Iterated Prisoner's Dilemma on Alliance Networks

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The objective of this paper is to clarify the characteristics of alliance network that Japan belonged to after the World War II. On that alliance network, which Japan belonged to after the World War II, iterated prisoner's dilemma game will be played.

1 Introduction

Between countries, there are a lot of interactions; wars, trade, finance, and so on. Among those interactions, it is the national security that is most important one for a nation. In this paper, of all interactions of the national security, the focus will be on security alliance.

In this paper, in order to clarify the characteristics of the "alliance network", which Japan has belonged to after the World War II, iterated prisoner's dilemma game will be played on its network.

This analysis can make it clear that multilateral alliances affect bilateral alliances each other. This research is suggestive in that it provides a new viewpoint for International Political System.

2 Alliance Networks

By defining nation as node, and alliance as edge, it becomes possible to look at international relations as alliance networks. The characteristics of this alliance networks can be clarified through examining historical changes of "clustering coefficient" and "average path length".

As a result of analyses[1], it became clear that the characteristics of alliance networks changes drastically after World War II. Especially the network centering the U.S.A. after World War II became clear that it is an "small-world network", having large clustering coefficient and small average path length.

By actually visualizing the alliance network of year 2000 centering U.S.A., as seen on fig.1, it can be confirmed that it is a "small-world network"

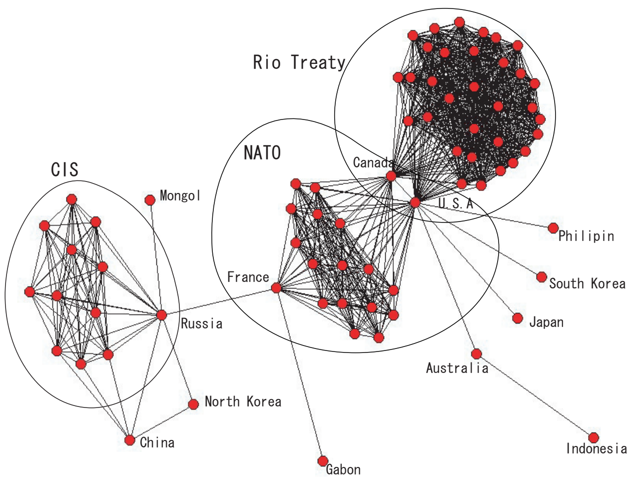

Figure 1: One Alliance Network in 2000

3 Alliance Dilemma

After the alliance is concluded, it is most ideal for allies to support each other. "Franco-Russian Alliance"(1892-1917) concluded before World War I, is a good example of ideal alliance. French and Russian General Staff Office cooperated to create tactics to fight against German threat.

However, it is a rare case for allies to give full support with each other. In most situations, one of the allies support the other, in one way. For example, although U.S.A. has an alliance with multiple nations, it is obvious that most nations are being supported by the U.S.A. and not the other way around. This creates a load of costs for U.S.A.. This is why U.S.A. asks its allies to give

[1] http://cow2.la.psu.edu/. We use "Formal Data Set ver. 3.03" for this paper.

	strengthen commitment	weaken commitment
strengthen commitment	support each other R	free rider heavy cost S
weaken commitment	heavy cost free rider T	abandon each other P

Figure 2: Alliance Dilemma

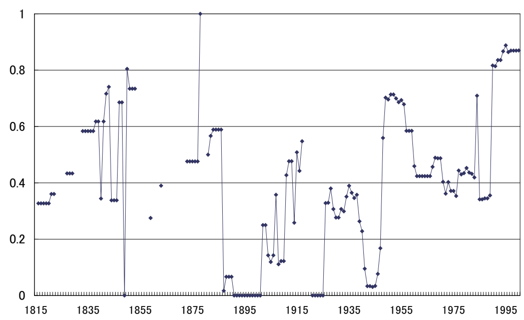

Figure 3: Clustering Coefficient of Japan

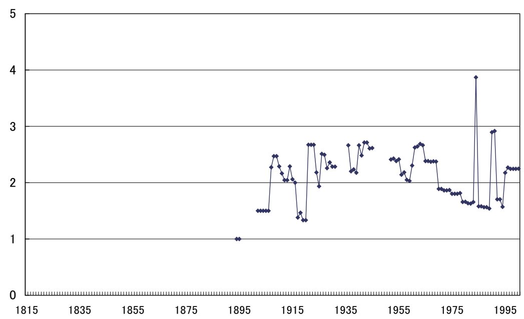

Figure 4: Average Path Length of Japan

supports like financial aids. This can be seen especially when U.S.A. has a financial or economic crisis. For the allies the load of a lot of support to maintain the alliance with U.S.A. will be heavier as well. However, stopping the support will lead to rupture, which is the worst result for all allies.

