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Modeling Organizations Using a Hybrid Simulation Approach

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Introduction

We developed a prototype simulation that embodies a hybrid modeling approach derived from both system dynamics and agent-based simulations for modeling complex organizational behaviors and interactions.

In agent-based behavior-oriented simulations, agents are entities (like employees and company) that are endowed with certain behaviors and the interactions among these entities executing their behaviors give rise to complex dynamics. We coupled the vast body of insights from the system dynamics community with the agent-based modeling techniques to develop a hybrid simulation approach. The models in our prototype, called TalentSim, rely on this approach that represents a middle ground between the analog modeling based on differential equations in system dynamics and the discrete rule-based modeling methods common in the agent-based simulation community. At the individual agent-level, the modeling is more akin to system dynamics models. However, at the interaction level, the agents behave more like behavior-oriented simulations of agent-based models.

Agent-based modeling requires that the domain be modeled as a set of behaviors. It is an "interaction oriented" modeling paradigm, where the focus of the knowledge acquisition effort concentrates on defining the behaviors of the entities and the interactions among them[Epstein96]. In this type of simulations, agents are entities that are endowed with certain behaviors and the interactions among these entities executing their behaviors give rise to complex dynamics. Some of the discrete-decision making and symbolic reasoning tied to sense-and-respond behaviors (e.g., if most of my colleagues aren't planning to come to work today, I may take a day off) common in business domains may be more amenable to agent-based modeling.

Agent-based techniques can handle heterogeneity in behaviors and domain descriptions. They are very amenable to data-driven modeling without the need for gross aggregations and averaging. For example, it is possible to feed the profiles, interests and behaviors of music buffs obtained by extensive data gathering into an artificial agent-based model world to anticipate or forecast the probability of a particular kind of soon to be released album becoming a hit[Farrell98].

In this paper, we discuss our hybrid modeling approach and illustrate our claims using examples from the TalenSim prototype. Then we briefly sketch some of the elements of our model that lies at the core of TalentSim Simulator.

The TalentSim Simulator

We developed the model in the context of an organization that is trying to change its strategic-orientation and the company culture from a traditionally Operationally efficient (OE) environment to a more Customer Intimate (CI) environment ([Treacy97] and [Gubman98]). Issues such as the role of formal communications, employee skill set misalignment, both with work requirements and the organizational vision, organizational commitment of the employees become relevant in this situation.

We will now discuss the components of the model underlying TalentSim. The current paper will only illustrate parts of the model. Details can be found elsewhere[Nagendra Prasad99].

We use a 2-dimensional vector space representation --S_A versus S_B -- as the core for our model. S_A and S_B represent suitability for type A and type B environments. Work comes in as an entity chosen from a distribution (at this point it has two values, one for S_A and the other for S_B, both drawn from two independent distributions). In a CI environment, the work event has a distribution with S_B biased to be larger than S_A (say drawn from a Gaussian-like distribution with S_B's mean being larger than S_A's mean) and in the case of OE, vice versa. The two values of the work event can be looked at as a vector in 2-D space. This vector indicates to us how much of skills of type A or type B are needed to perform effectively on the work event.

Different employees have different personal attribute profiles. They are represented in the same vector space as the work event. This addresses the question of "fit of an employee to a work event" and a number of other related questions. Thus an employee is represented by a 2-D vector. An employee attribute vector is represented by $[S_A , S_B]$. This indicates to us the skill level of an employee in type A and type B jobs.

So what is the fit of an employee to a work event? It is the projection of the employee profile vector E_V on the work event vector W_V . We will represent this as $E_V \mapsto W_V$.

TalentSim models a number of domain aspects, some of which include:

- **Performance, Motivation, Experience and Workload** of an employee.

- **Employee fit** is determined by the match between the employee's profile (skills, abilities, and competencies) and the job profile (skills, abilities, and competencies required for the job). An employee who has a good fit with his/her job will perform at a higher performance level.

- **Perception of Culture (CCp)** An individual develops his/her perception of an organization's culture based on their own background. When an organization changes its culture, an employee's perception of the new culture and its relevance to his/her work and how they perceive their "fit" to their work affects their motivation.

- **Communication of Vision & Enablements** An organization will facilitate an individual's alignment to the new culture through its communication and "enablements." Enablements are processes that are aligned to the new vision of the organization. They reinforce behaviors that are aligned with the new culture. When a message (in this case, the vision) is communicated by an organization to an individual, that person will seek to determine the message's relevance. Relevance is determined by how the individual perceives the "fit" between the vision and his/her job, role, or task. An individual's organizational commitment will be affected by this perceived relevance.

- **Nature of work** The type of work and the employees' perception of the fit of the work to their ability and skill profiles plays an important role in the motivation of the employees. If the employees are consistently saddled with work they are not suited for or trained to perform well at, their motivation is likely going to decline over time. Support for this exists in a number of sources including [Gubman98] and [EIU99].

- **Peer pressure:** Belonging to a good team makes people want to work together effectively. A highly cohesive team has an increased commitment level toward a project or organization. In the domain we are modeling, peer pressure has an affect on an employee to change and adjust his/her profile. This process of adjustment depends on the flexibility of an employee. The more flexible an employee is, more likely they will be affected by peer pressure to conform.

