Selection of Partners for Co-operation Based on Interpersonal Trust

Arnoštka Netrvalová†, Jiří Šafařík†, *Member, IEEE*
† Department of Computer Science and Engineering, University of West Bohemia, Pilsen, CR

***Abstract* — This paper presents the deployment of interpersonal trust for selection of partners in the community. The term trust and its representation are addressed. The risk of co-operation and its influence for selecting partners using mutual trust are studied. Our approach to the evaluation of the caution against co-operation is based on application of the game theory. Results of experiments using proposed method for selection of partners are presented.**

***Keywords* — Trust, trust modeling, co-operation, game theory**

I. Introduction

INTERACTIONS between human and systems often take place in an uncertain environment. Examples are Peer-to-Peer systems, e-commerce systems, etc. [1]. In such a system the decision on partner selection plays an important role.

Consider a community, in which the partners for cooperation have to be determined, often in order to achieve a common goal. When the trust is included in the society model, the decision can be partially based on interpersonal trust.

Trust is a fact of everyday life and plays an important role in societies. The acceptation of the trust is wide. Various explanations [2] are offered; from firm belief in honesty, truthfulness, justice, confident expectation or hope, something managed for the benefit of another, confidence in ability or intention of a person to pay at some future time for goods or services, till business credit. To summarize, we will understand the trust as a given credit, hope, confidence in ability or intention of persons to pay for services at future.

One of the first definitions of the trust was formulated by Deutsch [3]. The definition states: "Trusting behavior occurs when an individual perceives an ambiguous path, the results of which could be good or bad, and the occurrence of the good or bad result is contingent on the actions of another person; finally, the bad result is more harming than the good result is beneficial. If the individual chooses to go down that path, he can be said to have made a trusting choice, if not, he is distrustful".

Similar definition was presented by Golembiewski and McConkie [4], "… the loss or pain attendant to un-fulfillment of the trust is sometimes seen as greater then the reward or pleasure deriving from fulfilled trust. Trust implies some degree of uncertainty as to outcome. Trust implies hopefulness or optimism as to outcome."

We treat as a basic point Gambetta's definition of trust, which was derived as a summary of the contributions to the symposium on trust in Cambridge, England, 1988 [5].

Taking the main social aspects of the definitions above, we can propose our short simple definition of the trust: The trust in an individual is a commitment to an action based on a belief that the future actions of that individual will be make for a good outcome.

II. Trust Representation

Naturally, it the society models with trust, the trust has to be measured. However, some simplifications and limiting presumptions must be done. For examining the trust as a behavioral pattern, some ways of representing and possibly visualizing it must be known

Even trust is a very hazy term [6]; it is not so much inter-subjective as it is widely understood. Its indeterminateness should be taken into account, when trying to represent the trust as a value. Modifying Marsh's way [7] of representation, and [8], [9], we treat the trust as a value between 0 and 1, where 0 means the complete distrust, value 0.5 is ignorance and 1 means the "blind trust". The interpretation of the trust value is very model dependent [8]. A single trust value can be visualized as a point on the line between point 0 and 1 on the horizontal axis, which is acquired by mapping of circumlocution on vertical axis in Fig.1.

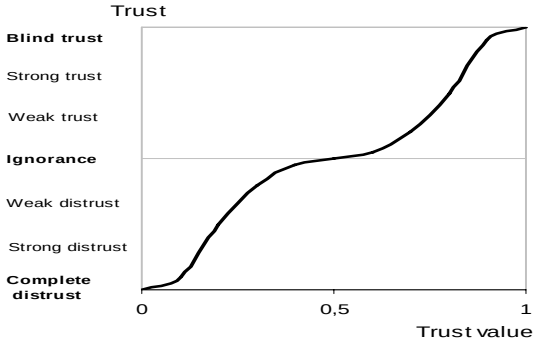

Fig. 1. Trust value mapping function

The work was granted by the Ministry of Education, Youth and Sport of the Czech Republic - University spec. research - 1311.

†Arnoštka Netrvalová, is with the Department of Computer Science and Engineering, Faculty of Applied Sciences, University of West Bohemia, Univerzitní 8, 30614 Pilsen, Czech Republic, {e-mail: netrvalo@kiv.zcu.cz, phone: +420 37762425}.