Allies want support but does not want to give support. This dilemma is called "Alliance dilemma". Such situation can be described as shown on fig.2.

Alliance dilemma is made into a same model as "prisoner's dilemma"[2]. In prisoner's dilemma, the profit order is $T > R > S > P$ as shown on fig. 2.

In International Politics, "Alliance Dilemma" has been studied as "Prisoner's Dilemma" for years. However, alliance researched in those studies are either multilateral alliances, like NATO, or bilateral alliance, like Japan-U.S.A. alliance. No studies treats all alliances as networks.

4 The Alliance Network of Japan After The WWII

After the World War II, Japan concluded an alliance with U.S.A. in 1952, leading to take part in an alliance network of U.S.A..

Judging from numerical transition on 3 and 4, the small-world network which Japan joined after World War II seems like an stable network. However, U.S.A.'s tremendous cost to keep the alliance is a big issue. After Japan gained its economic strength around 1980s, there had been a request from U.S.A. to raise the defense budget a couple of times. This situation has been called "defense friction". Even between friendly Japan and U.S.A., there is an alliance dilemma, and it shows the difficulty to maintain the alliance.

However, the difficulty to maintain the alliance cannot be seen from cluster coefficient nor average path length. The difficulty to maintain the alliance can be rephrased as how much they can keep cooperating when in an alliance dilemma. If this was to be experimented in a simulation, new characteristics of alliance network can be found.

5 Simulation Model

Simulation experiments had been done in order to further look into alliance network. For this simulation model, an alliance network, centering U.S.A., Japan joined after the World War II was used.

When allies are in an "alliance dilemma", it can be said that dilemma game is iterated on an alliance network. Therefore, in this simulation, iterated prisoner's dilemma game will be played on alliance network for each year.

The initial setting and method to change the strategy will follow the model in [3][4], which will be explained below.

For each game, nation or player, has a choice of either "cooperate" or "betray" as their strat-

Prisoner's Dilemma

	C	**D**
C	1	0
D	b	0

b > 1

Figure 5: Payoff Matrix

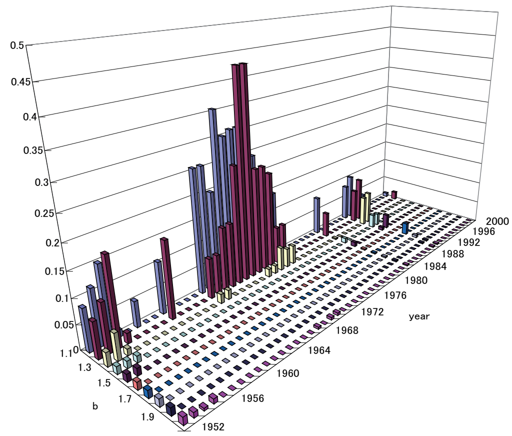

Figure 6: fraction of cooperators(1)

egy. Each nation will play against its linked allies. After each game, based on the payoff matrix, nation receives P_x points.

Before the next game, each player rethinks its strategy. Randomly, each nation chooses one ally. If the chosen alley's points P_y are lower than itselfP_x, the strategy does not change. If $P_y - P_x > 1$, the strategy will be changed in the percentage shown in this equation.

$$prob = \frac{P_x - P_y}{Dk_>}$$

D is $D = T - S$. For $k_>$, the larger of number of nation's degree(allies) or chosen alley's degree will be chosen.

Payoff matrix follows [3][4] as shown on fig. 5. Also, for initial setting, the percentage of cooperators and betrayer is set to be the same.

b was changed by 0.1.

When this iterated dilemma game is played, there will be a change in the percentage of cooperators. This change will lead us to new aspects of alliance network.

