An Agent Model for Personal Development Support

Tibor Bosse¹, Rob Duell², Zulfiqar A. Memon¹,³, Jan Treur¹, and C. Natalie van der Wal¹,²
¹Vrije Universiteit Amsterdam, Department of Artificial Intelligence
De Boelelaan 1081, 1081 HV Amsterdam, The Netherlands
²Force Vision Lab, Barbara Strozzi laan 362a, 1083 HN Amsterdam, The Netherlands
³Sukkur Institute of Business Administration (SIBA), Air Port Road Sukkur, Sindh, Pakistan
{tbosse, rduell, zamemon, treur, cwl210}@few.vu.nl

Abstract

This paper introduces an agent-based support model for leadership, which can be used by an ambient system to support a leader in the development of his team member(s). Using model-based reasoning, an intelligent agent analyses the development level of an employee and provides support to the leader by proposing effective leadership behaviour. Simulation experiments performed within a dedicated software environment are discussed.

1. Introduction

Leadership can be defined as the process of influencing activities of an individual or a group towards goal achievement in a given situation [1, p. 86]. Different leadership models focus on different aspects that define how effective a leader can be. Some models focus on the traits of the leader and group members [2], others on their attitudes [7], [8], or on the situational organisational context. The support model introduced in the current paper is based on the informal situational leadership model in [1, p.171-204]. They added a third dimension of leadership behaviour, named the effectiveness dimension, to the dimensions task-oriented and relationship oriented leadership behaviours taken from [7], [8]. The integration of the third dimension, enables to predict the effectiveness of the leadership styles in the specific situational context.

The motivation for formalising a computational leadership model originated from the goal to design an ambient software agent that supports effective team performance. As at present no computational models of situational leadership are known to the authors, this paper explores such a model. The idea is that an intelligent agent estimates the development level of a person and match this with the appropriate leadership style. Based on this and the context, which also reflects the history and communication with the person, it proposes effective leadership behaviours to the leader.

In the description of the detailed model the temporal relation a → b denotes that when a state property a occurs, then after a certain time delay (any positive real number), state property b will occur. In this language (called LEADSTO) both temporal logical relationships and numerical calculations can be specified, and a dedicated software environment is available to support specification and simulation; for more details see [4]. Below, in Section 2, a detailed model of development level is explained and formalised. Section 3 introduces the main aspects of the multi-agent support model for personal development. In Section 4, simulation results of the personal development level and the support mechanisms are shown. Finally, Section 5 concludes the paper with a discussion.

2. A Model for Development Levels

Multiple (informal) models of group development have been suggested by different researchers; for example, see [5] and [6]. For the current paper the Situational Leadership Theory [1] was adopted, which includes a group development model. In this theory, a leader is responsive to the behaviours of a group member (‘employee’), whom he categorises in one of four development levels. In this way the group member’s behaviour determines the leader’s behaviour. By effective leadership behaviour, the group member can grow to a higher development level. It is also possible to categorise the whole group in one of the development levels. Therefore, throughout this paper one can read ‘group’ instead of ‘group member’ or ‘person’ as well. Another situational approach to leadership can be found in [3]. In [1] the authors define development levels (‘readiness’ levels) as the extent to which a group member shows the ability and willingness to accomplish a specific task. Readiness is not a personality characteristic, but a concept that is being used in a specific situation, for a specific task. They define ability as the experience, skill or
knowledge of the person or group and willingness as the degree of confidence, commitment and motivation a person or group has in accomplishing a specific task. A person can be able or unable and willing or unwilling in task performance. The four combinations that can be made of these four states, define the four development levels of a person. Thus, the continuum of possibilities of the readiness of a person can be structured according to four levels: R1, R2, R3 and R4, see Figure 1 (comparable to [1], Figure 8-2, p.177). Here R1 defines a development level where the person is unable and unwilling. The unwillingness is either the lack of commitment and motivation or the lack of confidence in task performance. In R2 the person is unable but willing. Willingness can be either motivation and commitment the person demonstrates, or the confidence the person demonstrates in the guided task performance. At level R3, the person is able but unwilling. This means that the person now has the ability (experience, skill and knowledge) to perform a task, but lacks commitment and motivation or lacks confidence. In R4 the person is able to perform a task and has the motivation and commitment or shows confidence in performing the task.

