The Basic Instinct of Autonomous Cognitive Agents

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Abstract

Cognitive agents are more known as a reasoning entity which performs its predefined plan. However, many unexpected events may suddenly happen during this plan realization, requiring a quick reaction. The main problem is then to find the next action to be performed as both the plan and the forthcoming events must be considered and in an appropriate way. This problem may occur at any time. To model the reactive part of the agent, we propose to integrate in the agent the notion of instinct that we also called: the lowest level of the agent need.

This paper presents an approach to model this agent's need, and to describe then the positive behavioural impact of the instinct to the agent autonomy in action selection (the behaviour). We also show that this work is considered as the basic layer in the making of an intelligent cognitive agent. Furthermore, we discuss the general interests of our model in a 'cognito-reactive' agent design.

The base of our work is what the psychologist MASLOW highlights in his needs pyramid. When in our previous work, we considered only the vertical aspect of this pyramid, the current work also treats the horizontal one as well as the collective part of the study.

Keywords: Instinct, Need, Autonomy, Agent, Behaviour, Action, Reactive, Cognitive

1 Introduction

In agents possessing both the reactive and cognitive capabilities (also called hybrid agents by [WOO 95]), the action selection is complex because they have to cope, not only with all unexpected coming events, but also with their current goal. So, at a time *t*, an agent does not actually know what it may perform at the time *t + 1*. To deal with this action selection, we propose to integrate the notion of instinct, such as we can find in animal or human features. We define the instinct as the lowest level of an agent need when the desire ([BRA 99]) is an example of the one, situated at a higher level. We then show the positive impact of the instinct notion in the agent's behaviour autonomy and in the future design of its intelligence (as now, we act only at a very basic level). The notion of autonomy follows that of many works [FER 97], [BAR 99] which means that at any time, the agent must be able to choose by himself among the existing actions, and from his own capabilities.

In this work, we also attempt to first integrate the notion of hybridism in the collective behaviour of the agent.

Note that the main focus of the study is the position of the reaction compared to the actual cognitive goal of the agent. The deepening of this cognitive part (such as intention, knowledge, belief, etc.) is still to be deepened in a future work. That is, in our case study (see section 3.1), we assume that the agent has an initial plan and also has knowledge about other ones' states (explained later). We present how he will handle this reactive part.

To make the paper objective clearer, we organize it as follows: section 2 presents our basic architecture, followed then by the definition of needs and their relation with the actions selection (section 3). Afterwards, section 4 describes how the agent behaves when taking into account his unexpected instincts in its current plan. Section 5 discusses the general model before we conclude the paper in section 6.

2 Basic architecture

2.1 Generalities

The basic architecture we use is the pyramid of needs (hence Π) made by the psychologist Abraham Maslow [HOF 96] made up with by five levels of needs. In a previous work, [AND 01], we already used the model, but we rather discussed the hierarchy part (vertical needs) of the model. Moreover, the current work also presents the following aspects:

- the handling of the needs' satisfaction situated in the same level (horizontal needs);
- the progressive introduction of the social agent behaviour in the model.

MASLOW's defining work was the development of the hierarchy of five main Human being needs. We hierarchically have:

- the *physiological needs* related to the survival instinct: eating, sleeping, etc.
- the *need of safety*: stability, to be protected by a stronger person, etc.
- *the need of love and social belonging*: desire of love, relationships, a place in a family or in a society
- *the need of esteem:* to be considered as an important person, well-known (ex: being a pop-star)
- *the self-actualization*: related to the self-fulfilment of the potential, the dream (e.g. climbing the Himalayas), etc.

Beside this concept of MASLOW, we set the notion '*basic need' (BN)* which are innate into the agent. BN can be handled in a reactive way (e.g. by animal). But cognitive agents have their plan to handle it by making plan. The needs (in the form of objective) tending to satisfy these BN are then called *HN* for *high-needs* (the term *high* is with regards to BN but not having any term relation with the high level of the pyramid).
This classification leads to the division of the pyramid in two horizontal parts, presented in Figure 1. Further clarification will be found throughout the paper.

