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A Historical and Geographical Visualization System of International Trading Information in 5D World Map

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Abstract— *The analytical visualization system for dynamically and multi-dimensionally creating overviews of international trading-information resources leads to new global research environments in the historically and geographically world-wide scope. Our system connects the international-relations history database with the international trading database as the significant information resources. This system has functions for analyzing the volume of international trade about a specific international-relations phenomenon and mapping the analytical results to 5D World Map (a set of chronologically ordered global maps), and discovering facts on trading by the qualitative and historical analysis. This paper presents an implementation method of the analytical visualization system for international trading information analysis finding international interactions related to specific phenomena (synchronic analysis) and the time series changes (diachronic analysis). The information resources are historical data of international conflicts and numerical data of arms trades between international actors in 1950 and later.*

Keywords— *5D World Map, Information Visualization, Social Science, International Relations*

I. INTRODUCTION

Currently, a vast amount of document data resources related to the humanities and social sciences exist in digital archives, electronic libraries and on-line museums on WWW and wide-area networks. The important issue for research and study in the humanities and social sciences is to analyze appropriate information resources, according to their concerns and viewpoints from a lot of document data resources and statistics digital data resources in main and sub-domains. Particularly, in the field of historical science, political science, sociological science and cultural studies, the synchronic analysis (analysis of a spatial spread of the contents of data in a specific time) and diachronic analysis (time-series analysis of the change of the contents of data) are essentially important, in addition to the exact information acquisition reflecting the knowledge of the special field of study [7][8][9].

The most important aim of our system is to realize a multi-database for humanities and social sciences, which connects heterogeneous databases about historical phenomena by using

common spatiotemporal information resources, and then maps the connected results onto 5D World Map (chronologically ordered global map). By this system, researchers and students of the humanities and social sciences become possible conducting quantitative and dynamic analysis of documents and statistical data about history and society according to their contexts, situations, and viewpoints.

Generally, the method of learning correspondence relations between historical phenomena is to use textbooks with chronology and atlases in school education. If a student does not have enough interest and cue in the starting point, it is hard to acquire broad knowledge with wide views and investigate the details of individual phenomenon deeply.

We propose a system which enables to visually grasp general views of interaction about international-relations and obtain the detailed data of an individual phenomenon by using a simple access method. By checking countries concerned visually on a map by choosing the name of phenomenon learned in lectures at school, students can recognize intuitively what kind of interactions which those actors were performing at the time of the phenomenon. Historical and heuristic study about time-series changes with geographical distribution of phenomena can also be important, which can be visualized on a global map with a time-axis.

In this paper, we apply our system to international conflict/war and arms trades as historical phenomenon to be analyzed. The system analyzes and visualizes the spatiotemporal relevance between the historical phenomenon and event data about international arms trades, and enables intuitive understanding with quantitatively grasps of synchronic and diachronic analyses. Not only military elements of the battle actions between actors directly involved in a conflict, but also non-military elements, such as economic assistance and supply of arms from the countries of non-combat areas, are analyzed in this system. By using this system, students and researchers in the field of the international-relation field obtain arms trade volumes and information resources of directional relations among the related actors of a specific conflict and in the world visually.

The main feature of our system is to enable users to grasp international trade transactions quantitatively by connecting the volume data of arms trades between the international actors, and to discover the common elements of the interactions among the actors heuristically from a diachronic viewpoint of conflict around the world, not only by examining displayed temporary information, but also by accumulating the analysis results about several different phenomena.

II.OVERVIEW OF THE 5D WORLD MAP SYSTEM

"5D World Map System" is a knowledge representation system which enables semantic, temporal and spatial analysis of documents, and integrates and visualizes the analyzed results as a 5-dimensional dynamic historical atlas (5D World Map Set). The main feature of this system is to create various context-dependent patterns of historical/cultural stories according to a user's viewpoints dynamically. This system generates multiple views of semantic and temporal-spatial relationships among documents of the humanities and social sciences. This system organizes the relationships among documents into various historical/cultural stories by a user's viewpoints. A semantic associative search method is applied to this system for realizing the concept that "semantics" of words, documents, and events vary according to the "context". Semantically-evaluated and analyzed document data are also mapped dynamically onto a time-series multi-geographical space. This system provides high visibility of semantic correlations between documents in time series variation with geographic information.

