for self-efficiency concept formalization as presented in equation (2)

$$Sb(t) = Ba(t)\,[1-(1-Ar(t))] \quad (1)$$
$$Se(t) = Pb(t).[1- Ng(t)] \quad (2)$$

Challenge (*Cg*) is perceived obstacle or impediment to target behaviour. From the designed model challenge (*Cg*) is high when any two of ability (*Ab*), social influence (*Si*) and motivation (*Mv*) are high which was formalized as shown in equation (3). This same procedure was used for the concept formalization of both perceived benefit (*Pb*) and performed action (*Pc*) as presented in equations (4) and (5) respectively.

$$Cg(t)=w_{c1}.Ab(t) + w_{c2}.Si(t) + w_{c3}.Mv(t) \quad (3)$$
$$Pb(t)=[w_{pb1}.Ac(t)+w_{pb2}.Mv(t)+ w_{pb3}.Cg(t)].(1-Pr(t)) \quad (4)$$
$$Pc(t)=[w_{Pc1}.Pa(t)+w_{Pc2}.Ic(t)+w_{Pc3}.Se(t)].(1-Ar(t)) \quad (5)$$
$$Ar(t)=[w_{Ar1}.Df(t)+w_{Ar2}.Hr(t)+w_{Ar3}.Pa(t)].(1-(Pc(t)) \quad (6)$$

where $\sum_{j=3}^{1} Wcj = 1$, $\sum_{j=3}^{1} Wpbj = 1$, $\sum_{j=3}^{1} \mathrm{Wpcj} = 1$and $\sum_{j=3}^{1} \mathrm{Warj} = 1$

Also, w_{c1}, w_{c2}, w_{c3}, w_{pb1}, w_{pb2}, w_{pb3}, w_{Pc1}, w_{Pc2}, w_{Pc3}, w_{Ar1}, w_{Ar2} and w_{Ar3} are the weight of the equations.

Similarly, motivation (*Mv*) is the simulative drive and intrinsic interest in performing behaviour. Based on the designed model motivation (*Mv*) is low if attitude to change

(*Ac*) is low and one of ability (*Ab*), challenge (*Cg*) and social influence (*Si*) are low as presented in equation (6). Also, Attitude to Change (*Ac*) is the mental state which implies a formed view or perception about a behaviour. It is high when negative thoughts (*Ng*) is low and any of behaviour knowledge (*Bk*) or belief (*Bf*) is high as presented in equation (7). This same procedure was used for the concept formalization of equations (8), (9), (10), (11), (12) and (13).

$$Mv(t) = \sigma\,(w_{m1}\,.\,Ab(t) + w_{m2}\,.\,Si(t) + w_{m1}\,.\,Cg(t)) + (1-\sigma)\,(Ac(t)) \quad (7)$$

$$Ac(t) = [\gamma * Bk(t) + (1-\gamma) * Bf(t)]\,[1-Ng(t)] \quad (8)$$

$$Pr(t) = Sb(t) * [1-\rho * Cg(t) + (1-\rho) * Pb(t))] \quad (9)$$

$$Dc(t) = Bf(t).[\,\eta.Mv(t) + (1-\eta).Pb(t)] \quad (10)$$

$$Ic(t) = Dc(t) * [\nu * Se(t) + (1-\nu) * Ba(t)] \quad (11)$$

$$Ng(t) = \psi.Pr(t) + [\,(1-\psi).Se(t)] \quad (12)$$

$$Hr(t) = \phi * Df(t) + [\,(1-\phi) * Ng(t)] \quad (13)$$

Likewise, based on the designed model, dissatisfaction (*Df*) is the negative unpleasant feeling, negative expectation and negative reaction from behaviour. Dissatisfaction (*Df*) is high when negative thought (*Ng*) is high which was formalized in equation (6). The same procedure were used to formalize for consistency in action (*Ca*) and consistency refusal in action (*Cr*) as presented in equations (7) and (8). Also, these equations (14) to (15) are known as the temporal equation of the model because they show the resultant outcome of behaviour. While equations (1) to (13) are the instantaneous equations because they give resultant process that led to the temporal equations.