- **Susceptibility:** Susceptibility refers to an employee's openness to a job offer from another. According to [EIU99], individuals who have job satisfaction are still susceptible to job offers if they have low organizational commitment. In our modeling effort, susceptibility is affected by organizational commitment and turnover in the acquaintance network (leading to destruction of trust networks).

Agent-based modeling is an "interaction-oriented" modeling paradigm, where the focus of the knowledge acquisition effort concentrates on defining the behaviors of the entities and the interactions among them. For our modeling effort, we define three types of interactions. Notice how the interactions are defined akin to the more behavior-oriented agent-based modeling methods.

Employee-to-work event:

An organization attracts "work events" that are defined by duration and certain requirements. Examples of work events are projects, customer phone calls, transactions, and so on. Work events can be defined along certain dimensions of requirements – like personal interaction involved, listening, problem-solving, process control, teamwork, financial understanding, attention to detail, etc. Each work event has values along these dimensions. The relative values determine the type of skills needed for its execution. In our initial prototype we simplified these dimensions and started with just two features S_A and S_B.

An employee has a profile comprising of some of the same dimensions as work (or at least functionally mapped abstractions thereof – for example, creativity could be mapped to listening, relationship-building and rapid problem-solving into it). The level of performance regarding a given work event is determined by the employee's profile and the fit of the work event to that profile. Performance is also determined by workload, experience, company culture, motivation and knowledge management efforts. It is a function of all these factors.

Employee-to-employee and employee-to-company:

An employee's motivation is reduced by mismatches between his profile and the company culture. His profile is altered by his perception of the "people culture" in the organization. A person's flexibility also a plays a role in the amount altered. Consistently large mismatches between the profiles of employees a person meets and the work events a person deals with, lead to lower motivation and higher turnover.

Externalities also lead to turnover. Externalities represent "other greener pastures" like job offers from the competition or opportunities that are attractive elsewhere. An externality becomes more attractive based on a person's experience and a person does not leave the company until he is with it for a certain duration. Training has the effect of increasing the knowledge of work processes and skill in performing them. Experience also plays a role in the effectiveness of training. However, the effects of experience are different in different kinds of environments. For OE, experience is not as important a player as in CI environments. Communication and strategic enablement affect the profiles of employees and their effectiveness in particular kinds of jobs (OE versus CI jobs). Higher performance leads to higher satisfaction. Satisfaction has an effect on the turnover.

Entities in the Simulation

Environment

In this paper, we use a "tick" to represent a day. A tick is a unit of time in the simulator and can be mapped to the model in a domain-specific way. S_A is used interchangeably with OE, and S_B is used interchangeably with CI.

The environment selects **Work Event** X at random from a distribution of S_A – S_B, hours and the number of people needed to execute it.

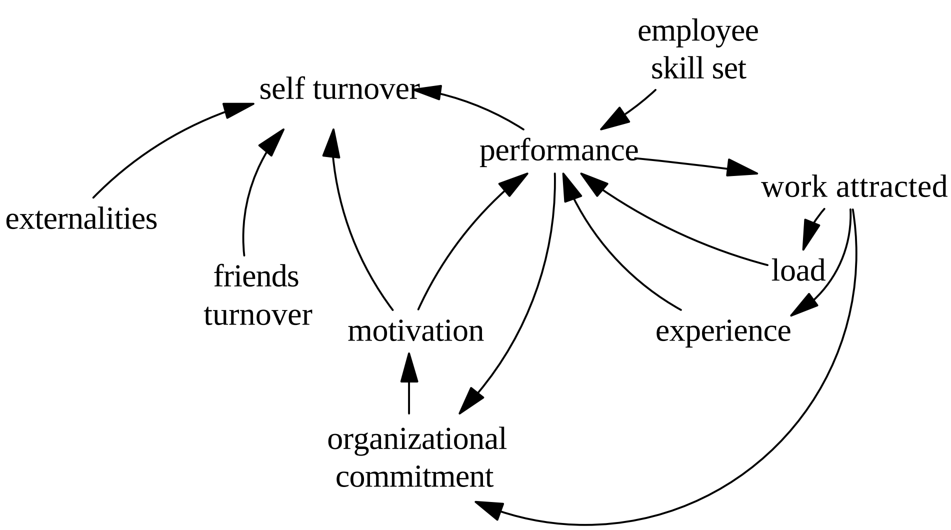
The organization attracts work events based on the difference in performance of the organization and that of the competitor. As the company performance gets better, it attracts an increasing fraction of the work available in the marketplace

People with different skills approach the company to be hired. There is a rate at which **potential employees approach the company**

Company

Individuals are hired according to a **hiring policy**. In our prototype, we used a **replacement-level policy**. Whenever there is attrition, hiring goes on until the replacement level is reached. A company hires a person if he is within the threshold requirement. This determination is affected by the pressure on hiring (which varies with the gap between the required versus actual number of employees) and the company's effectiveness at finding people with appropriate profiles.