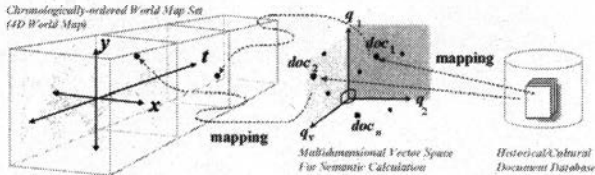


Fig. 1. Basic Concept of the 5D World Map System

III.BASIC METHOD

A. System Structure

This system realizes an analytical visualization of the trend of arms trades in the world at the time of a specific conflict by following 3 steps. The system architecture is shown in Figure 2.

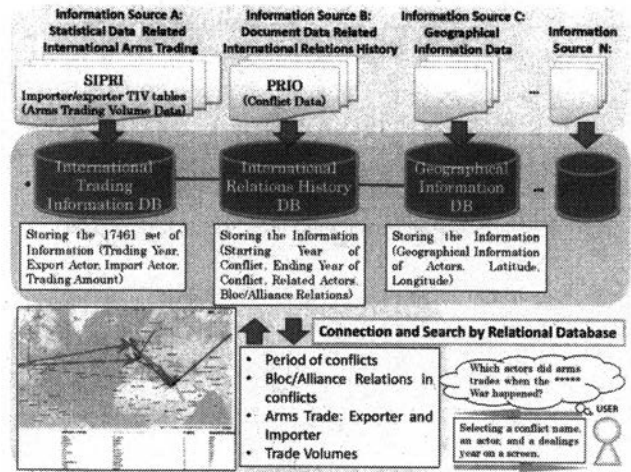


Fig. 2. The structure chart and visualization of a multi-database in an international trade transaction information visualization system for 5D World Map.

- STEP-1: Connection between the heterogeneous database (historical database of international conflict and numerical database of arms trade)

First, we define the information sources A about the history of international relations and the information sources B about international trade, in order to connect the document data about international relations history with the numerical statistical data about international trade volume.

By the arms trade information in the information source B about international trade volume, we can know how many arms the specific actor imported and exported in a specific year. However, searching them one by one takes time since many actors participate in a specific conflict. Moreover, we cannot know mutual correlation between the specific conflict and the arms trade volume only by seeing separate numeric data. For example, we cannot know what kind of relation those actors had built with the other actors at the time of conflict, though the actor directly involved in the conflict is indicated in the information sources A about international relations history,

To solve this problem, this system connects the information sources A about the history of international relations and the information sources of B about international trade volume by the space-time information common to them. This connection enables to discover a new relation which could not be known only by the retrieval in each single database.

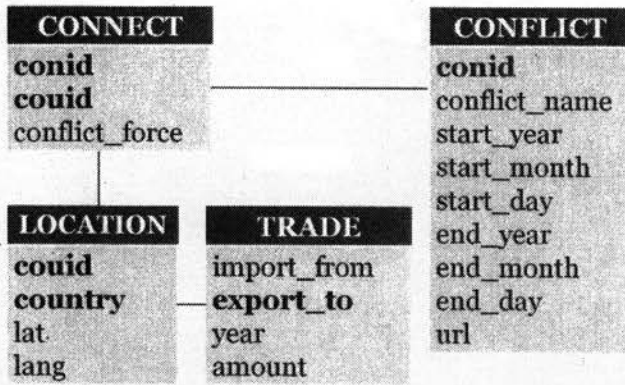


Fig. 3. Database structure of global trading analysis.

- STEP-2: Query Processing

After a user of this system selects the name of conflict and year registered in the system as a query, the query processing function of this system issues it to the newly connected database and combines conflict data and arms trade data, and outputs the arms trade information performed by the actor directly involved in the conflict in the selected year.

- STEP-3: Visualization of Search Results

This system represents the search results in STEP-1 by visualizing (1)the export actors and the import actors as direction of an arrow, (2)the trade volume as thickness of an arrow, and (3)the bloc/alliance relation on the international relation of the actor directly involved in the conflict as color of an arrow on the 5D World Map [8][9].