$$Df(t+\Delta t)=Df(t)+\lambda*[Ng(t)–Df(t)]*(1-Df(t))*(Df(t)*\Delta t) \quad (14)$$

$$Ca(t+\Delta t)=Ca(t)+\zeta*[Pc(t)–Ca(t)]*(1-Ca(t))*(Ca(t)*\Delta t) \quad (15)$$

$$Cr(t+\Delta t)=Cr(t)+\varphi*[Ar(t)–Cr(t)]*(1-Cr(t))*(Cr(t)*\Delta t) \quad (16)$$

Where: λ, ζ and φ = Regulating Parameters, Δt = Change in time (*t*).

Detailed descriptions and discussion on the model was presented in study [4].

III. MODEL VERIFICATION

Model verification is the process of ensuring that the conceptual description and the solution of the model are implemented correctly. Moreover, this process is performed to improve important understanding of system behaviour, improve computational models, estimate values of parameters, and evaluate system performance The first step is to make sure that the model reflects the real world. For instance, if the behaviours of the system of interest are linear, then those linear behaviours must be reflected in the formal specification underlying the model. To address this question, properties of the models with important characteristics will be evaluated as reported in literature [7]. Figure 2 summarizes the verification process that was involved in this model.

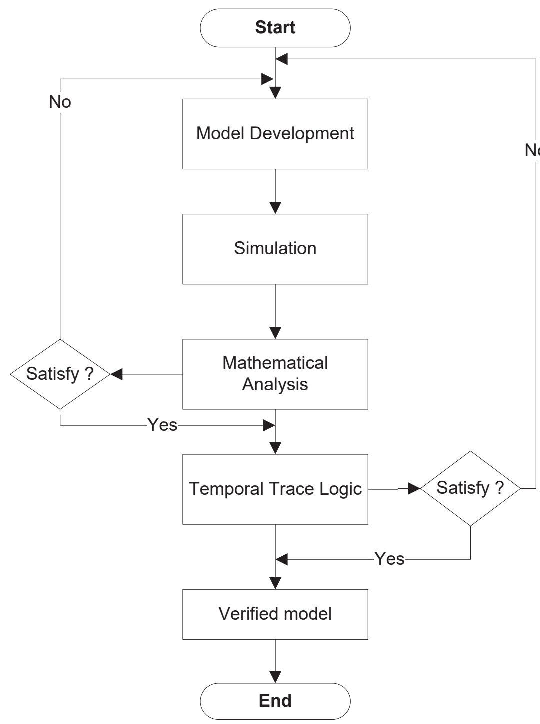

Fig 2 Verification Process [7]

The first step is to generate simulated results (simulation) from the develop model. These simulated results provide essential traces and patterns to represent the behaviour of the model. It is assumed that these results are an abstract version of the real behaviour of reactant in humans. In this article, two methods were used for the verification process. These are mathematical analysis and logical verification. Mathematical analysis was conducted to verify the structural and theoretical correctness of the model. For this article, equillbria analysis was performed. The equilibria describe situations in which a stable situation has been reached. It means, if the dynamics of a system is described by a differential equation, then equilibria can be estimated by setting a derivative (or all derivatives) to zero. One important note that an equillibria condition(s) is considered stable if the system always returns to its original position after small disturbances. For example, using this autonomous equation,

$$dy/dx = f(y)$$

the equilibria or constant solutions of this differential equation are the roots of the equation

$$f(y) = 0$$

These equillibria conditions are interesting to be explored, as it is possible to explain them using the knowledge from the theory or problem that is modelled. As such, the existence of reasonable equilibria is also an indication for the correctness of the model. For the logical verification, the ability of the Temporal Trace Language (TTL) and its software environment as a specification language and verification tool was used. TTL allows researchers to verify both qualitative and quantitative processes under analysis and has the ability to reason about time [5]. The interval of such checks varied from one second to a couple of months, related to the complexity of the models. In order to verify whether the model indeed generates results that are in adherence to psychological literatures, a set of properties have been identified from related literatures. These properties have been specified in a language called Temporal Trace Language (TTL). The implementation of this process will be covered in Section IV and V.

