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Modular architecting for effects based operations

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MODULAR ARCHITECTING FOR EFFECTS BASED OPERATIONS

by

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ABSTRACT

Effects Based Operations (EBO) is a way of thinking for planning, executing and assessing any operations for the effects they produce, rather than dealing with actions, targets or even objectives. The literature on EBO has been growing day by day; however, there is still a need for modeling techniques and tools that provide more efficient and effective effects based assessment, planning and analysis in order to further develop the capabilities of the operations. In this context, this thesis presents an introduction to EBO by focusing on its methodology, its challenges and also its applicability in different systems. Moreover, this thesis illustrates the importance of modular architecting in effects based planning stage. Modular architecting provides synchronization of the right actions and decisions, makes strategic aim consideration easier and provides efficiency in the cases where there are multiple strategic aims. The most important benefit of this research is its ability to facilitate the achievement of economy of national power for military EBO and economy of action sources for other systems. Approaches presented in this thesis utilize clustering of effects and actions by using two neural network architectures; namely, Adaptive Resonance Theory (ART1) and Kohonen's Self Organizing Maps (SOM). The applications of the approach are illustrated with a defense industry related example in the development of a modular EBO system. Overall, the modular architecting approach has been successfully applied to the example and it is concluded that although ART1 is a good architecture for clustering, Kohonen's SOM is more helpful in defining modules for effects and actions in EBO. Finally, it is understood that further research of this thesis would contribute to the modular architecting of EBO by applying other neural network architectures with larger input data sets.

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1. INTRODUCTION

The literature on effects based operations (EBO) has been growing each day. There is no agreed definition of EBO; however, it can be described as a way of thinking for planning, executing and assessing military operations for the effects they produce; rather than dealing with actions, targets or even objectives [1]. Some of the research about EBO is based on effects and other research focuses on applying capabilities toward affecting adversary or competitor systems. This wide range of definition and the range of current capabilities make the advancement of an EBO culture slow. There has been an argument condemning whether EBO is a "new way of warfare" or if it is just a new term for an old strategy. Besides the growing literature about EBO, military service and joint doctrine writings often carry a view of multi-polarity when defining EBO methodology. The most critical issue in EBO is to understand the adversary's system of systems and design architecture for the execution of EBO in order to reach victory. However, cause and effect chains are complicated and are often beyond the capacity of an expert to comprehend and provide practical advice. There is an ongoing argument about past wars and there is no completely objective method for defining the most suitable actions to create the same effect or even better effects. This is another limitation in the EBO concept. Finally, there is also the risk of over reliance on experts' opinions such as a field commander and his staff.

In this thesis, the aim is to overcome these limitations and make an improvement for EBO methodology. The study considers adversary systems as a system of systems (SoS) which includes political, military, economic, social, informational and infrastructural (PMESII) systems of adversary. The need for an SoS approach arises from the fact that the effects of the actions may have different and unpredicted reactions, and also undesired secondary effects or cumulative effects on other systems of the adversary system. Therefore, in the next section of the thesis, the literature review about SoS definition of the EBO and its methodologies are given. In the last part of the section, the challenges for the EBO are explained in order to point the proposed solution for one of those challenges. The third section of the thesis illustrates the importance of modular architecting as a modeling methodology for the study. The steps of the model are also described. Modular architecting was chosen as the modeling methodology because it provides the EBO synchronization of the right actions and decisions, makes strategic aim consideration easier and provides efficiency in the cases where there are multiple strategic aims. A major benefit of modularity is creating modules which provide the ability to achieve multiple effects on different systems. This means that modules provide the ability to achieve strategic aim variability or effects variability through the combination and standardization of actions. Therefore, the most important advantage of this research is the ability to facilitate the achievement of economy of action resources which are national power (diplomatic, informational, military and economic (DIME)) for military EBO. In this thesis, new approaches are presented that allow effects based planners to develop a modular architecture that can be shared across different systems and different strategic aims. In the fourth section of the thesis, the model of a hypothetical example of EBO for a terrorist country based on literature review is developed. One of the neural network architectures; namely Adaptive Resonance Theory I, is used in order to cluster effect-action matrix. The study then presents another neural network architecture; Kohonen's SOM, for clustering of the data. A comparison of their results between is also presented. In the next section the motivation to use modular architecting methodology for solving one of the challenges of EBO is highlighted.