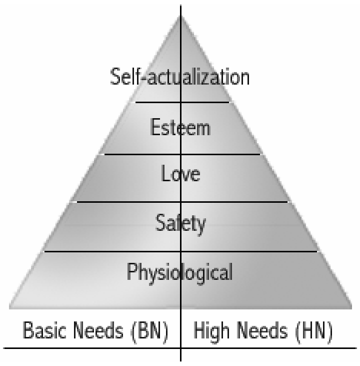

Figure 1: the structure of the need pyramid

2.2 Motivations

This choice of the basic instinct modelling in agent is mainly due to our future real-world application. Indeed, we plan in a further date to test the model in the environment, not only in the Reunion Island, but also in Madagascar about the collective action of population in the forest management. Human, fauna and flora are involved.

As for the model itself with respect to the multi-agent design, the reason of choosing the pyramid of Maslow is based on the followings:

- the pyramid is the result of MASLOW's work of the real word (the human behaviour) like biologists also studied the animal behaviour. That is, we can model here both the cognitive and reactive agents
- as we see, it considers both the individual and collective domain of the behaviour (respectively level 1, 2, 5 and level 3, 4, 5), a very interesting feature.
- the pyramid contains a generic need model and we note that most of agent behaviours in MAS research are motivated by the objective to satisfy at least one of these needs. For example, in the soccer-team challenge where each team member wants to win [TAM 99], it does so, not because seeing the ball in the goal is beautiful per se but winning makes it being liked by supporters (need 3) or well-known (need 4), depending on the context.

3 Needs and behaviour

3.1 Case-study

Our current case study concerns robots which are conveying ores from ore-base to robots' base. The initial scheme of the study was already described in [AND 01]. But here, we add a second robot (Figure 2). The objective of the robots R_1 and R_2 is to convey each 4 ores, from the ores-zone to the robots-base when following a road (assuming that in road extremities, there are 'mortal' ravines). They must also avoid some obstacles which in the current context may be set dynamically to see the robot reaction.

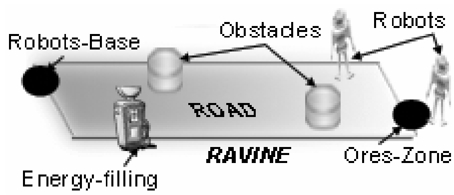

Figure 2: the scheme of the case study

The initial plan (see section 3.3 about this notion) of the robot is: *P={goTo<Ores>, take<Ore>, goTo<Base>, put<Ore>}* until the 8 (4x2) ores are conveyed.

3.2 Definition of needs

A need is an internal pulsing which contains state information (see section 3.3), leading the agent to undertake some actions. In characteristics, we have:

- the instinct or basic-level needs (hence, *BN*) which are common to all agents, allotted to them at their creation and are *permanent* (always active[1]) till their life-end. The level of a BN in Π is *static*

[1] Active=always taken into account in the behavior.

(e.g.; hunger=level 1). We note by BN_x a basic need at a level x.

- the high-level needs (hence *HN*), driven by the personal activity of the agents. The HN is an intermediate need to satisfy some BN[2]. The level of a HN in Π is *dynamic* and may be *temporary* (sometimes inactive). The activity depends on the objective of the agent. For instance, an agent needs to work (HN) because he has nothing to do (BN_5) or because he has to earn money to buy food (BN_1). Obviously, the HN level does not exist for pure reactive agents.

The notion of *temporary* means that some HN is just used to realize another high-level action. For instance, the need to reach the ore location is only active when the action *goTo<Ores>* is performed. It is inactive otherwise. Likewise, the need to have 4 ores is itself active, only during the plan *P* execution and inactive otherwise. On the other hand, whatever is the plan of the robot, the need to have enough energy (BN) is always active. Furthermore, if a plan (so HN) is at the level *i*, all actions involved by this plan are also HN at this same level.

Both BN and HN are called a Pyramidal Need (*PN*) as they are situated in a level of Π. Thus, ({PN}={BN} $\cup$ {HN}). But it is only a writing simplification for the paper. Actually, PN is written PN_{ij} where i=1$\in$ 1...5, is the level of PN and $j \in \mathbb{N}^*$ is an index used only to discern PN in the same level *i*. On the whole, Π ={PN_{ij}}.

3.3 From needs to actions

Action definition

We have two kinds of actions, a *primitive* the fine-grained (indecomposable) one, and a *plan*, composed by one or more primitives and sometimes other sub-plans.