Generally, the mapping function is neither linear nor symmetrical. Further we will work with trust values from the interval <0, 1>.

Next, we specify how an interpersonal trust, i.e. trust between two individuals, can be described. Consider an group of n autonomous (acting individually) individuals modeled as the set $X = \{x_1, x_2, \ldots, x_n\}$. We formulate the measure of the interpersonal trust (between two individuals x_i and x_j) as

$$t_{ij} = t(x_i, x_j),\ t_{ij} \in \langle 0,1 \rangle,\ \ i,j = 1, \ldots, n,\ i \neq j \qquad (1)$$

We describe the situation, when both t_{ij} and t_{ji} exist, as the reciprocal trust of the pair of individuals x_i and x_j .e. pair). This reciprocal trust of the pair will be denoted as $[t_{ij}\,;t_{ji}]$.

We use the directed weighted graph to represent the interpersonal trust in the group. The vertices represent the individuals. The interpersonal trust is represented by a directed edge connecting two individuals (vertices). The weight of an edge indicates the interpersonal trust between connected individuals. The direction of the edge reflects possible interpersonal trust asymmetry, i.e. $t_{ij} \neq t_{ji}$ (individual x_i trusts to x_j differently than individual x_j trusts to x_i). Note that complete distrust is represented by an edge exists with zero weight, while non existence of an edge between two vertices represents the situation when the individuals have no contact.

Example of the representation of the interpersonal trust in the group is shown by the graph in Fig.2. The group consists of three individuals *A*, *B* and *C*. The value individual *A* trusts to *B* is 0.9, the trust value of individual *B* to *A* is 0.6, individual *B* to *C* is 0.5, and individual *C* to *A* is 0.8. Individual *A* has no contact to *C* and *C* has no contact to *B*. Note, that the graph does not contain self-looped edges.

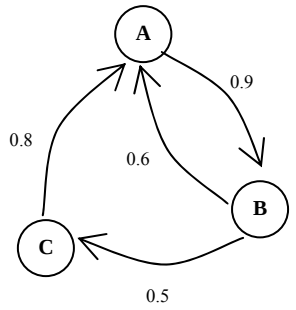

Fig. 2. Graph of the interpersonal trust in a group

We use the adjacency matrix for graph representation. The matrix of a graph of interpersonal trust in a group is denoted as trust matrix *T*. The matrix *T* for the graph in Fig.2 is following

$$T = \begin{pmatrix} -1 & 0.9 & -1 \\ 0.6 & -1 & 0.5 \\ 0.8 & -1 & -1 \end{pmatrix} \qquad (2)$$

The first line (column) of the matrix represents the trust value of individual *A* to *A*, *B* and *C*, the second one represents the trust of individual *B* to *A*, *B* and *C* and the third one describes the same of individual *C*, i.e. the weights of corresponding edges in the graph. Matrix entry -1 denotes non existence of the edge.

Symmetrical matrix entries, both different from -1, form a reciprocal trust of pair of individuals. The reciprocal trust of the pair of individuals *A* - *B* exists in our example. For the other pairs, i.e. *B* - *C* and *A* - *C*, the reciprocal trust does not exists.

III. Co-operation and Risk

Selection of the partners for co-operation from the group of individuals can be made in several ways. The random selection can be the first eventuality, e.g. [10]. Decision on selection of partners is often based on trust using some trust model [11]-[14]. The game theoretic approach to modeling trust based decisions is proposed in [15], [16]. Next important concept used in decision support is risk [17]. We will add the concept of caution against co-operation [18] based on reciprocal trust to the selection of the partners.

Each of the partners can maintain pursuance of the task independently, but upon whole, it is comprehensible, that the co-operation of partners with common interest will make for better effect, i.e. the task will be accomplished faster or a very difficult task would be solved.

First, we select the partners for the co-operation by any criterion. But all of the partners, which have common interest on solving some of the tasks, may not be applicable for co-operation. It is natural to select the very trustful partner for co-operation.

The Fig.3 shows the process for choosing the preselected pairs for the co-operation using the reciprocal trust. The square points represent the reciprocal trust of partners considered for co-operation. Partners with equal trust of each to other would be positioned on the slim dash line.