1.1. MOTIVATION

Complexity is one of the main problems in traditional warfare. Lack of understanding about effects based operations (EBO) from a system of systems perspective could be attributed as one of the reasons for the perception of complexity in any military operation. Effects based operations for defense are complex military operations. They include many actors such as enemies, neutrals and allies and include different types of actions such as diplomatic, informational, military and economic. They also include many systems such as political, military, economic, social, information and infrastructure systems. Moreover, they also includes different types of effects such as desired, undesired, direct, indirect or collateral effects. A commander or his staff may be able to reach the objective if he has a clear understanding of the complex environment of effects based operations and has knowledge about the EBO process. EBO system of systems is an evolving entity which continually needs to be monitored and updated. In order to build an effective EBO that serves a given strategic aim, it is very important to have an understanding of the way the complex environment of the EBO looks and behaves. Complexity in the EBO can be grouped around three main challenges [1].

The first complexity is determining and estimating direct and indirect effects of planned actions. For instance, reactions of many physical actions can be perceived by the actors immediately. On the other hand, the perception of the effects of many behavioral actions on systems can take several years. Eliminating undesired effects which are usually caused by indirect effects is a challenge for the EBO.

The second complexity is determining actual conclusions of executed actions. Although EBO are planned and executed after careful understanding and deep study about nodes and links in system of systems of the EBO, it is still possible to have unintended and unplanned results. To deal with this challenge, EBO needs a carefully chosen measurement of effectiveness and measurement of performance criteria in order to decide the results of executed actions.

Synchronization of the right actions is the last reason for complexity of EBO. Choosing right actions for EBO depends on many computer based simulations and computer aided programs. It is crucial to model likely responses and choosing the right action which follows current action. Thus, designing the EBO process in a way that helps to overcome these complexity challenges can provide better effectiveness in the operations.

Modular architecting has been used several times to solve design problems in different fields. It is also known that the roots of most problems belong to design phase of a life cycle of any system. The systems engineering community has been looking for a solution to eliminate the disadvantages of unpredictability and mysteriousness of EBO. This thesis argues that modular architecting, which is based on clustering analysis, can help in the orchestrating of the most effective decisions in the course of action development and analysis (COA) phase of the EBO process. Such studies will improve both standardization of actions and variety of actions. Different EBOs with different strategic aims will be conducted in different ways but with standard actions. The EBO intended to group into modules provides better effectiveness in creating desired effects and also provides economy of national power for military EBO.

1.2. PROBLEM DEFINITION

The main goal of this research is to provide better understanding for effects based operations (EBO) and to demonstrate the usage of modular architecting in the development stage of effects based planning. Based on literature review, effects based operation methodology has been divided into four main phases; effects based analysis, effects based planning, effects based execution and effects based assessment. The modular architecting approach is used for describing modeling methodology in this thesis. The modeling methodology for architecting of EBO is composed of defining actions, defining effects, integration analysis and design analysis which are explained later. In the model development phase, appropriate architectures are investigated. Adaptive Resonance Theory I and Kohonen's SOM have been used to create action modules. The reason for choosing neural network models lies in the fact that they can be used to infer a function from observations. Also, neural network models are particularly useful in applications where the complexity of the data or task makes the design of such a function by hand impractical like in EBO. Therefore, rather than applying traditional statistical models, neural network models are chosen to solve complexity challenges of non-linear and adaptive EBO. Further explanations for using both ART1 and Kohonen's SOM to cluster effects and actions and the comparison between them will be highlighted in later sections. A hypothetical example is created for the model development phase. The reason for choosing a hypothetical example of an EBO for a terrorist country is the limited information about real military operations in the literature. In order to apply modular architecting to the hypothetical example and improve the model, two objectives are built in this thesis. The first objective is adapting modular architecting process into the planning stage of EBO in order to orchestrate the right actions to create desired effects. The second objective is to develop a modeling methodology to classify actions and effects to create modules by using ART1 and Kohonen's SOM.

In order to achieve the above mentioned objectives, the following tasks need to be accomplished. First of all, it is important to understand the EBO environment to develop more effective solutions for complexity problems of EBO. It is important to collect all the information about EBO environment and its methodology. Then, a modeling methodology of architecting EBO needs to be determined and its steps need to be explained. The following task is to apply the modeling methodology with an example which is close to real EBO scenarios. The phases of model development also need to be conducted for the example. ART1 and Kohonen SOM can be used as modeling architectures in order to create modules. The drawback of each architecture and results obtained from them need to be analyzed and illustrated. The last task is to design modules to solve the problem of synchronization of the right actions challenge.