In the visualization function, the center latitude of the export actor is defined as 'from_lat', the center latitude of the import actor as 'to_lat', the center longitude of the export actor as 'from_lng', the center longitude of the import actor as 'to_lng', the thickness of line as a constant 'a'.

B. Contribution of our system for the actual users

As users of this system, we assume student who studies world history and/or international relations in higher education institutions. For example, we design a use scenario of our system as a learning tool by following 8 steps.

STEP-1: A teacher gives students an assignment to investigate one of the conflicts in a certain period.

STEP-2: Each student accesses to this system and selects the conflict name on the user interface, and then this system displays the age which the conflict happened.

STEP-3: The student selects the year before the conflict happened.

STEP-4: The student selects the 'export_to' button and submits.

STEP-5: This system visualizes the search result that which actors exported the arms to the actors directly involved in the conflict which the user selected.

STEP-6: The student takes a screen shot of the search result.

STEP-7: The student reselects the next year and repeats operations from STEP-4 to 6 until the year after the conflict happened.

STEP-8: By comparing the results, the student analyses and discusses the relations between the conflict actors and trade actors by him/herself, and summarizes the discussion as a report.

IV. IMPLEMENTATION METHOD

A. Data Sources

1) SIPRI (STOCKHOLM INTERNATIONAL PEACE RESEARCH INSTITUTE) [4]

SIPRI is the independent international organization specialized in conflict, armaments, arms control, and disarmament, which was founded in 1966. In this implementation, we use the arms trade data between two actors by the U.S. dollar using the form of a trend indicator value (TIVs) from 1950 to 2010 which this offers. However, this does not express a monetary value directly and is an index of the volume of arms trades.

2) DICTIONARY OF WARS Third Edition [5]

This dictionary provides summaries of all notable wars from earliest recorded history to the present day.

We use the data from 1950 to 2010 and integrate the conflict name using this system with this dictionary.

3) PRIO(the Peace Research Institute Oslo) [1]

Founded in 1959, the Peace Research Institute Oslo (PRIO) is an independent research institution known for its effective synergy of basic and policy-relevant research.

The arms trade volume of money between two actors for every year from SIPRI and the definition and the actor directly involved in the conflict from PRIO are stored in a database, and that information is combined by PostgreSQL [3]. Thereby user becomes possible to recognize fragmentary information as comprehensive pertinent information on the basis of the year to which a certain phenomenon (conflict) happened.

B. Implementation

1) Data Structure

This system connects and combines the data of SIPRI and PRIO by using PostgreSQL [3].

This system defines the actor directly involved in the conflict which stored in CONFLICT relation by CONNECT relation and connects it with 'export_to' or 'import_from' of TRADE relation. This system outputs the actor who performed arms export or arms import to the actor directly involved in the conflict as search results.

In LOCATION relation, in order to display each actor's position on a global map, latitude and longitude [2] are stored.

This system sets the actor directly involved in the conflict as an arms importer or an arms exporter, and displays the positions and relations of importer and exporter as the origin point and destination point of an arrow by the visualization function of STEP-3.

2) Database and Query Creation

When we specify the actor directly involved in the conflict as an importer, this system issues user's input and selection as a search query by the following SQL sentences.

In the WHERE phrase, this SQL sentence connects the actor directly involved in the {\$conflict}, the conflict name which user selected, as the importer. And it takes out the search result from *From Year* to *To Year*.

```
SELECT
    trade.import_from,
    trade.export_to,
    l2.lat AS from_lat,
    l2.lang AS from_lng,
    l1.lat AS to_lat,
    l1.lang AS to_lng,
    trade.amount,
    trade.year AS trade_year,
    connect.bloc
FROM
    conflict
JOIN connect ON conflict.conflict_id =
connect.conflict_id
JOIN location AS l1 ON connect.country_id =
l1.country_id
JOIN trade ON l1.country = trade.export_to
JOIN location AS l2 ON l2.country =
trade.import_from
WHERE
    conflict.conflict_name = '*Conflict Name*'
    AND *From Year* <= trade.year
    AND trade.year <= *To Year*;
```

3) Visualization

Based on the basic method described in STEP-3 in Section 3, a user interface and a visualization function with the 5D World Map [8][9] are implemented by using HTML, PHP, and Google Maps API [6].