IV. MATHEMATICAL VERIFICATION

For the mathematical verification, equillibria analysis is used to describe situations in models where the values (continuous) approach a limit under certain conditions and stabilize. It means, if the dynamics of a model is described by a differential equation, then equilibria can be estimated by setting a derivative (or all derivatives) to zero. Figure 3 visualizes several types of stability points.

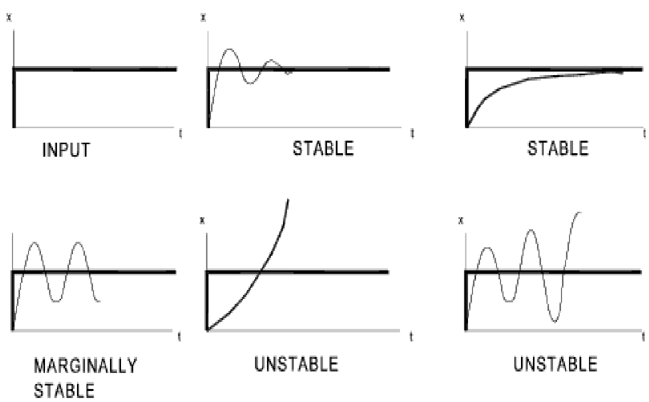

Fig 3 Types of Stability Points

The stability of a model relates to its response to inputs or disturbances. A system which remains in a constant state unless affected by an external action and which returns to a constant state when the external action is removed can be considered to be stable. Model stability can be defined in terms of its response to external inputs or in terms of bounded inputs.

- A model is stable if its impulse response zero as time approaches infinity
- A model is stable if every bounded input produces a bounded output.

One important note that an equillibria condition(s) is considered stable if the model always returns to its original position after small disturbances. These equillibria conditions are interesting to be explored, as it is possible to explain them using the knowledge from the theory or problem that is modelled. As such, the existence of reasonable equilibria is also an indication for the correctness of the model. To obtain possible equilibrium values for the other variables, first the temporal equations are described in a differential equation form.

$$\frac{dDf(t)}{dt} = \lambda.[Ng(t) - Df(t)].\big(1 - Df(t)\big).(Df(t))$$

$$\frac{dCa(t)}{dt} = \zeta.[Pc(t) - Ca(t)].\big(1 - Ca(t)\big).Ca(t))$$

$$\frac{dCr(t)}{dt} = \varphi.[Ar(t) - Cr(t)].\big(1 - Cr(t)\big).Cr(t))$$

Assuming the parameters φ,ζ,λ, are nonzero, from the equations X to Y, the following cases can be distinguish.

$$[Ng(t) - Df(t)].\big(1 - Df(t)\big).(Df(t)) = [Pc(t) - Ca(t)].\big(1 - Ca(t)\big).Ca(t)) = 0$$
$$[Ar(t) - Cr(t)].\big(1 - Cr(t)\big).Cr(t)) = 0$$

Later these cases can be distinguished into

$$(Ng = Df) \lor (Df = 1) \lor (Df = 0)$$
$$(Pc = Ca) \lor (Ca = 1) \lor (Ca = 0)$$
$$(Ar = Cr) \lor (Cr = 1) \lor (Cr = 0)$$

From here, a first of conclusions can be derived where the equilibrium can only occur when *Ng=Df, Df=1,* or *Df=0*. By combining these three conditions, it can be re-written into a set of relationship in *(A ∨ B) ∧ (D ∨ E)* expression:

$$\big((Ng = Df) \lor (Df = 1) \lor (Df = 0)\big) \land$$
$$\big((Pc = Ca) \lor (Ca = 1) \lor (Ca = 0)\big) \land$$
$$((Ar = Cr) \lor (Cr = 1) \lor (Cr = 0))$$