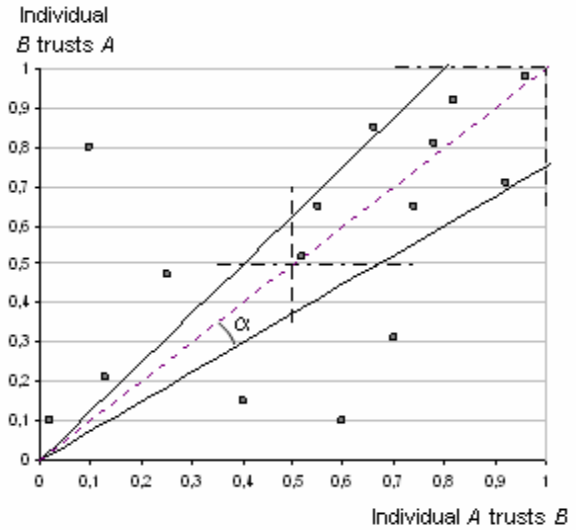

Fig. 3. Simple selection criteria of pre-selected pairs

We propose to reduce the set of possible partners based on following considerations:

- The mutual trusts of the partners should be closed each to other, while preferring partners with higher trust values.
- The reciprocal trust values should be high enough

The first one is realized by choosing partners with reciprocal trust values from V-sector (full line) parameterized by α. The second one is achieved by choosing pairs with both trust values higher than ignorance, e.g. $t_{ij} > 0.5$ and $t_{ji} > 0.5$ bold dotted and dash-dotted lines. The reduced set of possible co-operating pairs is given by pairs laying in the intersection of these two areas. Let us call this set as a set of pre-selected pairs and denote by *P*.

The question is how we can express overall trust of the selecting partner to the selected partner considering reciprocal trust, in order to determine the most trustful pair.

Boyle and Bonacich in [18] described simple method how to measure the risk applying game theory. They use 2-player, 2-strategy non-zero-sum game represented by the payoff matrix

		Partner *B*	
		Yes	*No*
Partner *A*	*Yes*	*x*, *x*	*w*, *z*
	No	*z*, *w*	*y*, *y*

(3)

Yes in (3) denotes acceptance of co-operation, *No* denotes non-acceptance of co-operation of the partners *A* and *B*. The first entry is the payoff received by the row player (Player A); the second is the payoff for the column player (Player B).

Then, they define following quantities. Risk of in co-operation because the opponent may not cooperate

$$r = (y\text{-}z), \tag{4}$$

gain from co-operation

$$g = (x\text{-}y), \tag{5}$$

and temptation to default from mutual co-operation

$$t = (w\text{-}x). \tag{6}$$

Based on these three factors, they introduced an intuitive "caution index" *c*

$$c = \frac{\sqrt{rt}}{g} \tag{7}$$

as a measure of amount of caution the player feels in taking co-operative choice. The higher index is the minor expectations of co-operation are.

To apply the caution index as the criterion of selection partners for co-operation, we have to have a payoff matrix based on reciprocal trust. Using introduced trust notation t_{ij} for interpersonal trust, the values of entries of the trust payoff matrix we define as follows

$$x = t_{ij}\ t_{ji}, \tag{8}$$

$$w = t_{ij}\ (1\text{-}\ t_{ji}\ ), \tag{9}$$

$$z = (1\text{-}\ t_{ij}\ )\, t_{ji}, \tag{10}$$

$$y = (1\text{-}\ t_{ij}\ )\,(1\text{-}\ t_{ji}\ ). \tag{11}$$

The following example (see Table1) relates the values of the previous parameters of risk *r*, gains *g*, temptation *t* and caution *c* for the pre-selected pair with the reciprocal trust [0.78; 0.81].

TABLE 1: CAUTION OF CO-OPERATION ACCEPTANCE.

x	***y***	***w***	***z***
0.63	0.04	0.18	0.15
r	***g***	***t***	***c***
-0.11	0.59	-0.45	0.37

For the positive gain and obvious requirement $rt \geq 0$, we get that for $[t_{ij}\,; t_{ji}]$ must hold $t_{ij} > 0.5, t_{ji} > 0.5$. Further, for these $[t_{ij}\,; t_{ji}]$ for corresponding values of cooperating is dominant strategy for both. This is in nice conformance with our former intuitive requirement of mutual trust values of the partners higher than ignorance.

The values of caution index for several interpersonal trust values from the interval (0.5, 1.0⟩ are listed bellow.