The color of arrow is represented as translucent so that user can know the arms trade compactness by the density of color.

To focus on the arms trade interaction, when no arms trade is carried out for the specified year, conflict actors are not displayed on the map.

a) This system represents the export actors and the import actors by direction of an arrow.

b) This system represents the bloc/alliance relation on the international relation of the actor directly involved in the conflict as color of an arrow.

c) This system represents the trade volume as thickness of an arrow.

```
if ($amount[$i] == 0) {
    $boldness[$i] = log(1.5);
} else {
    $boldness[$i] = log($amount[$i]*10);
}
```

V. EXPERIMENT

The purpose of this experiment is to verify the analytical visualization function of this system by applying to arms trades performed before and after each conflict using the created information by combining SIPRI and PRIO data.

By a set of a conflict name and a year arbitrarily selected by a user as a query, the system represents a heuristic fact acquired from the data visualized as an arrow on the map. The user interface displays the period of conflict so that the user can combine the year before and behind the conflict.

In order to examine an influence which the conflict affected to arms trading, we analyzed by adding not only the conflict term but the data for several order years.

A. SAMPLE-1: 1956/ Arab-Israeli War of 1956 (Suez or Sinai War)

We picked up the Arab-Israeli War of 1956 (Suez or Sinai War) and examined the volume of arms trading to the actor directly involved in the conflict to which it was carried out at the time before and behind that and a relation with an exporting actor by applying the data in which SIPRI and PRIO were combined.

The issued queries for this test were "the conflict name = Suez or Sinai War, year = 1955", "the conflict name = Suez or Sinai War, and year = 1956", and "the conflict name = Suez or Sinai War, and year = 1957."

The search results are shown in Table 1 and the visualization results are in Figure 4.

Table 1 shows the list of the actors directly involved in the conflict, the actors who exported the arms to them, he bloc/alliance relations where the actor in the conflict, the arms trade amount of money in million dollars.

It also shows that the following actors are the actor directly involved in the conflict of the Suez or Sinai War and the actors exported arms to them.

The actors directly involved in the Suez or Sinai War: France, Israel, UK, and Egypt.

The actors who exported arms to them in the year when the Suez or Sinai War happened: USA, USSR, France, UK, Sweden, Yugoslavia, Italy, Czechoslovakia, and Unknown Country.

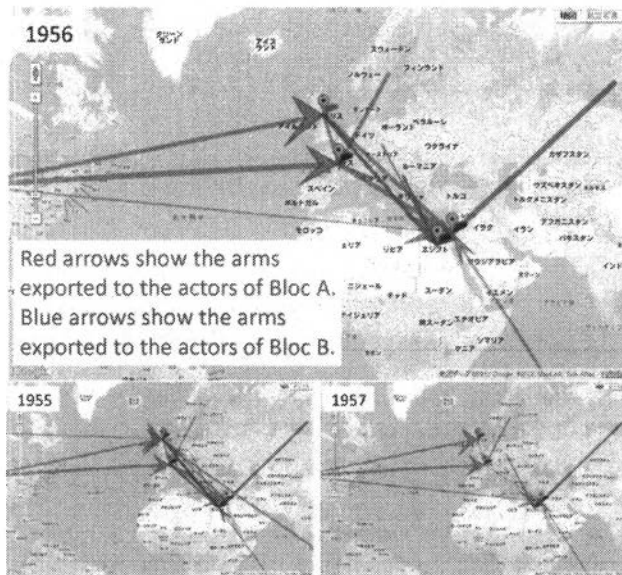


Fig. 4. Time series change visualization of the arms trade volume supplied to the actors directly involved in the Suez or Sinai War in 1955 ~ 1957
(Point of the arrow shows the actors directly involved in, the origin of the arrow shows the export actors, color of the arrow shows the bloc/alliance relation of the actors, and thickness of arrow shows trade volume.)

