Introducing Agent Based Implementation of the Theory of Reasoned Action: A Case Study in User Acceptance of Computer Technology

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Abstract-It is important to predict and analyze user acceptance of computer technology in order to address success and failures of technological products. The Theory of Reasoned Action has been used for two decades in empirical studies to predict user acceptance of computer technology based on parameters of attitude, subjective norm and behavioral intention. Empirical studies are expensive to carry out and inflexible in predicting the diffusion of parameters over time. In this paper we introduce an agent-based implementation that implements a simple version of the theory of reasoned action model. Our agent-based implementation simulates continuous data compared to empirical studies, which collect static data over discrete intervals of time. Empirical studies are unable to account for the changes in data between successive time intervals. Our implementation is cost effective and easy to use. The results we produced corroborate the results obtained from the last few decades of empirical research in this field.

1. INTRODUCTION

The Theory of Reasoned Action (TRA) model predicts human behavior. The *intention* of a person to behave in a particular manner is a function of two determinants, one the person's nature and the other the social influence on that person. A person's positive or negative view to perform a particular behavior is known as his /her *attitude* [3]. The social pressure to perform a particular behavior put on him/her by the society of which he/she is a part is known as *subjective norm*.

The TRA is used in empirical social simulations like predicting and understanding women's occupational orientations [7, 9, 18], weight loss [8, 10, 16, 17], family planning behaviors [11, 13, 19], consumer behavior [14] and voting in british elections [4]. One of us, Fred Davis has applied TRA to model the user acceptance of computer technology [5].

Over the last two decades, user acceptance of computer technology has been modeled by introducing the system to a user and getting his /her opinion via a questionnaire. This process is repeated again after a certain amount of time (Typically about three times, once before the technology has been introduced to the user, then immediately after technology has been introduced to users and finally after the technology has been used for a few months). Then the empirical data is analyzed to check for any changes in the various parameters of human models of TRA. This method of modeling is not very efficient and flexible because analysis of the empirical data is discrete and not continuous. Changes that have occurred between these successive time cycles cannot be accounted for by the current empirical implementations. Also, the process of collecting user opinions through questionnaires is cumbersome and expensive.

In this paper we introduce an agent-based implementation, which overcomes these limitations by generating the data continuously over time. We have modeled two systems one in which agents are independent of each other and another in which agents are connected to each other through social links. It is cost effective, since running a computer program is not expensive. Our system is flexible in the sense that it can be modified at runtime with varying parameters.

In the remainder of this paper, we will discuss our agent-based implementation of the TRA with respect to user acceptance of computer technology. In the next section we will describe our project model and the algorithm developed for this implementation.

II. Agent Based Implementation of the TRA to model User Acceptance of Computer Technology

Lack of user acceptance has always been an obstacle to the success of new computer technologies. Determining user acceptance is very important as it enables us to predict and analyze user behaviors. It answers problems related to failure and success of technologies, and explains abnormal behaviors [5].

We have designed a basic version of the TRA that targets user acceptance of computer technology. Much richer models of TRA are available like the Technology Acceptance Model (TAM) [5]. However, our agent-based implementation is our initial attempt and leaves complex parameters found in TAM models.

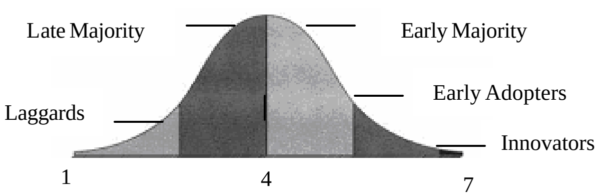

Figure 1: Bell Curve representing Attitudes of a population towards accepting a new technology. This is similar to the curve found in [15].

Our implementation has two versions and we will refer to them as cases.
Case 1: agents are independent of each other and do not influence each other.
Case 2: agents are connected through a social network and are influenced by their friends who are users. In this case the user can specify the level of connectivity between the agents. For example the user chooses a connection of 20% between the agents then there is a probability of 0.2 that the agents could be connected to each other i.e. for a social network that has a given connectivity percentage say X%, probability of each pair being connected is set to X %.

The assumptions that we have made in our agent-based implementation are:
- *Attitudes* of the entire population are represented using a bell curve because "*technology is absorbed into any given community in stages corresponding to the psychological and social profiles of various segments within that community" [15]*.
- As shown above in Figure 1, *attitudes* of entire population range from 1-7 wherein innovators have a high *attitude* value of 7 and laggards have a very low *attitude* value of 1. Majority of the agent population falls in the early and late majority categories with *attitude* around value of 4.
- *Subjective norm* and *behavioral intention* range on a scale of 1 to 7 similar to the options given in questionnaires. (7 represents maximum *intention* to use the new computer technology and 1 represents the minimum *intention* to use the technology)
- Initially, all the agents have a *subjective norm* value of 1.
- Every agent is assigned an independent error in his or her *intention*. We assign the error to agents in the range of -1 to +1 resembling a bell curve (as in figure 1) with most of them having an error of zero. This error term accounts for the inaccuracies across individuals.