The evaluation and the choice of actions are performed by a module called CP for *cognitive process*. In the current work, its role also concerns the execution of the plan *P*. Another module called HP for *homeostasis process* (the basic tendency of the agent to safeguard internal stability) is working on the management of the BN-level. We will see in section 4.1 the interaction between the two modules. Both the HP and CP are independent processes.

All chosen actions are sent in a third module called *EM* (for *execution module*) to be effectively executed.

[2] The linkage of the two levels need is still let to a future work. Now, we just adopt that BN=f(HN) $\Rightarrow$ level(HN)=level(BN).

The need states

Each *PN* may be in three states (see also [AND 01]): the *quiet*, the *threatened* and the *missing* ones. A state can be represented throughout an axis *0x* having a length *L* (Figure 3) whose the current value is indicated by *x*. The Figure 3 represents the example of the robot energy level when it is performing its current plan *P*.

Each state of a given PN is a predicate, which corresponds to a definition domain. Then, in the Figure 3, we set:

- `quiet (PN)= ROBOT_ENERGY ≥10/20,`
- `threatened(PN)= ROBOT_ENERGY >8 // and always minus the domain defined in quiet (PN)`
- `missing (PN)= ROBOT_ENERGY ≤8`

When a need is worsening, it will be taken into account only if it is more important (see section 3.4 about this notion) than the one who triggered the current action.

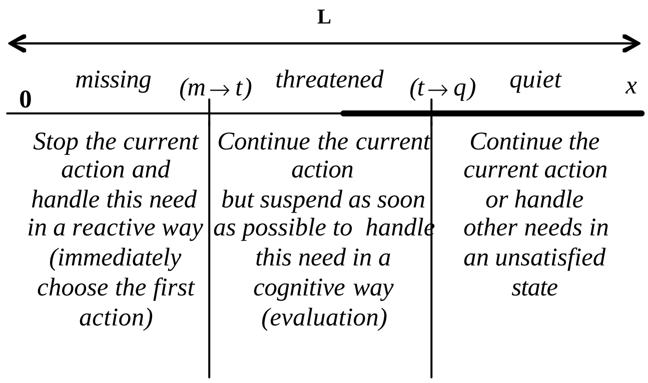

Figure 3: the state of one PN-Need

The state variation is due to the fact that each performed action may affect one or more of the agent's internal properties when these ones mainly characterize the need state.

Predicates and functions

In this work, we improve the following some predicates and functions. Let a time value *t timeUnit*, *PN.isxxx(t)* means *PN* is *xxx* at the time *t*.

We then have:

- `PN.isSatisfied(t)= PN.isQuiet(t) or PN.isThreatened (t)`
- `PN.isUnsatisfied(t)= PN.isMissing(t)`
- `PN.isStationary(t)= PN.isxxx(t)== PN.isxxx(t-1)`
- `PN.isImproving(t)= [PN.isUnsatisfied (t-1) and PN.isSatisfied(t)] or [PN.isThreatened(t-1) and PN.isQuiet(t)]`

- `PN.isWorsening(t)= isQuiet(t-1) and PN.isThreatened(t)`
- `PN.isVeryWorsening(t)= PN.isSatisfied(t-1) and PN.isUnsatisfied(t)`
- `PN.isMoreImpThan`[3]`(PN`$_1$`) // see section 3.4`
- `PN.state(t)=…// the current state of PN`

3.4 *The importance of each need*

Generality

The choice of the next action depends on knowing what need is presently more important and then, has to be immediately treated. It means that a need may not be important at a time *t* may be so at t + 1, depending on the agent activity.

About the importance, there is another parameter, which is in each PN and is called a *state ratio* (*sr*). This one allows the agent to evaluate the current position *x* of the need in the axis of PN. Then,

$$sr = \frac{x}{L}$$

The need classification

About the attribution of the level (vertically), it is not quite a problem (thanks to the Π classification of Maslow). Note that when the level is taken into account in the need importance, the index is not.