TABLE 1. SAMPLE OF SEARCH RESULT: THE AMOUNT OF EXPORTED ARMS TO THE ACTORS DIRECTLY INVOLVED IN THE SUEZ OR SINAI WAR IN 1955 ~ 1957. (TOP 4 IN THE RANKING)
(IMPORT FROM: ACTOR WHO EXPORTED THE ARMS TO THE ACTOR DIRECTLY INVOLVED IN THE CONFLICT, BLOC: THE BLOC/ALLIANCE RELATIONS WHERE THE ACTOR IN THE CONFLICT, AMOUNT: THE ARMS TRADE AMOUNT OF MONEY IN MILLION DOLLARS)

Import From	Actor directly involved in the conflict	Bloc	Amount (US\$M)
1955			
USA	France	A	1196
USSR	Egypt	B	523
UK	France	A	244
USA	UK	A	182
1956			
USA	France	A	1091
USSR	Egypt	B	992
France	Israel	A	445
USA	UK	A	150
1957			
USA	France	A	593
USSR	Egypt	B	477
Sweden	France	A	91
USA	UK	A	84

The trading patterns continuously performed over these three years are following 7 patterns: from USA to France, USA to UK, USA to Israel, USSR to Egypt, France to Israel, Sweden to France, and Czechoslovakia to Egypt.

Figure 4 shows the visualization result by connecting and combining SIPRI and PRIO data that Belgium, Australia and

Canada had been exporting arms to the actor directly involved in this war in the previous year of when the Suez or Sinai War happened.

Moreover, we can find that actors other than the USSR and Czechoslovakia, who belonged to Bloc A, stopped exporting the arms to Egypt, who belonged to Bloc B, bordering on the year the Suez or Sinai happened. France also exported arms to Egypt in the previous year when the conflict happened, then stopped exporting to Egypt after the year.

B. SAMPLE-2: 1963-64/ Algerian-Moroccan War of 1963-64

We picked up the Algerian-Moroccan War of 1963-64 and examined the volume of arms trading to the actor directly involved in the conflict to which it was carried out at the time before and behind that and a relation with an exporting actor by applying the data in which SIPRI and PRIO were combined.

The issued queries for this test were "the conflict name = Algerian-Moroccan War of 1963-64, year = 1962", "the conflict name = Algerian-Moroccan War of 1963-64, and year = 1963", "the conflict name = Algerian-Moroccan War of 1963-64, and year = 1964", and "the conflict name = Algerian-Moroccan War of 1963-64, and year = 1965."

The search results are shown in Table 2 and the visualization results are in Figure 5.

Table 2 shows the list of the actors directly involved in the conflict, the actors who exported the arms to them, the bloc/alliance relations where the actor in the conflict, the arms trade amount of money in million dollars.

It also shows that the following actors are the actor directly involved in the conflict of the Algerian-Moroccan War of 1963-64 and the actors exported arms to them.

The actors directly involved in the conflict of the Algerian-Moroccan War of 1963-64: Algeria, Morocco.

The actors who exported arms to them in the year when the Algerian-Moroccan War of 1963-64 happened: USSR, France, Egypt, USA.