This expression can be elaborated using the *law of distributivity* as (*A ∧ D) ∨ (A ∧ E)* ∨,..,∨ *(C ∧ F)*.

$$(Ng = Df \land Pc = Ca \land Ar = Cr) \lor$$
$$(Ng = Df \land Ca = 1 \land Cr = 1) \lor \ldots$$
$$(Df = 0 \land Ca = 0 \land Cr = 0)$$

Table 2 provides a summarization of these equilibria.

Table 2. Equilibria States

Concept	Equilibrium Equations
Sb	$Sb = Ba.\ [1-(1-Ar)]$
Se	$Se = Pb.[1- Ng]$
Cg	$Cg=w_{c1}.Ab + w_{c2}.Si + w_{c3}.Mv$
Pb	$Pb=[w_{pb1}.Ac+w_{pb2}.Mv+ w_{pb3}.Cg].(1-Pr)$
Pc	$Pc=[w_{Pc1}.Pa +w_{Pc2}.Ic +w_{Pc3}.Se].(1-Ar)$
Ar	$Ar=[w_{ar1}.Df+w_{ar2}.Hr+w_{ar3}.Pa)].(1-Pc)$
Mv	$Mv = \sigma\ (w_{m1}.Ab+ w_{m2}.Si+ w_{m3}.Cg) + (1- \sigma)\ (Ac)$
Ac	$Ac = [\gamma.\ Bk + (1- \gamma).Bf]\ [1-Ng]$
Pr	$Pr = Sb.\ [1-\rho.\ Cg + (1- \rho)\ .Pb]$
Dc	$Dc = Bf.[\ \eta.Mv + (1- \eta\ ).Pb]$
Ic	$Ic = Dc.\ [\nu.Se + (1- \nu\ ).Ba]$
Ng	$Ng = \psi.Pr + [\ (1- \psi).Se]$
Hr	$Hr = \phi.Df + [\ (1- \phi).Ng]$

This later provides possible combinations equillibria points to be further analyzed. However due to the huge amount of possible combinations, (in this case, 3^3= 27 possibilities), it makes hard to come up with a complete classification of equilibria. However, for some typical cases the analysis can be pursued further.

Case 1: (*Ng=Df*)

$Se = Pb.[1 - Df]$

$= Pb.[1 + ((w_{ar2}.Hr + w_{ar3}.Pa)/ w_{ar1})]$

$Ac = [\gamma.\ Bk + (1-\gamma).Bf].[1-Df]$

$= [\gamma.\ Bk + (1-\gamma).Bf].[1-(w_{ar2}.Hr + w_{ar3}.Pa)/ w_{ar1}]$

$Hr = \phi.\ Df(t) + [\ (1-\phi).Df]$, assuming $\phi = 0.5$,

$= Df = (w_{ar2}.Hr + w_{ar3}.Pa)/ w_{ar1}$

Case 2: (*Df = 1*)

$Ar = [w_{ar1} + w_{ar2}.Hr + w_{ar3}.Pa)].(1-Pc)$

$= [w_{ar1} + w_{ar2}.\ (\psi.Pr + [\ (1-\psi).Se]) + w_{ar3}.Pa)].(1-Pc)$

$Hr = \phi + [\ (1-\phi).Ng]$, assuming $\phi = 0$,

$= Ng = \psi.Pr + [\ (1-\psi).Se]$

Case 3:(*Pc = Ca*)

$Ar = [w_{ar1}.Df + w_{ar2}.Hr + w_{ar3}.Pa].(1-Ca)$

$= [w_{ar1}.\ (w_{ar2}.Hr + w_{ar3}.Pa)/ w_{ar1} + w_{ar2}.\ \phi.\ w_{ar2}.Hr + w_{ar3}.Pa)/ w_{ar1} + ((1-\phi).Ng) + w_{ar3}.Pa].(1-Ca)$