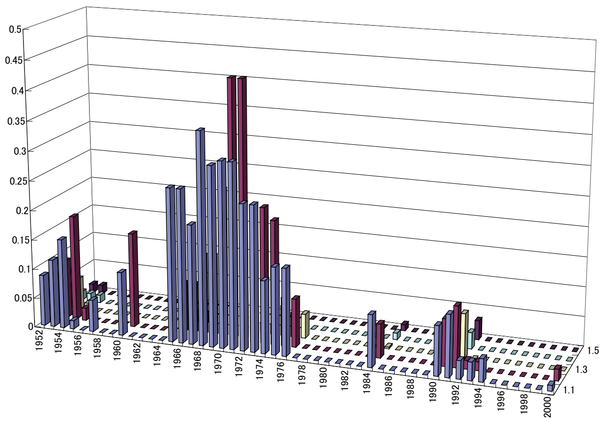

Figure 7: fraction of cooperators(2)

6 Simulation Results

Using the parameters written, the iterated prisoner's dilemma game was played 2100 times to calculate the percentage of cooperators. Then the last 100 times of that percentage of cooperators was averaged. This was done for 10 random seeds, and that 10 numbers were averaged. That result is shown in fig.6 and fig.7. These two figures show the same result but from an different angle. For easier understanding, 7 shows only up to $b = 1.5$.

It is already known that, when an iterated prisoner's dilemma game is played on a small world network, number of cooperators become 0 after b takes a value little bigger than 1[3][4].

Fig.6 and fig.7 leads to same results. Except for couple of years, most end up with cooperators vanishing in the end. This outcome proves that the alliance network Japan belonged to was a small-world network. From this result, it becomes clear that in an alliance network Japan belonged to, if there is a free-rider nation, who just receives support, there is a tremendous influence on all alliance. The criticism by U.S.A. for passivity of Japan in an alliance, may have come from understandings of this effects in an alliance network.

However, from 1964 to 1976, there are around 50 percent of cooperators for $b = 1.1$ and $b = 1.2$. Early 1950s show cooperators surviving through betrayal.

7 Analysis of Inner Mechanisms

Further research was done to see the changes in strategy for each year. Inner mechanism will be researched especially for the year 1976, when cooperators survived.

Fig. ?? is a graph showing how percentage of cooperators changed for each random seed number. Half the times nations abandon the alliance immediately, while the other half maintains cooperators around 40 to 60 percent. Up to an certain point, the cooperators decreases but jumps back up due to some trigger.

In order to search in details, see fig.9 which is a graph showing the changes in cooperators for first 50 steps in 1976, Seed6. As soon as it starts, the cooperators decrease to around 20 percent, but endure the betrayal and drastically increases around 32nd step.

This change is shown in fig.10 to fig.15. Each circle represents nation and red is betrayer and the blue is the cooperator. The second step(fig.11) and third step(fig.12 tells that the number of cooperators decrease suddenly. Also it can be seen that nations allied with Britain and France are cooperating. On the 33nd step, right after U.S.A. turns into a cooperator, number of cooperators increase greatly. This increase is simply due to U.S.A.'s influence as a cooperator.

The reason cooperators survive is because when nations like Britain and France, who has its multilateral alliances, cooperates, the cooperation remains maintained within the multilateral alliance. Having that group of cooperators, Britain and France, also being a member of NATO, gains the power to change U.S.A. into cooperator. When U.S.A. becomes a cooperator, it can effect so many nations that as a result, cooperators increase greatly.

8 Consideration

As a result of the experiment, different characteristics of alliance network which Japan belonged to after the World War II was found. It also became clear that for that alliance network, the existence of British and French multilateral alliance was important.