We compute the *behavioral intention* of an agent by multiplying the *attitude* and *subjective norm* with the respective weights and then taking a sum of their products and the error term, i.e.,
For any agent i,

$$\textit{Behavioral intention}_i = \textit{Weight on Attitude}_i * \textit{Attitude}_i + \textit{Weight on Subjective Norm}_i * \textit{Subjective Norm}_i + \textit{Error}_i \quad (1)$$

In the first case, where the agents are independent of each other, if the computed *behavioral intention* is greater than the threshold specified then update the *subjective norm* using the equation below.

$$\textit{Subjective Norm}_i = (6*(\textit{Total number of users/population size})) + 1; \quad (2a)$$

In the second case, individuals are connected through a social network and subjective norm is updated using the equation below.

$$\textit{Subjective Norm}_{i=} (6* (\textit{Actual Users who are friends}_i / \textit{Total friends}_i) + 1; \quad (2b)$$

In equation (2b), if the number of friends for an agent is zero then the subjective norm for that agent remains unchanged.

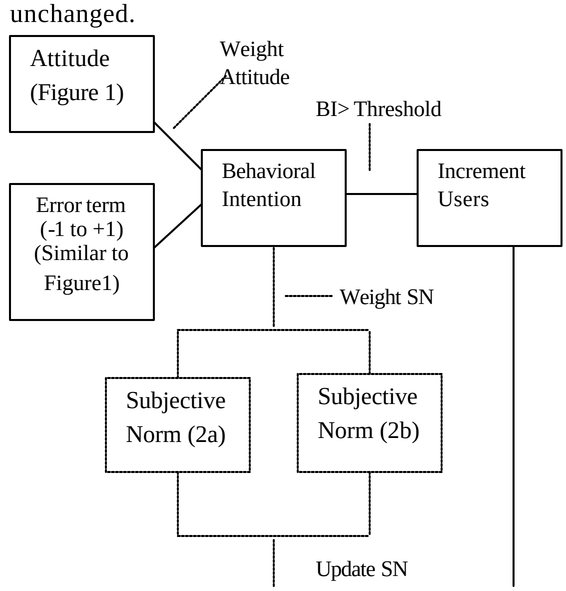

Figure 2:TRA Model

The TRA model of our implementation is shown in figure 2. As shown in the figure, the *behavioral intention* influences the number of users of the technology, which in turn influences the *subjective norm*.

An agent whose *behavioral intention* is greater than the threshold set at runtime is considered as a new user of the technology.

The algorithm developed for this implementation is given below:

```
Instantiate all parameters (Population size, Attitude,
Subjective Norm, their corresponding weights and
Behavioral Intention Threshold)
If the social network option is selected create a
network of agents using the user specified level of
connectivity.
 For every time cycle
   For each agent n
     If the agent is not a user
      Compute its Behavioral Intention using
      equation (1);
        If the Behavioral Intention is greater than
        the threshold then
         Increment the number of users;
          If social network option is enabled then
          update the subjective norm for the entire
          agent population using equation (2b) else
          use update subjective norm using
          equation (2a);
        End If
     End If
   End Loop
 End Loop
```

The GUI of our implementation is shown in Figure 3.

Our graphical user interface presents the user with the following options. The user can make selections on the following:

-Population size: user can specify the size of the agent population.

-Types of attitude, i.e., 'attitude bell curve' option where the entire population is assigned attitudes in the form of a bell curve that range between 1 and 7 and 'constant attitude' option where the entire population is assigned constant attitude.

- Types of subjective norm i.e., 'incrementing SN' where the subjective norm of every agent is incremented each cycle and 'constant SN' option where the subjective norm of all agents remains constant throughout the simulation.

- Types of behavioral intention i.e., 'probabilistic BI' where the actual behavior of the agent is computed in a probabilistic manner and 'threshold BI' where actual behavior is computed using the threshold value specified.

- Error term: user can specify if the error term should be considered.

- Enable social network: user can specify if agents are independent. If this option is enabled then the user can further specify the percentage of the connection between agents representing the strength of the network.