Case 4: (*Df = 0*)

$Ar = [\ w_{ar2}.Hr + w_{ar3}.Pa].(1-Pc)$

$= [\ w_{ar2}.Hr + w_{ar3}.Pa].(1-[w_{Pc1}.Pa + w_{Pc2}.Ic + w_{Pc3}.Se].(1-Ar))$

$Hr = (1-\phi).\ Ng$, assuming $\phi = 0$,

$= Ng = \psi.Pr + [\ (1-\psi).Se]$

$= \psi.\ Sb.\ [1-\rho.Cg + (1-\rho)\ .Pb] + [\ (1-\psi).\ Pb.(1-Ng)]$

All of these equillibria conditions can be found in our simulation results.

V. AUTOMATED VERIFICATION

This section deals with the verification of relevant dynamic properties of the cases considered in the human agent model, which is consistent with literatures. The Temporal Trace Language (TTL) is used to perform an automated verification of specified properties and states against generated traces. A state for a given Ontology *Ont* is an assignment of truth-values {truth, false} to the set of ground atoms *At(Ont)*. The set of all possible states for an ontology *Ont* is denoted by STATES(*Ont*). Therefore, STATES(*InteractionOnt*) is the set of *all interaction states*. The standard satisfaction relation |= between states and state properties is used *S* |=*P* means that property *P* holds in state *S*. Here, |= is a predicate symbol in the language, usually used in infix notation, which is comparable to *Holds*-predicate in Situation Calculus, a logic formalism designed for representing and reasoning about dynamical domains. In the situation calculus, a dynamic world is modeled as progressing through a series of situations as a result of various actions being performed within the world (e.g., situation represents a history of action occurrences). In addition to this, a fixed time *T* is assumed which is linearly ordered. Therefore, a trace γ over an ontology *Ont* and time frame *T* is a time-indexed set of states can be formalized as, $\gamma_t(t \in T)$ in STATES(*Ont*) in a mapping;

$$\gamma : T \rightarrow STATES(Ont)$$

From aforementioned perspectives, to express dynamic properties in a precise manner, it is important to make direct reference to time points and traces. Comparable to the concept in Situation Calculus, TTL is designed on atoms, to represent the states, traces, and time properties. This relationship can be presented as a *state(γ, t, output(R))*|= *p*, means that state property *p* is true at the output of role *R* in the state of trace *γ* at time point *t* [6]. In this paper, these kinds of atoms will be referred as *Holds atoms*. Based on such *Holds atoms* the dynamic properties (from the differential equations) can be built using the basic logical connectives and quantification. For example, the following dynamic properties can be expressed:

> *"In any trace, for any points in time t1 and t2 after t1, if the agent A has the belief b at t1 in the trace, then agent A has the belief b at t2 in this trace".*

In formalized form, this statement can be presented as:

∀γ∈ W ∀t1,t2
[state(γ,t1, internal) |= b & t1 ≤ t2
⇒ state(γ,t2, internal) |= b]

Based on that concept, several dynamic properties can be formulated using a sorted predicate logic approach. As for the local properties, several properties reflect the main aspects in the theory have been evaluated by analyzing interaction among defined concepts using causal relationships that have been found in empirically founded literature. Often, over a longer period, a process specified by temporally local properties in computational models generates patterns that can be considered as emergent phenomena or temporally global properties. In this paper, different types of global properties have been considered, as put forward by empirically founded literature. These types of properties are:

- Achievement properties.
  These properties express that; given some conditions (initial and/or intermediate) eventually a certain state is reached.
- Equilibrium properties.
  There properties concern resulting in a stable, balanced, or unchanging state in the process.
- Representation properties.
  These properties explain how internal states relate to external states in past and /or future. They can be categorized into two specific types, namely: 1) backward representation relations (relations to the pre-cursor conditions) and 2) forward representation relations (relations to the future conditions).
- Comparison properties.
  These properties concern the comparison of certain state properties at different time points (e.g., monotonically increasing or decreasing), or comparison between different generated traces (e.g., with or without a specific intervention).