TABLE 2: CAUTION OF THE PARTNER *A*, WHO SELLECTED PARTNER *B* FOR CO-OPERATION.

t_{AB} / t_{BA}	***0.55***	***0.60***	***0.75***	***0.90***	***0.95***
0.55	0.50	0.66	0.83	0.88	0.90
0.60	0.33	0.49	0.70	0.78	0.80
0.75	0.14	0.25	0.43	0.53	0.56
0.90	0.07	0.12	0.23	0.30	0.32
0.95	0.04	0.08	0.16	0.21	0.22

The entry in the table is the caution c ($[t_{AB\,;}\ t_{BA}]$) of the partner *A* choosing partner *B* for the co-operation for corresponding values of interpersonal trust t_{AB} and $t_{BA.}$ In the interval (0.5, 1.0⟩, where the selection of the partners is winning, we can observe caution decreasing for the certain trust value of partner *A* (to partner *B*) along with the growing of the trust measure of partner *B* (to partner *A*). Similarly, c ($[t_{BA;}\ t_{AB}]$) is the caution of co-operation when partner *B* is choosing *A*. Because of possible asymmetry of mutual interpersonal trust, these values may differ. For the group in Fig. 2 we have *c* ($[t_{AB\,;}\ t_{BA}]$) = 0.81 and *c* ($[t_{BA;}\ t_{AB}]$) = 0.03. Generally, for the set *P* of pre-selected pairs we get |*P* | doublets of caution.

We propose the following two procedures for partner selection from all of the pre-selected pairs:

- Calculate arithmetic mean of doublet of caution for all pre-selected pairs; choose the pair with the lowest calculated value

- Determine greater value in doublet of caution for all pre-selected pairs; choose the pair with the lowest calculated value

The chosen pair for co-operation by above procedure may or may be not the same.

IV. EXPERIMENTS

To validate the properties of proposed method for selection of partners we have carried out series of experiments. The groups of individuals of various size n have been generated. Reflecting possible non-linearity and/or non-symmetry of the trust distribution by the mapping function, the interpersonal trust has been chosen with uniform distribution from the interval <0, 1> randomly.

First, we have looked how the selected partners are positioned in the pre-selected set. The demonstration of the position of reciprocal trust of chosen partners is depicted in Fig. 4 (n=15, α=10°) displaying just the relevant segment of pre-selected pairs. The chosen partners, i.e. their interpersonal trust, by both procedures are represented by the triangle points. Experiments gave evidence to conformance of selected pairs to our intuitive criteria for trust based partner selection.

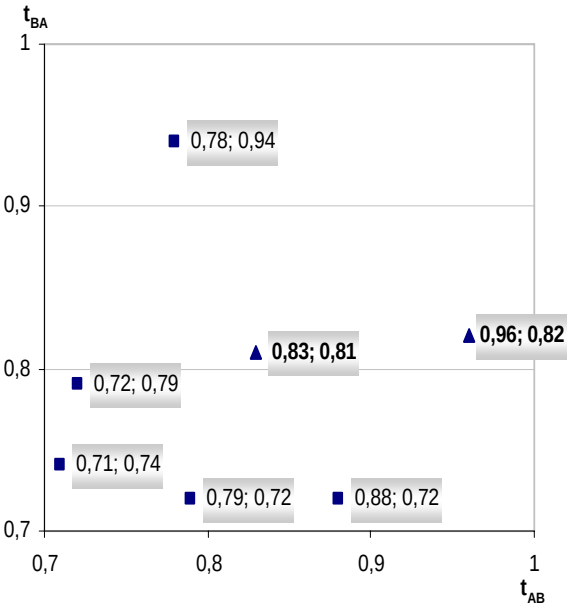

Fig. 4. Position of chosen pairs

Next, we have investigated the influence of the parameter α on selection of the pair for co-operation. Clearly, if the proposed method would not work for its values less than ($\pi/4$ – arctg 0.5), i.e. about 18°, the reduction of potentials partners by the V-sector would be useless.

Example of received results for the group of 15 individuals and both of the procedures are listed in Table 3 and Table 4. The experiments indicate that even the small parameter α is reasonable for the reduction of potential partners and chosen pair is independent on its value. This result enables us using small values of α for achieving substantial reduction of the set of pre-selected partners and speeding up the following calculations.