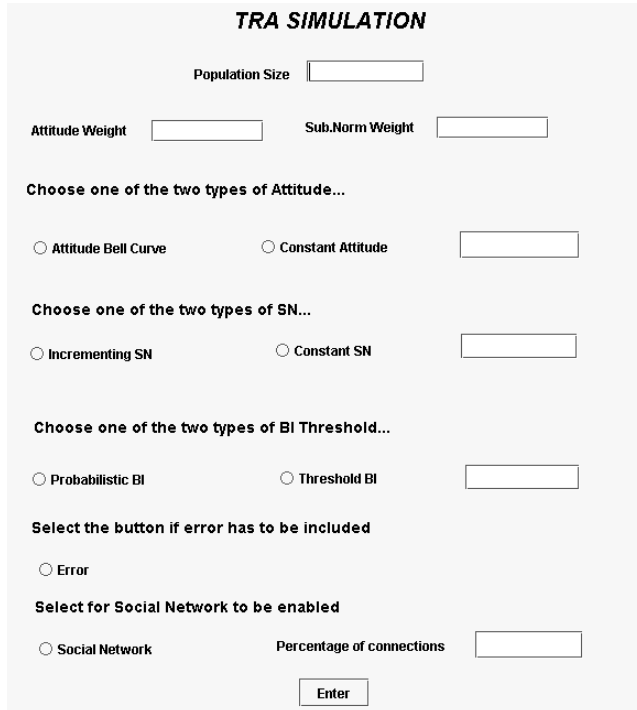

Figure 3: GUI of our implementation

In the next section, we explain the results of the experiments conducted and our future work.

3. EXPERIMENTAL RESULTS

We conducted several experiments by varying the parameters such as the weights of *attitude* and *subjective norm*, population size and threshold values.

3.1 Case 1: Independent agents

We conducted an experiment with a population size of 1000, *attitude* weight of 0.52 and *subjective norm* weight of 0.52 by giving equal weight to both *attitude* and *subjective norm*. The *behavioral intention* threshold was set to 4.0. The results of this experiment are shown in Figure 4.

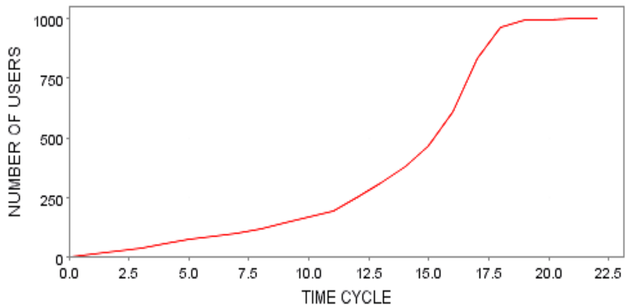

Figure 4:Case1: S – Shape Curve generated using the algorithm with attitude weight 0.52 and subjective norm weight 0.52

Our model fits the classic s-shaped cumulative diffusion curve as in [15]. The S-shape of the curve (Figure 3.0) occurs because once the early users adopt the new technology, they influence the *subjective norm* of the entire population and hence the number of users per unit time increases rapidly.

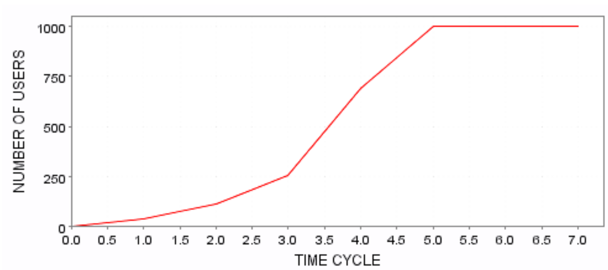

Figure 5:Case1: S – Shape Curve generated using the algorithm with attitude weight 0.52 and subjective norm weight 0.9

In another experiment, the population size was set to 1000, *attitude* weight to 0.52 and *subjective norm* weight to 0.9 wherein the weight on *attitude* is higher compared to the weight on *subjective norm*. The *behavioral intention* threshold was set to 4.0. The results of this experiment are shown in Figure 5.

3.2 Case 2:Agents in a social network

In this experiment, the social network was enabled, the population size set to 100, attitude weight to 0.52 and *subjective norm* weight to 0.55.The *behavioral intention* threshold was set to 4.0 and the percentage of connection was 20%. The results of this experiment are shown in Figure 6.

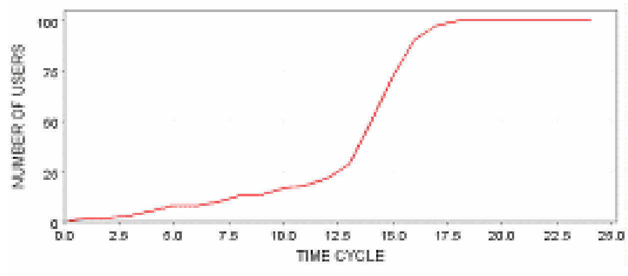

Figure 6:Case2: S – Shape Curve generated using the algorithm with attitude weight 0.52 and subjective norm weight 0.55 and percentage of connection to 20%.