<table>
<thead>
<tr>
<th>R1</th>
<th>R2</th>
<th>R3</th>
<th>R4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unable and unwilling</td>
<td>Unable but willing</td>
<td>Able but unwilling</td>
<td>Able and willing</td>
</tr>
</tbody>
</table>

**Figure 1** Continuum of readiness

The current development level of a person is reflected in the aspect $g_R$ with possible values $R1$, $R2$, $R3$ and $R4$ for $R$. For each of the four development levels multiple profile attributes $p_{ij}$ have been determined, which correspond with the behavioural indicators introduced by [1]. The attributes taken into account for level $R1$ are: defensive behaviour, complaining behaviour, intense frustration, late task completion, performance only to exact request, argumentative behaviour, discomfort in body language, confused unclear behaviour, fear of failure, concern over possible outcomes.

The attributes used for $R2$ are: nodding_head, seeming eager, speaking_intense and quickly, listening carefully, accepting_tasks, acting quickly, seeking clarity, making yes I know comments, answering_questions superficially.

Each profile attribute $p_{ij}$ can be seen as a category or behavioural category of a certain development level. Index $i$ defines the development level: $i \in \{1,2,3,4\}$. Index $j$ defines the attribute name/position within this development level, for example for $i \in \{1,2,3,4\}$, $j \in \{1,2,3,4,5,6,7,8,9,10\}$. For example profile attribute $p_{11}$ ‘defensive behaviour’ belongs to development level R1 and is the first attribute name of this development level. This profile attribute reflects the degree to which the person shows defensive behaviour. Therefore it has a negative meaning. In the proposed model of group development, 10 profile attributes are suggested for development level R1, 9 for development level R2 and 7 both for levels R3 and R4.

Each profile attribute $p_{ij}$ has a profile attribute value $v_{ij}$ which reflects how often the person has shown certain behaviours that indicate the specific profile attribute. Aspect $v_{ij}$ has been formalised numerically by numbers in the interval $[0, 1]$. For example $v_{18} = 0.5$ means that the person has shown certain behaviours that indicate that the person is being responsible. The exact dynamics of these profile attribute values depend on the settings of the other parameters, as explained below. Each profile attribute $p_{ij}$ has a default profile attribute value $v_{ij}$. The default value of $v_{ij}$ depends on the positive or negative meaning of the profile attribute $p_{ij}$. A profile attribute $p_{ij}$ with a positive meaning has a default value 0.1 for $v_{ij}$ and one with a negative meaning has a default value of 0.9 for $v_{ij}$. For example the profile attribute $p_{18}$, which is ‘confused_unclear__behaviour’ has a negative meaning. For this reason it is chosen that the default profile value of $v_{18}$ is 0.9. Whenever a person will show behaviour that corresponds with this profile attribute $p_{18}$, the profile attribute value $v_{18}$ will decrease. A profile attribute $p_{ij}$ with a positive meaning, for example $p_{25}$ ‘accepting_tasks’, will have a default value of 0.1 for $v_{25}$. If the group (member) shows behaviour that corresponds with this profile attribute $p_{25}$, this profile attribute value $v_{25}$ will increase. The idea is that the person will follow the development levels from R1, to R2, to R3 to R4, by slowly increasing or decreasing certain profile attribute values $p_{ij}$.

An experience name $n_{ij}$ with experience value $e_{ij}$ was introduced for the degree to which a certain behaviour indicates a certain profile attribute $p_{ij}$. Aspect $e_{ij}$ has been formalised by numbers in the interval $[0, 1]$. If a profile attribute value $p_{ij}$ has a positive meaning, then the higher the value of $e_{ij}$ the more this behaviour is an indication of the corresponding profile attribute $p_{ij}$. This is opposed to $e_{ij}$’s that indicate profile attribute behaviours with a negative meaning. Therefore a value of 0.2 for $e_{11}$ reflects the same degree of $p_{11}$ as the value of 0.8 for $e_{21}$ that reflects $p_{21}$. More specifically, in both cases the behaviour indicates the profile attribute to an extent of 80%. For example, behaviour ‘crossed_arms’ has an experience value $e_{11}$ of 0.2 (negative meaning), and behaviour ‘nods_head’ has an experience value $e_{21}$ of 0.8 (positive meaning). In this example ‘crossed_arms’ indicates profile attribute $p_{11}$ ‘defensive_behaviour’ just as strong as ‘nods_head’ indicates profile attribute $p_{21}$ ‘noding_head’, namely they both indicate their $p_{ij}$
with 80%.