As for the needs in the same level, we give the following rules (followed in order of citation):

- $\forall$ i∈ 1...5, j∈ □ *, all BN_i is always more important than HN_i // it is obvious because the basic needs are more important than the high-level ones. As we said in section 3.2, the latter is just a manifestation of the former (may be in a much longer time).
- then, about the same HN_i, only the currently active needs are considered.
- finally, for each PN at the same level, if $sr(PN_{i1})<sr(PN_{i2})$, then PN_{i1} is more important than PN_{i2}.

We agree that the probability that two PN have exactly the same importance at a given time *t* will be never *=0*. However, the above rules concretely reduce this probability. For instance, choosing between eating and drinking (BN) at a time *t* may be resolved by the state ratio value.

[3] more important than

4 Behaviour

4.1 *Combining reactive and cognitive actions*

The actions to be performed are put in a queue (Figure 4) each element of which is a primitive. Then, all plans must also have been decomposed to primitives before being set in the queue.

The process is the following: the CP continuously put its next action to the queue. Meanwhile, the HP always monitors all BN-needs. if one of the needs is in a *threatened* or *missing* state, the HP inserts an action named *consider<BN>* in the head of the queue so that it will be immediately considered by the EM. Thus, after ending with its current primitive (as it is indecomposable) triggered by a need PN, the EM executes the action *consider* as follows:

```
if not BN.isMoreImpThan(PN) then exit;
if missing(BN) then
      performAction(missing(BN))
if threatened (BN) then
if haveATimeYet() then exit; // ignore for later
else
      evalAction(threatened(BN))
      performAction(threatened (BN))
```

For the moment, the predicate *haveATimeYet()* just gets the distance between *x* and *(m→ t)*. As it involves a larger cognitive process (learning the action duration), we leave it in the future work. The e*valAction()* function content is presented in section 4.2.

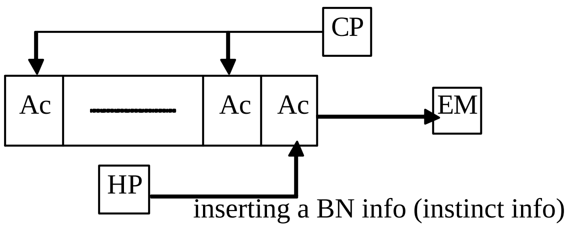

Figure 4: execution of reactive and cognitive actions

4.2 *The evaluation*

General evaluation

Once the important need PN is at the *threatened* state, the agent should stop its current action and start to evaluate the best actions so that PN should not switch to the *missing* state. The evaluation is done by respecting the following rules (where *t'* is the time after which A is performed and all PN-form∈ Π):

1. $\forall$ PN'/PN'.isMoreImpThan(PN) and PN'.isSatisfied(t)
   if (A_1.exec(A) $\Rightarrow$ $\forall$ PN'/PN'.isStationary(t') or PN'.isImproving(t')) then A is chosen.

else if (A_1.exec(A) $\Rightarrow \forall$ PN'/PN'.isSatisfied(t')) then A is chosen but if (exec(A) $\Rightarrow \exists$ PN'/PN'.isWorsening()), then PN' must be immediately handled (PN' $\rightarrow$ PN and back to 1.)

2. if $\exists$ PN'/PN'.isMoreImpThan(PN) and (A_1.exec(A) $\Rightarrow$ PN'.isVeryWorsening(t')), then A is rejected.

The social evaluation

Our objective in this paper is not yet to deepen all the social aspects (concurrence, coordination, etc.). On the other hand, we also want to situate the validity of the instinct concept in the collective domain. Remind that currently, the cognitive part of the agent is assumed: each agent is considered as having an initial plan to perform, and having knowledge about the state of the other one.

From the MASLOW concept, the collective behaviour is an inner-need of the agent. As such, the action selection follows the rules above, and the behaviour when coping with the instincts remains the same (see previous section).