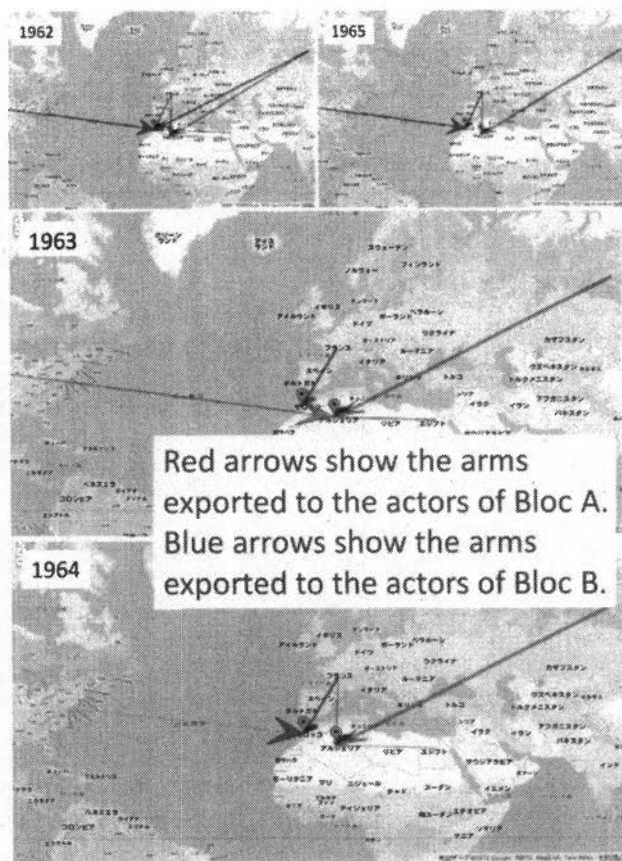


Fig. 5. Time series change visualization of the arms trade volume supplied to the actors directly involved in the conflict of the Algerian-Moroccan War of 1963-64 in 1962 ~ 1965

TABLE II. SAMPLE OF SEARCH RESULT: THE AMOUNT OF EXPORTED ARMS TO THE ACTORS DIRECTLY INVOLVED IN THE ALGERIAN-MOROCCAN WAR OF 1963-64 IN 1962 ~ 1965. (TOP 4 IN THE RANKING)

Import From	Actor directly involved in the conflict	Bloc	Amount (US\$M)
1962			
USSR	Morocco	B	57
USSR	Algeria	A	35
France	Algeria	A	18
USA	Morocco	B	17
1963			
USSR	Algeria	A	76
France	Morocco	B	11
Egypt	Algeria	A	8
USA	Algeria	A	2
1964			
USSR	Algeria	A	150
France	Morocco	B	16
Egypt	Algeria	A	1
France	Algeria	A	1
1965			
USSR	Algeria	A	306
France	Morocco	B	33

USA	Morocco	B	29
France	Algeria	A	19

The trading patterns continuously performed over these three years are following 2 patterns: from USSR to Algeria and France to Morocco

Figure 5 shows the visualization result by connecting and combining SIPRI and PRIO data that although Morocco had been exporting arms to Algeria which is confrontation Bloc in the previous year of when the Algerian-Moroccan War of 1963-64 happened, it stopped exporting after the year.

C. SAMPLE-3: 1973/ Arab-Israeli War of 1973

We picked up the Arab-Israeli War of 1973 and examined the volume of arms trading to the actor directly involved in the conflict to which it was carried out at the time before and behind that and a relation with an exporting actor by applying the data in which SIPRI and PRIO were combined.

The issued queries for this test were "the conflict name = Arab-Israeli War of 1973, year = 1972", "the conflict name = Arab-Israeli War of 1973, and year = 1973", and "the conflict name = Arab-Israeli War of 1973, and year = 1974."

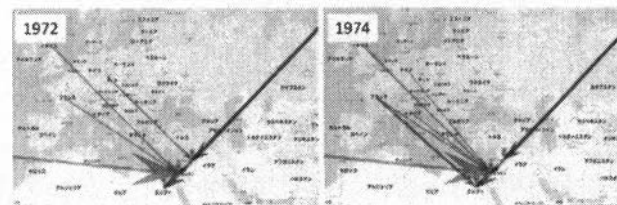
The search results are shown in Table 3 and the visualization results are in Figure 6.

Table 3 shows the list of the actors directly involved in the conflict, the actors who exported the arms to them, he bloc/alliance relations where the actor in the conflict, the arms trade amount of money in million dollars

It also shows that the following actors are the actor directly involved in the conflict of the Arab-Israeli War of 1973 and the actors exported arms to them.

The actor directly involved in the conflict of the Arab-Israeli War of 1973: Israel, Syria, and Egypt

The actors that exported arms to them in the year when the Arab-Israeli War of 1973 happened: USSR, USA, Poland, Hungary, UK, Czechoslovakia, France, Italy, Germany (FRG).