TABLE 3: STUDY OF PARAMETER α - THE FIRST PROCEDURE.

α	*Pair*	*Trust*	*Caution*
0	0	0	0
5	0	0	0
10	[0,6]	[0.96;0.82]	0.30 [0.45;0.15]
15	[0,6]	[0.96;0.82]	0.30 [0.45;0.15]
20	[0,6]	[0.96;0.82]	0.30 [0.45;0.15]
25	[0,6]	[0.96;0.82]	0.30 [0.45;0.15]
30	[0,6]	[0.96;0.82]	0.30 [0.45;0.15]
35	[0,6]	[0.96;0.82]	0.30 [0.45;0.15]
40	[0,6]	[0.96;0.82]	0.30 [0.45;0.15]
45	[0,6]	[0.96;0.82]	0.30 [0.45;0.15]

TABLE 4: STUDY OF PARAMETER α - THE SECOND PROCEDURE.

α	*Pair*	*Trust*	*Caution*
0	0	0	0
5	0	0	0
10	[12,14]	[0.83;0.81]	0.40 [0.40;0.36]
15	[12,14]	[0.83;0.81]	0.40 [0.40;0.36]
20	[12,14]	[0.83;0.81]	0.40 [0.40;0.36]
25	[12,14]	[0.83;0.81]	0.40 [0.40;0.36]
30	[12,14]	[0.83;0.81]	0.40 [0.40;0.36]
35	[12,14]	[0.83;0.81]	0.40 [0.40;0.36]
40	[12,14]	[0.83;0.81]	0.40 [0.40;0.36]
45	[12,14]	[0.83;0.81]	0.40 [0.40;0.36]

Finally, we asked about the soundness of deploying the caution concept based on reciprocal trust for the selection of partners for cooperation. We have studied the coincidence of pairs selected by both proposed procedures exploiting the caution.

The example of the dependence of the coincidence value on the α parameter is listed in Table 5. For each value of α parameter, the number of runs was 1000 and the group size n=50 in the experiments.

TABLE 5: STUDY OF PARAMETER α - PAIR COINCIDENCE.

α	*Coincidence*	*[%]*
0	0	0
5	656	65.6
10	673	67.3
15	661	66.1
20	668	66.8
25	659	65.9
30	655	65.5
35	665	66.5
40	657	65.7
45	648	64.8

Next, the variance of coincidence has been studied. Example of 10 coincidence values, each calculated from 1000 runs, for groups of n=100 individuals and α=10° is

in Table 6. The arithmetic mean is 66.5 %, the mean deviation is 1.008 % and the standard deviation is 1.32 %.

TABLE 6: STUDY OF COINCIDENCE VARIANCE.

Number	*Coincidences*	*[%]*
1	678	67.8
2	648	64.8
3	644	64.4
4	660	66.0
5	671	67.1
6	665	66.5
7	661	66.1
8	671	67.1
9	692	69.2
10	664	66.4

The experiments approved the independence of coincidence of selected pairs by both procedures on α parameter and showed low variance of coincidence.

Eventually, we have studied how the coincidence of the selected pair by both procedures depends on the size of the group of individuals.

We have carried on experiments with 1000 runs for the groups of size *n*=15, 50, 100, 500, 1000 (α=5°and 15°). Summary of results of these experiments are listed in Table 7 and Table 8.

TABLE 7: EXPERIMENT SUMMARY (α=5°).

Group size	*Coincidences*	*[%]*
15	695	69.5
50	679	67.9
100	664	66.4
500	668	66.8
1 000	652	65.2

TABLE 8: EXPERIMENT SUMMARY (α=15°).

Group size	*Coincidences*	*[%]*
15	669	66.9
50	659	65.9
100	663	66.3
500	672	67.2
1 000	662	66.2

To summarize, the proposed method are stable with the coincidence about 66%. We conclude that the deployment of caution based on reciprocal trust in the selection of partners of co-operation is sound.

V. CONCLUSION

Currently, we have developed an agent based system for modeling of trust evolution, which is now being implemented. The model incorporates selection of partners. The proposed deployment of the caution is intended for the primary partner selection. As the reciprocal trust of the co-operating partners evolves, in the repeated partner selections new values of caution will be calculated.

Next issues for research are following situations. The second entry of the reciprocal trust is not known. There is no partner who is trusted enough, i.e. more than 0.5.