Below, a number of them are introduced in semi-formal and in informal representations.

VP1: High Ability Will Reduce Dissatisfaction

Individuals with high ability to perform certain actions develop lesser chance of having dissatisfaction.

VP1≡ ∀γ:TRACE, t1, t2, t3 :TIME, v1,v2,w1,w1:REAL
[state(γ, t1)|= personal_ability(v1) &
state(γ, t1)|=level_dissatisfaction(w1) &
state(γ, t2)|=personal_ability(v2) &
v2 > v1] ⇒ ∃t3:TIME > t2:TIME &
t2:TIME > t1:TIME [state(γ, t3)|= level_dissatisfaction (w2) & w1 > w2]

VP2: Low in Social Influence Will Increase Refusal Behaviour

Individuals with low social influence tend to develop high chance in refusing to perform actions.

VP2 ≡ ∀γ: TRACE, ∀t1, t2:TIME, ∀F1,F2,H1,H2, d:REAL
[state(γ,t1)|= social_influence(F1) &
state(γ,t1)|= consistency_refusal_action(H1) &
state(γ,t2)|= social_influence (F2) &
state(γ,t2)|= consistency_refusal_action (H2) &
t2 ≥t1 +d & F1 < 0.3 & F1 > F2] ⇒ H2 > H1

VP3: Belief and Knowledge Will Improve Willingness to Change

Individuals with high self-belief and knowledgeable tend to develop high chance to change their behaviour.

VP3 ≡ ∀γ: TRACE, ∀t1, t2:TIME, ∀F1,H1, M1, d:REAL
[state(γ,t1)|= self_belief(F1) &
state(γ,t1)|= consistency_refusal_action(H1) &
state(γ,t2)|= consistency_ action (M1) &
t2 ≥t1 +d & F1 ≥ 0.8 & H1 ≥ 0.8] ⇒ M1 ≥ 0.5

VP4: Monotonic Increase of Variable, v for Planned Action Amplifies Future Positive Response over Willingness to Change

For all time points t1 and t2 between tb and te in trace γ if at t1 the value of v is x1 and at t2 the value of v is x2 and t1 < t2, then x2 ≥ x1

VP4 ≡ ∀γ: TRACE, ∀t1, t2:TIME, ∀X1,X2:REAL
[state(γ,t1)|= has_value(v, X1) &
state(γ,t2)|= has_value(v, X2) &
tb ≤ t1 ≤ te &
tb ≤ t2 ≤ te &
⇒ X2 ≥ X1

VP5: Monotonic Decrease of Variable, v for Belief Amplifies Future Negative Response over Willingness to Change

For all time points t1 and t2 between tb and te in trace γ if at t1 the value of v is y1 and at t2 the value of v is y2 and t1 < t2, then y1 ≥ y2

VP5 ≡ ∀γ: TRACE, ∀t1, t2:TIME, ∀Y1,Y2:REAL
[state(γ,t1)|= has_value(v, Y1) &
state(γ,t2)|= has_value(v, Y2) &
tb ≤ t1 ≤ te &
tb ≤ t2 ≤ te &
⇒ Y1 ≥ Y2

VI. CONCLUSION

A model was developed earlier [4] to explain the development of reactance related to behavioural change based on personal characteristics. Next, based on the model, a mathematical analysis was performed to demonstrate the occurrence of equilibrium conditions, fundamentally beneficial to describe convergence and stable state of the model. To prove the relations, simulations were conducted and results were verified based on several properties using mathematical analysis and automated verification. It can be concluded that the proposed model provides a basic building block in designing a software agent that will support the human.

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