The next step is to maintain each profile attribute value $v_{ij}$. The formula for updating the profile attribute values $v_{ij}$ is expressed as follows:

If $v_{ij}$ has a positive meaning
then new $v_{ij} = a v_{ij} + (1-a)e_{ij}$

If $v_{ij}$ has a negative meaning
then new $v_{ij} = 1 - a(1-v_{ij}) + (1-a)(1-e_{ij})$

Here $a$ is a number in the interval $[0, 1]$ which reflects how persistent the $p_{ij}$ value is. If $a = 0$ then every new experience ‘overwrites’ the old profile attribute value $v_{ij}$ completely. If $a$ is a high number, like 0.8, then the ‘old’ profile attribute value $v_{ij}$ is very persisting, since the new experience can adjust only 20% of the ‘old’ profile attribute $v_{ij}$ into the ‘new’ profile attribute $v_{ij}$.

Note that for the second formula: $1 - new v_{ij} = a(1-v_{ij}) + (1-a)(1-e_{ij})$, is equivalent with: $new v_{ij} = 1 - a(1-v_{ij}) + (1-a)(1-e_{ij})$. As an example: if the value of $v_{ij}$ (negative meaning) is 0.9 at time point 1, the group shows a defensive behaviour with $e_{ij} = 0.2$, and $a$ is set to 0.5. Then the new value for $v_{ij}$ at time point 2 will be: $1 - 0.5(1-0.9) + 0.5(1-0.2) = 0.55$.

Expressed in differential equation format, the update mechanism for profile attribute $p_{ij}$ is as follows:

$$p_{ij}(t+\Delta t) = p_{ij}(t) + \beta (e_{ij}(t) - p_{ij}(t)) \Delta t$$
$$\frac{dp_{ij}(t)}{dt} = \beta (e_{ij}(t) - p_{ij}(t))$$

where $\beta = 1 - a$ can be considered a flexibility factor.

The final step is to calculate $q_i$ for each development level, which indicates the degree the group member has shown behaviours of the specific development level. This $q_i$ has been formalised by numbers in the interval $[0, 1]$ and reflects the average of the profile attribute values $p_{ij}$ of the corresponding development level. For example, $q_j$ is the average of all $p_{ij}$ with index $i = 1$. If $q_j$ is 0.1, then the person has not shown any behaviours yet that are indicative of development level R1, since it is the average of all (rescaled) default profile values $v_{ij}$. The model to average the profile attributes $p_{ij}$ is $q_i = \sum_{j=1}^{n} w_{ij} / n_j$ where, $n_1 = 10$, $n_2 = 9$, $n_3 = 7$ and $n_4 = 7$, and $w_{ij} = v_{ij}$ if the meaning is positive and $w_{ij} = 1 - v_{ij}$ if negative.

The person will reach a next development level by exceeding a certain threshold for each $q_i$. Below a threshold of 0.6 was chosen, but the threshold can be set to any other number that will provide predictive behaviour of the person. The criteria for the development levels are as follows:

<table>
<thead>
<tr>
<th>criterion</th>
<th>development level</th>
</tr>
</thead>
<tbody>
<tr>
<td>$q_i &lt; 0.6$ &amp; $q_j &lt; 0.6$ &amp; $q_k &lt; 0.6$</td>
<td>$g_{R1}$</td>
</tr>
<tr>
<td>$q_i \geq 0.6$ &amp; $q_j &lt; 0.6$ &amp; $q_k &lt; 0.6$</td>
<td>$g_{R2}$</td>
</tr>
<tr>
<td>$q_i = 0.6$ &amp; $q_j \geq 0.6$ &amp; $q_k &lt; 0.6$</td>
<td>$g_{R3}$</td>
</tr>
<tr>
<td>$q_i = 0.6$ &amp; $q_j &lt; 0.6$ &amp; $q_k \geq 0.6$</td>
<td>$g_{R4}$</td>
</tr>
<tr>
<td>$q_i \geq 0.6$ &amp; $q_j \geq 0.6$ &amp; $q_k &lt; 0.6$</td>
<td>$g_{R5}$</td>
</tr>
</tbody>
</table>