However, in the social aspect, we add two subsequent rules because there is now another pyramid in the system. The rules correspond to the consideration of the existence of the other agents. Now, with respect to the agent R_2 (respectively R_1), the agent R_1 (respectively R_2) must consider the followings:

3. if R_2.PN.isUnsatisfied(t) and (R_1.exec(A) $\Rightarrow$ R_2.PN.isSatisfied(t')), then A is chosen // taken if help some other one's need
4. if R_2.PN.isSatisfied(t) and (A_1.exec(A) $\Rightarrow$ R_2.PN.isUnsatisfied(t')), then A is rejected // not to be taken if worsens some needs of the other one

The social part of an agent (let R_1) is basically featured by three additional BN:

- the BN_i='integration': in the agent, this is the basic desire to be in an environment where there is at least one another agent (even if at this stage, there is not yet any relationship between them). As [BON 94] said, the social entity is in a society even if it is alone.
- the need PN_{h1}='help': let R_2 the other agent, PN_{h1} is a need which always corresponds to another need PN_2 of R_2. It means that *PN_{h1}.state(t)=PN_2.state (t)* R_1 will satisfy the need like if it is its one's. Obviously, the agent has not always the obligation to help in every situation. However, in the social domain, PN_{h1} should be associated at least with the primary needs (level 1 and 2) of the other agents. The rule 3 above corresponds to the satisfaction of this need.
- The need PNr='respect': which corresponds to the rule 4. To avoid confusion about the term, we emphasize here the notion of the 'internal' respect of the other agent, but not a 'cognitive' respect (such as respecting an explicit social convention, mutually adopted)

4.3 The case-study results

Before giving the case-study results, we present first the pyramid of both the agents.

The general aspects ---

- `PN`$_{11}$`: having energy, `*`sv`*`=1` $\Rightarrow$ physiological // When this need is in a fatal state, the robot cannot move any more (BN).
- `PN`$_{12}$`: not to be hurt` $\Rightarrow$ `physiological (BN)` // the need is evaluated by the distance from the obstacle. We set here the *missing* state as *distObs<5 units* and the *threatened* state as ≥ 5 and <10 (see the usage below).
- `PN`$_{21}$`: staying in road` $\Rightarrow$ `security (BN)` // avoiding the ravine

The social aspect---

- `PN`$_{30}$`: integration` $\Rightarrow$ `need to be in a society (BN)`
- `PN`$_{31}$`: help` $\Rightarrow$ `helping the other in a primary need (BN)`
- `PN`$_{32}$`: respect` $\Rightarrow$ `respecting the needs in the pyramid of the other`
- `PN`$_{33}$`: conveying 4 ores` $\Rightarrow$ `the plan (HN)`
- `PN`$_{34}$`: moving to Ores-Zone` $\Rightarrow$ `contributing to satisfy PN`$_{33}$` but active only when moving to the ores (HN)`
- `PN`$_{35}$`: moving to Robots-Base` $\Rightarrow$ `contributing to satisfy PN`$_{33}$` but active only when moving to the base (HN)`

According to this pyramid, we have the following behaviours when robots convey ores (remind, the plan *P* which is motivated by the HN: PN_{33}):

- the robots avoid themselves when they meet (due not only to the instinct PN_{32} but also the one PN_{12})
- the robots also avoid other obstacles (due to PN_{12}). When we put an unexpected obstacle at *4 units* from a robot (let R_1), *PN_{12}.isMissing(t)* becomes true. Then, the current plan must be immediately suspended and the action *go_back()* (corresponding to *PN_{12}.isMissing(t)*), coming from the HP is immediately performed (this is the instinct). After this back moving (3 units), R_1 must go forward again to continue the satisfaction of *PN_{33}*. But at this time, *PN_{12}* is still in the *threatened* state (at 7 units from the obstacle). It has then to avoid the obstacle again by evaluating (via CP) two possible actions corresponding to *PN_{12}.isThreatened(t')* state: *turnleft()* and *turnright()* After the evaluation,

R_1 will choose the latter because turning left makes PN_{21}*.isWorsening()* true. The detail of all the behaviours is illustrated in the Figure 5.

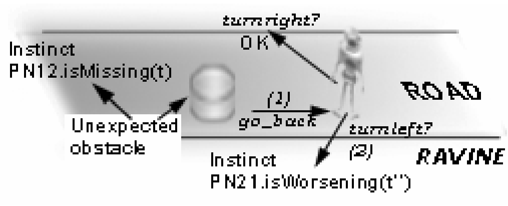

Figure 5: the avoidance-evaluation driven by the instinct

Moreover, the first robot which has finished its convey keeps on doing so. In fact, it corresponds to the help need of the second one.

Note that in this scenario, removing PN_{12} from R_1 keeps the avoidance procedure possible due to the still existence of PN_{12} in R_2. On the other hand, also removing it from R_2 makes the shocks inevitable.