REFERENCES

[1] Y. Wang, V. Varadharajan, *"Role-based Recommendation and Trust Evaluation"*. The 9th IEEE International Conference on E-Commerce Technology and The 4th IEEE International Conference on Enterprise Computing, E-Commerce and E-Services, Tokyo, 2007.

[2] *The World Book Dictionary*. World Book. Inc. Scott Fetzer Company. The World Book Encyclopedia, Chicago, 1964.

[3] M. Deutsch, *Cooperation and Trust: Some Theoretical Notes.* Nebraska Symposium on Motivation, Nebraska University Press, 1962.

[4] R. T. Gombiewski, M. MC Conkie: *The Centrality of Interpersonal Trust in Group Processes.* Theory of Group Processes, Wiley, 1975.

[5] D. Gambetta, "*Can We Trust Trust*?", in Trust :Making and Breaking Cooperative Relations, electronic edition, Department of Sociology, University of Oxford, chapter 13, pp. 213-237, 1970. Available: http://www.sociology.ox.ac.uk/papers/gambetta213-237.pdf

[6] E. Chang, P. Thomson, T. Dillon, F. Hussain, *The Fuzzy and Dynamic Nature of Trust.* S. Katsikas, J. López, G. Pernul (Eds.): TrustBus 2005, LNCS 3592, pp. 161-174, Springer – Verlag Berlin Heidelberg 2005.

[7] S. Marsh, "*Formalizing Trust as a Computational Concept*," Ph.D. Thesis, Department of Mathematics and Computer Science, University of Stirling, 1994.

[8] Š. Urbánek, "*Modeling and Simulation of Trust Evolution in Complex Systems*," Master Thesis, Slovak Technical University, Bratislava, Slovakia, 2004.

[9] A. Netrvalová, J. Šafařík: "*Human Trust Modeling*," 5thInternational Conference Aplimat, Department of Mathematics, Slovak Technical University, Bratislava, Slovakia, February 2006.

[10] H. Fort, "*Cooperation with random interactions and without memory or tags,*" in Journal of Artificial Societies and Social Simulation, vol. 6, no. 2, 2003. Available: http://jasss.soc.surrey.ac.uk/6/2/4.html

[11] A. Rettinger, M. Nickles, V. Tresp, *Learning Initial Trust among Interacting Agents.* M. Klusch et al. (Eds.): CIA 2007, LNAI 4676, pp. 313-327, Springer – Verlag Berlin Heidelberg 2007.

[12] W. Winsborough, N. Li: *"Towards Practical Automated Trust Negotiation"*. Policy 2002. Proceedings of the Third International Workshop on Policies for Distributed Systems and Networks, pp. 93-103. IEEE Computer Society Press, Los Alamitos, June 2002.

[13] T. Yu, M. Winslett: *"Policy Migration for Sensitive Credentials in Trust Negotiation"*. WPES '03. Proceedings of the 2003 ACM workshop on Privacy in the electronic society, pp. 9-20. ACM Press, New York, 2003.

[14] T. Yu, M. Winslett, K. Seamons: *Interoperable Strategies in Automated Trust Negotiation,* CCS '01. Proceedings of the 8th ACM Conference on Computer and Communication Security, pp. 146-155. ACM Press, New York, 2001.

[15] V. Sankaranarayanan, M. Chandrasekaran, S. Upadhyaya: *Towards Modeling Trust Based Decisions: A Game Theoretic Approach,* J. Biskup and J. Lopez (Eds.): ESORICS 2007, LNCS 4734, pp. 485-500, Springer – Verlag Berlin Heidelberg 2007.

[16] J. Baras, T. Jiang, *"Cooperative Games, Phase Transition on Graphs and Distributed Trust in Manet",* 43rd IEEE Conference on Decision and Control, vol. 1, pp. 93-98, IEEE Computer Society Press, Los Alamitos, 2004.

[17] A. Josang, S. Lo Presti, *"Analyzing the Relationship between Risk and Trust",* C. D. Jensen et al.(Eds.): iTrust 2004, LNCS 2995, pp. 135-145, Springer – Verlag Berlin Heidelberg 2004.

[18] R. Boyle, P. Bonacich: *"The Development of Trust and Mistrust in Mixed-Motive games",* Sociometry, 33, 123-139, 1970.