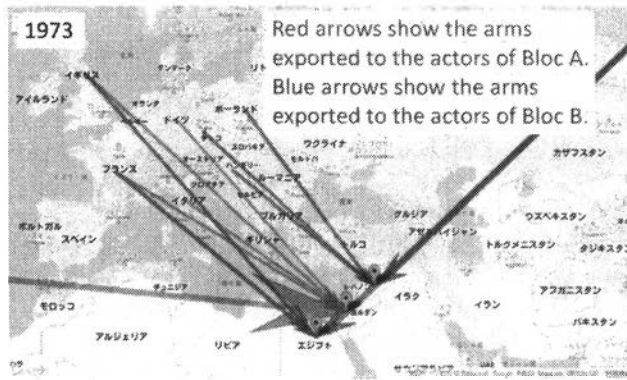


Fig. 6. Time series change visualization of the arms trade volume supplied to the actor directly involved in the conflict of the Arab-Israeli War of 1973 in 1972 ~ 1974.

TABLE III. SAMPLE OF SEARCH RESULT: THE AMOUNT OF EXPORTED ARMS TO THE ACTORS DIRECTLY INVOLVED IN THE ARAB-ISRAELI WAR OF 1973 IN 1972 ~ 1974. (TOP 4 IN THE RANKING)

Import From	Actor directly involved in the conflict	Bloc	Amount (US\$M)
1972			
USSR	Egypt	B	3695
USSR	Syria	B	1391
USA	Israel	A	752
UK	Israel	A	35
1973			
USSR	Syria	B	3405
USSR	Egypt	B	2512
USA	Israel	A	2387
France	Egypt	B	85
1974			
USSR	Syria	B	3814
USA	Israel	A	1218
USSR	Egypt	B	846
France	Egypt	B	232

The trading patterns continuously performed over these three years are following 4 patterns: from USSR to Syria, USSR to Egypt, UK to Israel, and France to Israel

Figure 6 shows the visualization result by connecting and combining SIPRI and PRIO data that UK and France had been exporting arms to both the actors of Bloc A and B in 1973 when the Arab-Israeli War of 1973 happened. And Poland and Hungary had been exporting arms to Syria only for the year conflict happened.

Table 3 shows that, from 1972 to 1974, the arms export volume from USSR to Egypt decreased every year but the arms export volume from USSR to Syria increased every year.

D. Analysis on the experimental results

From the experimental results shown as 5.1 – 5.3 samples, we could verify that this system enables to visualize the

historic facts that have been already confirmed by qualitative and hermeneutic historical studies, and to discover the fact that have been difficult to find by them.

Comparing SAMPLE-1 and SAMPLE-3, we could find the relationship of conflicts which have the same name of “Arab-Israeli War” in a different age of the 1950s and the 1970s: Egypt and Israel were the actors directly involved in the conflict common to both as antagonistic bloc/alliance, USSR was continuing export to Egypt from the 50s to the 70s continuously, the arms volume exported from USA to Israel increased in 1973 from 1956, and the arms volume exported from USSR to Egypt increased in the same period.

These experimental results show that our system enables an analytical visualization not only for the international interaction of a specific phenomenon but also for the time-series analysis on the change of phenomena (diachronic analysis).

VI. CONCLUSION

In this paper, we have presented an analytical visualization system for dynamically and multi-dimensionally creating an overview of international trading-information resources. Our experimental results have shown the applicability of our system to make discovery of new facts, which are not described explicitly in the text book of history. They have also verified the historical facts that have not been already known such as the structure of Cold War, by visualizing international relations through time and space.

The significant and strong point of this system is not only to display temporary information but also to look down and detect common elements. By using this system, we have actually analyzed international trading from a viewpoint of arms-trading and from a synthetic viewpoint. Those analyses have clarified the applicability and advantage of our system, leading to new global research environments in the historically and geographically world-wide scope. We have also shown our analytical processes for repeating and acquiring analytical results about several different phenomena by using several queries.

By visualizing and comparing the same phenomena, such as conflict, according to an age, we can validate time-series change of the interactions among the central actors of international relations, and discover an unexpected point of contact not only in a surrounding area but also in the indirect area and actors, by big-picture analysis with global point of view.

VII. FUTURE WORK

As future work, we expand the system with semantic association search function to calculate the causal relationships among the specific international-relations phenomena. This new function will help the user to discover the cause-and-effect relationships between historical facts of international relations and international trading.

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