3. The Leadership Support Model

In this section, a support model is introduced that uses the development level model of the previous section. This model provides intelligent support to a leader by proposing effective leadership behaviour to the leader. The idea here is that an intelligent agent can estimate the development level of the person and match this with the appropriate leadership style. Then based on the leadership style and the context, which reflects the history and communication with the person, it proposes effective leadership behaviours to the leader. In [1], four leadership styles are proposed that match with one of the four development levels discussed in previous section. The four leadership styles {S1, S2, S3, S4} are four different combinations of behaviours that are low or high on two dimensions: task behaviour and relationship behaviour. Typical task behaviour is telling people what to do, how to do it, where to do it and who should do it. The leader spells out the responsibilities and duties of the person. Relationship behaviour is characterised by two-way communication: the encouragement, listening, facilitating, and supportive behaviours. Figure 2 (upper part), (inspired by [1, p.182, Figure 8-7]) gives an overview of the four leadership styles.

![Figure 2 Situational Leadership Model](image)

The correct matches of each leadership style with one of the readiness levels of the person are defined in [1] as: R1 matches S1, R2 matches S2, R3 matches S3 and R4 matches S4. In [1] this is depicted as a Gaussian curve that goes through the four leadership style quadrants (see Figure 2, upper part). Beneath this, the four development stages are depicted. The developmental stage that matches with an interval on
the horizontal axis of the quadrants, matches with part of the Gaussian curve in that interval. The quadrant that is traversed by the Gaussian curve in that interval is the matching leadership style for that development level.

Below, the detailed specification of the leadership support model is explained in terms of LEADSTO specifications (executable temporal rules; cf. [4]). First, the intelligent agent observes the behaviour of the Ph.D. student and generates a belief about the student’s behaviour. This is shown in rule BS1. Rule BS2 represents the update process of one attribute value. Here, only one rule is given for the update of a certain profile attribute value, in case the Ph.D. student did show a behaviour indicating this profile attribute, otherwise the profile attribute value persists. After all profile attribute values are updated, the ambient agent calculates the four q-values. The calculation of the q-value for R1 is reflected in rule BS3. Next in rule BS4 the ambient agent calculates which q-value is highest. This value is used by the agent in rule BS5 to generate the belief about the development level of the student.

**BS1 Generating a belief on the Ph.D. student’s behaviour from an observation**

If the ambient agent observes body language BL of student STU in a certain context C then the ambient agent will believe that STU has body language BL in a certain context C

\[ \text{observation_result(body_language_of_in(BL, STU, C))} \rightarrow \text{belief(body_language_of_in(BL, STU, C))} \]

**BS2 Analysing the Ph.D. student’s behaviour in terms of profile attribute values**

If the ambient agent believes that student STU has behaviour BL in a certain context C and the ambient agent believes that body language BL of student STU has profile attribute value PVALUE for profile attribute PNAME and the ambient agent believes that the experience value for BL for profile attribute PNAME is E then the ambient agent will believe that the profile attribute value of profile attribute PNAME of body language BL of student STU is \( \text{ALPHA} \times \text{PVALUE} + (1-\text{ALPHA}) \times \text{E} \)

\[ \text{belief(body_language_of_in(BL, STU, C))} \rightarrow \text{belief(p_values_for_in(PNAME, PVALUE, BL, STU))} \]

**BS3 Calculating the estimated q-value of R1**

If the ambient agent believes that the first profile attribute PNAME1 of development level R1 has profile attribute value PVALUE1 for student STU then the ambient agent will believe that the estimated q-value of development level R1 of student STU is \( \frac{(\text{PVALUE1} + \text{PVALUE2} + \ldots + \text{PVALUE10})}{10}, \text{STU}) \)

**BS4 Calculating the highest estimated q-value**

If the ambient agent believes that the estimated q-value of development level R1 of student STU is X1 and the ambient agent believes that the estimated q-value of development level R2 of student STU is X2 and the ambient agent believes that the estimated q-value of development level R3 of student STU is X3 and the ambient agent believes that the estimated q-value of development level R4 of student STU is X4 then the ambient agent will believe that the highest estimated q-value for student STU is the maximum of X1, X2, X3 and X4

\[ \text{belief(estimated_qvalue_of(X1, r1, STU))} \rightarrow \text{belief(estimated_qvalue_of(X2, r2, STU))} \rightarrow \text{belief(estimated_qvalue_of(X3, r3, STU))} \rightarrow \text{belief(estimated_qvalue_of(X4, r4, STU))} \rightarrow \text{belief(highest_estimated_qvalue_of(max(X1,X2,X3,X4), STU))} \]