On the whole, the behaviour of a MASLOW agent is not driven by any internal (e.g. energy-level) or external (e.g. obstacle position) events, but only by their impact on the list of the internal pyramidal needs of the agents.

5 Discussion of the model

This work can be discussed from various angles that we present successively.

5.1 Concept

We consider this work as the modelling and the integration of the low-level source of motivations in agent behaviour. We call them the instinct. The reason is because we state that the reason of the agent objective in many works is due to at least one of these instincts. The concept of needs such as desire [BRA 99] is 'felt' as a higher-level of this work. In the soccer-team challenge [TAM 99] where each team member wants to win, the reason of the team behaviour is not because winning a match is beautiful in itself, but because it makes the team, may be, more well-known (BN_4=esteem), or, just because the players want to be together (BN_3=integration), to play a game (BN_1=physiological need) etc. Another example is that of the Robocop rescue challenge [KIT 99] where the main basic study is the saving of lives, explicitly considered here as a high level manifestation of the instinct BN_3= helping the other's need (BN_1= to be alive) to be satisfied.

5.2 Autonomy and intelligence

The instinct seems to be obvious for the agent's designer. So, during his creation, he assumes that such instincts already exist in his agents. To understand, we will take a trivial example: assuming that their ants are hungry, [BON 94] immediately study the way how ants will search some food. But by doing so, they are 'keeping' a part of their agent's autonomy to feel the hunger. Our idea is to give this 'feeling' to the ant itself so that it could go out only when its need to be fed up is in a *threatened* state (autonomy in 'reaction').

Another aspect we note is the impact of the instinct in the future intelligence design (i.e. at a cognitive level). This work may be considered as the basic layer for this objective. Indeed, owing to the HP manifestation, there is a reactive filter about the potential actions that the agent should perform at this cognitive level, making its behaviour yet more appropriate. Here, the realization of the plan P is automatically 'rescheduled' because of these instincts (see Figure 5), but this procedure is for the robot, the reasonable way to perform P till the end. Also note that the instinct is independent of the signification of the current plan.

5.3 Reactive/cognitive

As for the combination of the reactive and cognitive concepts, other works also already considered it. [MAL 00] for instance discussing the structural aspect of the combination. He proposes a model called GLA in which the reactive domain is at the lower level and the cognitive domain, at a higher one. The difference with ours is that the pyramid Π groups the reactive domain includes all levels at the same time (Figure 1). One may see Π as the *perpendicular* form of the GLA. [MAV 00] in their work, study the behaviour. Similarities may be found with ours about the fact that in deliberation process, there are evaluations of options while in reaction, there are not (Figure 3). However, the reactive part of their model considers the current mental state as well as the current planning of the agent. The reaction is then dependent on the current cognitive actions. In our work, there is no semantic relation at all from HP to CP (note that the inverse may be true). The HP always sends its information independently of the current action that CP is handling.

5.4 Regarding the previous work

Our previous work already discussed the model [AND 01]. But this work was rather focused on the advantage of the hierarchy aspect of the model. In other words, we made there the vertical concept of the needs and the involved results in action selection.

The present work is an extension of the first by considering the horizontal needs, i.e. needs in the same level. It leads us to more study the notion of need importance (started, in the first work, by the one given by the MASLOW criteria) and the actual distinction of high and low level need. Furthermore, this second stage progressively introduces the collective aspect of the model in the agent behaviour.

6 Conclusion and perspectives

In this paper, we presented the behavioural impact of the basic instinct in cognitive agents (considered in the present case-study as robots). For that, we presented our need-based structure of the pyramid of the psychologist MASLOW. This work is the basic level of the agent behaviour, particularly about the design of an intelligent agent (as the instinct 'layer' is a first filter of the future agent actions). We also aimed at stating that the instinct (according to our approach), once integrated and used by an agent itself improves its autonomy, either in individual or social domain.

In the next step of the work, we plan to improve the cognitive capacity of our agent as well as the relation between a HN and its corresponding BN (remind that it is unidirectional). We then go to a higher-cognitive level of the design by asking ourselves the following question: over the instinct filter, how the agent then will choose its next action ? For that, the work of [SUL 00] seems to be an interesting reference for us.

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