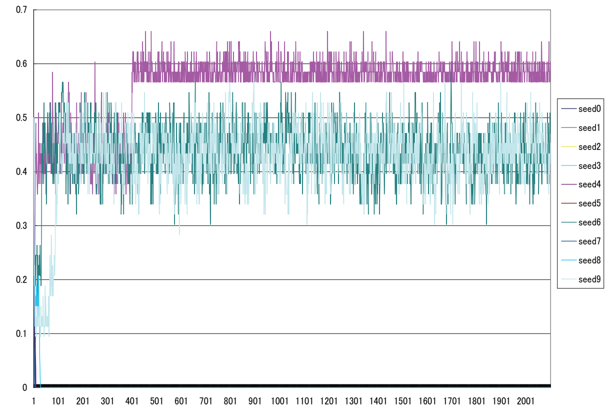

Figure 8: fraction of cooperators in 1976

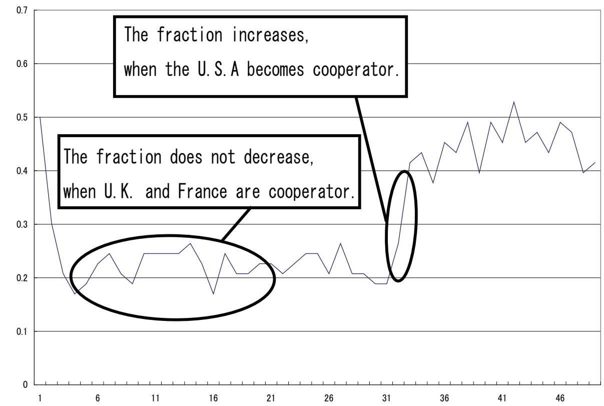

Figure 9: fraction of cooperators in 1976, seed 6

Reference

[1] Tomoki Furukawazono, Yuta Suzuki, and Takashi Iba. Historical changes of alliance networks among nations. In *Information Proceedings Society of Japan(in Japanese)*, 2006.

[2] Glenn H. Snyder. The security dilemma in alliance politics. *World Politics*, Vol. 36, No. 4, pp. 461–495, 1984.

[3] F.C.Santos and J.M.Pacheco. Scale-free networks provide a unifying framework for the emergence of cooperation. *Physical Review Letters*, 2005.

[4] J.M.Pacheco and F.C.Santos. Network dependence of the dilemmas of cooperation. *AIP Conference Proceedings*, 2005.

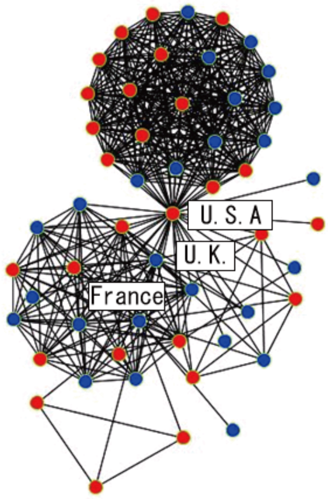

Figure 10: step 1

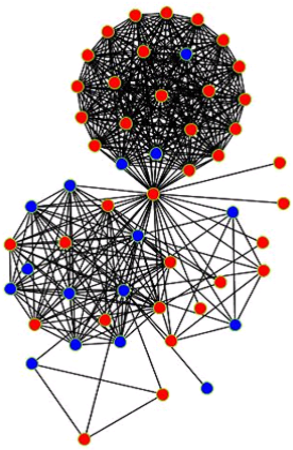

Figure 11: step 2

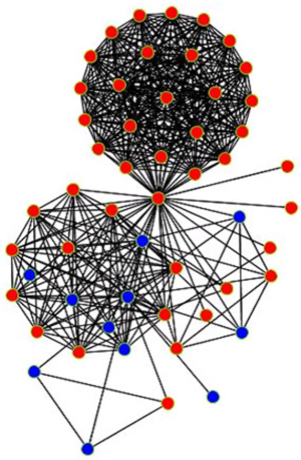

Figure 12: step 3

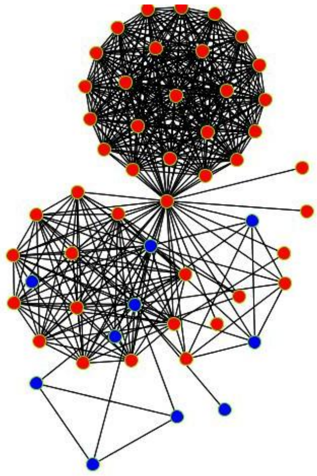

Figure 13: step 31

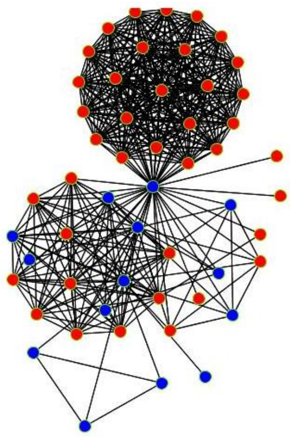

Figure 14: step 32

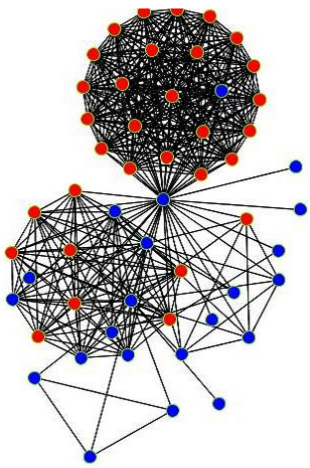

Figure 15: step 33