**BS5 Assessing the development level of the Ph.D. student**

If the ambient agent believes that the estimated q value of development level R1, namely X1, is the highest of the four estimated q-values for student STU then the ambient agent will assess that the development level of student STU in context C is R1

\[ \text{belief(highest_estimated_qvalue_of(X1, STU))} \rightarrow \text{assessment(development_level_for_in(R1, STU, C))} \]

Next, in the matching process, the intelligent agent generates its desire for the most effective leadership style of the leader, based on the group member’s personal development level. Determining which leadership style is most effective (S1, S2, S3 or S4) as in [1], is done by the following straightforward generic matching rule, which has been incorporated in the intelligent agent: if \( R_i \) then \( S_i \), where \( i \in \{1, 2, 3, 4\} \). Below, rule BS6 models this matching process.

**BS6 Matching leadership style with development level**

If the ambient agent assesses that the development level of student STU in context C is Ri then the ambient agent will desire that the leadership style for student STU in context C is Si

\[ \text{assessment(development_level_for_in(Ri, STU, C))} \rightarrow \text{desire(leadership_style_for_in(Si, STU, C))} \]

In the refinement process, the intelligent agent determines which leadership behaviours are appropriate in the given context, which it then proposes to the leader. This is represented in rule BS7 below. The context reflects the history and communication with the student. The intelligent agent has internal knowledge about which behaviours are most effective for which leadership style and in which context.

**BS7 Choosing the appropriate communication response for the leader**

If the ambient agent desires that the leadership style for student STU in context C is Si and the appropriate communication response of PRO to the behaviour BL of student STU in context C then the ambient agent will propose to PRO to respond with the communication COMM to student STU in context C

\[ \text{desire(leadership_style_for_in(Si, STU, C))} \rightarrow \text{proposal(communication_by_to_in(COMM, BL, C, Si))} \]
4. Simulation Results

To illustrate the personal development support model described above, a specific scenario is addressed. In Section 4.1, the simulation for the personal development level model is discussed and in Section 4.2 shows the simulation for the support model.

4.1. Simulation of the development model

Simulations for an example case have been generated in the LEADSTO software environment [4]. The scenario shown represents a situation in which a Ph.D. student is developing in explorative research.

![Figure 3 Simulation trace: q values for R1, R2 and R3](image)

The student can show behaviours of three types: body language, task performance and communication. They are indicators of certain profile attributes \( p_{ij} \), which in turn are indicative for one of the four development levels, according to [1]. Before the student has decided which behaviour to perform, all possibilities for behaviour that suit the situational context are derived. In this example case, there are 7 behaviours possible for the student in the given context. When the behaviour possibilities are derived, only the possible behaviours that match with the student’s current development level are chosen. For example, the development level of the student first is R1 and later R2. The student’s development level can also be derived from the values of \( q_i \), which are shown in the graphs in Figure 3 (showing time on the x-axis). This figure shows that from about time point 145, \( q_i \) is above the threshold of 0.6. From this time point on the student is in the next development level: R2.

![Figure 4 Estimated profile attribute values \( v_{ij} \)](image)

In Figure 4 the updates of the estimated profile attribute values \( v_{ij} \) are shown. In Figure 5 the estimated values of \( q_i \) are shown. In contrast, Figure 3 shows the real values of \( q_i \), but they are identical to the ambient agent’s estimates in Figure 5, only the intelligent agent derives the values at a later time point, since it first needs to observe the behaviours that the student performs.

After the intelligent agent has estimated the current development level of the student, it derives appropriate leadership behaviours within the current context and the most effective leadership style. In the example simulation the input of the ambient agent’s reasoning component ‘action_selection’ is the belief that the most effective leadership style is S2.

Thereafter this component outputs a leadership style behaviour ‘smiling’ which corresponds with the leadership style S2 and with the current context c(5). This leadership behaviour will be output by the intelligent agent as a proposal to the leader. The
intelligent agent is called ‘professor_agent’ in the simulation trace. The full LEADSTO specification can be found at: http://www.cs.vu.nl/~treur/gd-support.lt.

As a next step, various extensions of the support model will be explored. For example, the possibility that the intelligent agent does not estimate the development correctly. In that case, a possibility could be that the ambient agent is able to learn from its errors by adapting the parameters by which it estimates the development level. A more extensive external validation of the model is also part of future work, although the model is based on the situational leadership theory in [1], which itself has been validated empirically.

6. References