In another experiment, the population size set to 100, attitude weight to 0.52 and *subjective norm* weight to 0.55.The *behavioral intention* threshold was set to 4.0 and the percentage of connection was 50%. The results of this experiment are shown in Figure 7.

The slope of the S-Shape Curve varies with different weights of *attitude* and *subjective norm*.

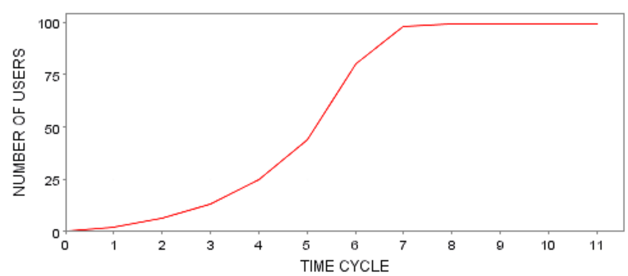

Figure 7:Case2: S – Shape Curve generated using the algorithm with attitude weight 0.52 and subjective norm weight 0.55 and percentage of connection to 50%.

4. CONCLUSIONS

This paper introduced an agent-based implementation of the TRA to model user acceptance of a computer technology. It was shown that it is more efficient than traditional empirical methods based on TRA. We have modeled an artificial society of agents closely related to human population wherein we tested for behavior of both independent agents and a network of agents socially connected.

This implementation can be used for various other studies that suffer from empirical limitations. This will reduce the cost of sending out surveys and makes it easier to predict the success or failure of a technology.

In future work we will extend our implementation to include other parameters in the Technology Acceptance Model reported in [5].

REFERENCES

[1] Ajzen, I., and Fishbein, M. Factors influencing *intention*s and the intentional behavior relation, Human Relations, 1974, 27, 1-15.

[2] Ajzen, I., and Fishbein, M. The prediction of behavior from attitudinal and normative variables, Journal of Experimental Social Psychology, 1970, 6,466-487

[3] Ajzen, I. and Fishbein, M., Understanding Attitudes and Predicting Social Behavior, Prentice- Hall Inc, 1980.

[4] Butler, D., and Stokes, D. Political change in Britain: Forces shaping electoral choice, New York: St. Martin's Press, 1969.

[5] Davis, F. D., Bagozzi, R. P., and Warshaw, P.R. User acceptance of computer technology: A comparison of two theoretical models, Management Science, 35, 1989, pp. 982-1003.

[6] Fishbein, M., and Raven, B.H, The AB scales: An operational definition of belief and attitude, Human Relations, 1962, 15, 35-44.

[7] Gysbers, N.C., Johnston, J.A., and Gust, T. Characteristics of homemaker and career-oriented women, Journal of Counse1ing Psychology, 1968, 15, 541-546.

8] Hall, S.M., and Hall, R.G., Outcome and methodological considerations in behavioral treatment of obesity, Behavior Therapy, 1974, 5,352-364.

[9] Helson, R. The changing image of career woman, Journal of Social Issues, 1972, 28, 33-46

[10] Jeffrey, D.B., Some methodological issues in research on obesity, Psychological Reports, 1974, 35,623-626.

[11] Kiser, C. The Indianapolis study of social and psychological factors affecting fertility, In C.V Kiser (Ed.), Research in family planning, Princeton University Press, 1962

[12] Mathews, E., and Tiedeman, D .V. Attitudes toward career and marriage in the development of life styles of young women, Journal of Counse1ing Psychology, 1964, 11,375-384

[13] Mauldin, W. P. Fertility studies: Knowledge, attitude and practice, Studies in Family Planning, 1965, 1(No. 7), 1-10.

[14] Mcneil, J. Federal programs to measure consumer purchase expectations, 1946-1973: A post-mortem, Journal of Consumer Research, 1974, 1, No.3, 1-15.

[15] Moore G.A., Crossing the Chasm: Marketing and Selling High-Tech Products to Mainstream Customers, Harper Business, 1999, 11-13.

[16] Rosenstock, I. M. Historical origins of the health belief model, Health-Education Monographs, 1974, 2,409-419.

[17] Stuart R.B., and Davis, B. Behavioral techniques for management of obesity, Champaign, I11, Research Press, 1971.

[18] Wagman, M. Interests and values of career and homemaking oriented women, Personnel and Guidance Journal, 1966, 44, 794-801.

[19] Whelp ton, P. K., Cmpbell, A., and Patterson, J.E. Fertility and family planning in the United States, Princeton University Press, 1966.

[20] Wilson. D.T., Matthews, H. L., and Harvey, J.W., An empirical test of the Fishbein behavioral intention model, Journal of Consumer Research, 1975, (March), 1, 39-48.