Individual



Performance of an employee on the work assigned to her is given by the following form:
Performance = (k_4 * Effect of Company culture & enablement + k_5 * Effect of Employee skill set) * motivation_factor * workload_factor * experience_factor)
where $k_4 + k_5 = 1.0$

Effect of employee skill set =

$(E_V \mapsto W_V)/|W_V|$ when $E_V \bullet W_V < |W|^2$

Else | W_V |/ |W_V | = 1.0

Notice that this looks akin to how System Dynamics based methods may model the effect of performance. In our experiments with TalentSim, we created hundreds of "employee" agents. Below, we look at the specifics of some of the elements in the model.

Details for Some Aspects of the Models

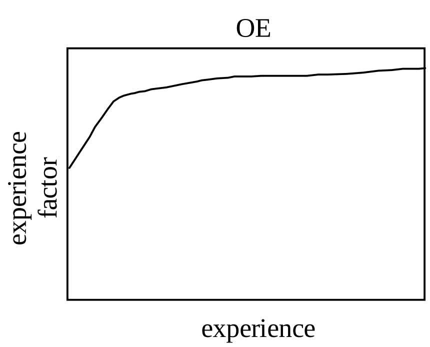
Let us see how **experience** effects performance. Employees build experience with every tick. Let us also look at the notion of experience profile from which experience is calculated. It is again a 2-D vector along [S_A , S_B]. When an employee does a particular job, the job just gets added to the experience profile, *scaled by performance*. We can just make this the exponentially weighted sum along each of the two dimensions. Experience with respect to a new job W_V is calculated as the projection: Experience vector $\mapsto W_V$. In addition to experience profile, an employee also has "experience time" –the time he spends building it.

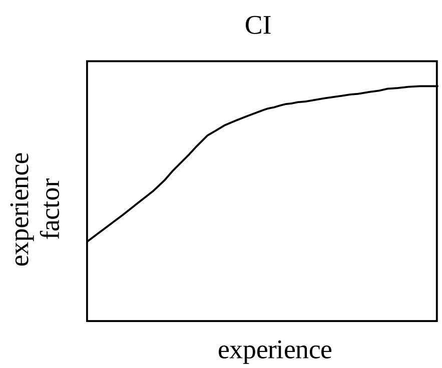
Total_exprience$_v$ = performance (on this task) * W_V + γ * Total_experience$_v$ (before this work event)

γ is a constant close to, but less than 1.0 (something like .999). It is called the discount factor.

Experience factor is calculated from experience. It is a non-linear function of experience as shown below.

The experience factor graphs for OE & CI are different. In OE, zero experience still gives a large value for experience factor. This means that even without any experience the person can deliver quite some performance. And the graph rises a little. So experience doesn't make too much difference and it rises





quickly. In the CI graph, experience is a great teacher and it takes time to learn it all.

Organizational Commitment variable ranges from [0 1.0] and is affected as follows:

Δ Organizational Commitment$_X$ = k_8 * |($^A CC_{PX}$ - $^A E_X$)| * Organizational Commitment$_X$
when the mismatch is greater than a threshold, i.e., ($^A CC_{PX}$ - $^A E_X$) > 0.5
where k_8 is a small negative fraction,
$^A E_X$ is the component of employee skill profile along A-dimension
$^A CC_{PX}$ is the A-component of X's perception of organizational culture.

We do a component-wise check to get the net loss of Organizational Commitment. This check can be done every 30 ticks once.

k_8 = - 0.03 or it takes about 36 months (about 1/0.03) for a person to lose all commitment when there is complete mismatch.

Δ Organizational Commitment$_X$ = k_9 * |($^A W_V$ - $^A E_X$)| * Organizational Commitment$_X$

when the mismatch is greater than a threshold, i.e., $({}^{A}W_{V} - {}^{A}E_{X}) > 0.5$
where k_9 is a small negative fraction

$k_9 = -0.01$ (or it takes about 20 changes of 30 ticks in length or about 600 ticks or about 2 years for a person to lose all Organizational Commitment in the case of extreme mismatch between his profile and the work requirements.

Δ Organizational Commitment$_X$ = k_{10} * performance * (1 - Organizational Commitment$_X$)
where k_{10} is a small positive fraction and the performance of a work event achieved performance greater than a threshold, performance > 0.6
$k_{10} = 0.01$ for reasons similar to the above.

Conclusion

We borrowed extensively from the vast body of insights that the system dynamics community developed over the last 40 years and adapted them to the agent-based modeling problems where appropriate. The models in TalentSim represent a middle ground between the analog modeling based on differential equations in System Dynamics and the discrete rule-based modeling methods common in behavior-oriented modeling in the agent-based simulation community. At the individual agent-level, the modeling is more akin to system dynamics modeling. However, at the interaction level, the agents behave more like behavior-oriented simulations of agent-based models. However, the tricky issue here is to be able to move from the analog world of differential equations into discreet world of behavior rules and vice versa. We don't have any systematic approaches to this problem. We currently use ad-hoc thresholding techniques, but this is an area that needs much more thought.

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