1.3. SECTION ORGANIZATION

This thesis is organized as follows. Section 2 provides deep understanding about effects based operations dependant on a literature review and gives definition of EBO in its system of systems environment. In order to provide more insights about the problem, the challenges for EBO and the EBO methodology which composed of effects based analysis, effects based planning, effects based execution and effects based assessment are also explained in Section 2. Section 3 discusses modular architecting methodology in order to look for a solution for the challenge of synchronization of the right actions. In Section 4, the modular architecting approach is presented and its phases; namely, defining action, defining effects, integration analysis and design analysis are explained with the hypothetical EBO example for a terrorist country with military EBO goals. ART1 and Kohonen's SOM, which are modeling architectures for modular architecting to EBO, drawbacks and comparisons are also explained in the Section 4. Section 5 provides conclusions and directions for further research.

2. LITERATURE REVIEW

In this section, a literature review and an introduction into the EBO and their steps are presented. A brief insight about the problem dealt in this research has been carried out before the methodology is presented here. Many descriptions and research about EBO has been conducted by many researchers both in academia and in defense departments of different countries. The main guide for all researches and application of the EBO is the "Commander's Handbook for an Effects-Based Approach to Joint Operations" which is published by the U.S. Joint Warfighting Center. The necessary information about the handbook can be found in Appendix. Moreover, the work of Smith [1] provides broad explanations for meaning and kinds of EBO. In the handbook, the methodology of EBO is grouped in four main steps: effects based analysis (1), effects based planning (2), effects based execution (3) and effects based assessment (4). In the study of Pollicott [2], EBO are discussed as system of systems and a SoS approach is presented for the effects based analysis step. On the other hand, many researches are focused on the effects based planning stage. The importance of human beings and the interpretation of commander's intent, which is the first step of effects based planning, are emphasized by some researchers [3, 4]. A tool for effects based course of action development and assessment, which is the most difficult part of effects based planning, is presented in [5]. On the other hand, a strategy development tool for entire effects based planning stage is generated by [6]. An answer for entire EBO with Cellular Automata is investigated by [7]. Moreover, besides providing deep research about EBO, it is suggested in [8] that more qualitative methods should be conducted for EBO and an analytical representation of EBO is also asserted in the same research. The challenges of effects based operations are investigated in the work of Smith [1]. He stated that there are three main challenges which are results of complex adaptive nature of EBO environment. These are determining and estimating direct and indirect effects of planned actions (1), determining actual conclusions of executed actions (2) and synchronization of the right actions which is the consideration of this study (3). Although these literature reviews are considered the EBO as military operations, in this research the explanations and the methodology of the EBO are defined in a more general concept. A brief insight into the literature on EBO, their methodology and challenges are provided below.

2.1. DEFINITION OF EFFECTS BASED OPERATIONS

Researchers have argued about the origin of effects based operations (EBO): Is it a new way or more sophisticated name for an old way? Actually, EBO have always been used in the history. Although in the past wise generals, admirals and other commanders of different nations did not know the EBO term, they applied EBO, not only for defeating adversary's forces but also for shaping adversary's behaviors. During World War I, Lieutenant Colonel Edgar Gorrell of the Army Air Service first alluded to the concept of effects based operations while he was serving in France. He asserted that attacking ammunition production factories would have the same effect, which was ceasing the fire, as destroying artillery tubes. Moreover, during most of World War II, there was a lack of understanding to determine the effectiveness of air operations on the strategic level. Airmen started to analyze technical and tactical problems to solve them. They understood that the enemy system is a reflection of their system. Furthermore, the Gulf War was the airmen's first time to focus on effectiveness of their air power and on systems, not just defined targets. Therefore, Gulf War became the first military operation where effects based strategies are applied and the EBO concept started to come together. If not for the rise of EBO in the air force, it would not be an important approach unless applied by other military forces. The Desert Storm was one of the EBO accomplishments of US Army [9].

EBO have become a significant concept used in the military and defense area. Especially, it is used for planning, executing, and assessing air operations in wartime and against terrorist organizations during peace time. As an approach, EBO reaches beyond the realm of military activities. It considers the battle space as an interrelated system of systems, which encompasses political, military, economic, social, information and infrastructure systems. The broad utility of EBO grows from the fact that opponents are intelligent, convoluted, and proactive [6]. Also, complex environment in the global war necessitates the practice of EBO with respect to achieving desired end state or "effect". Figure 2.1 shows system of systems illustration of military EBO.

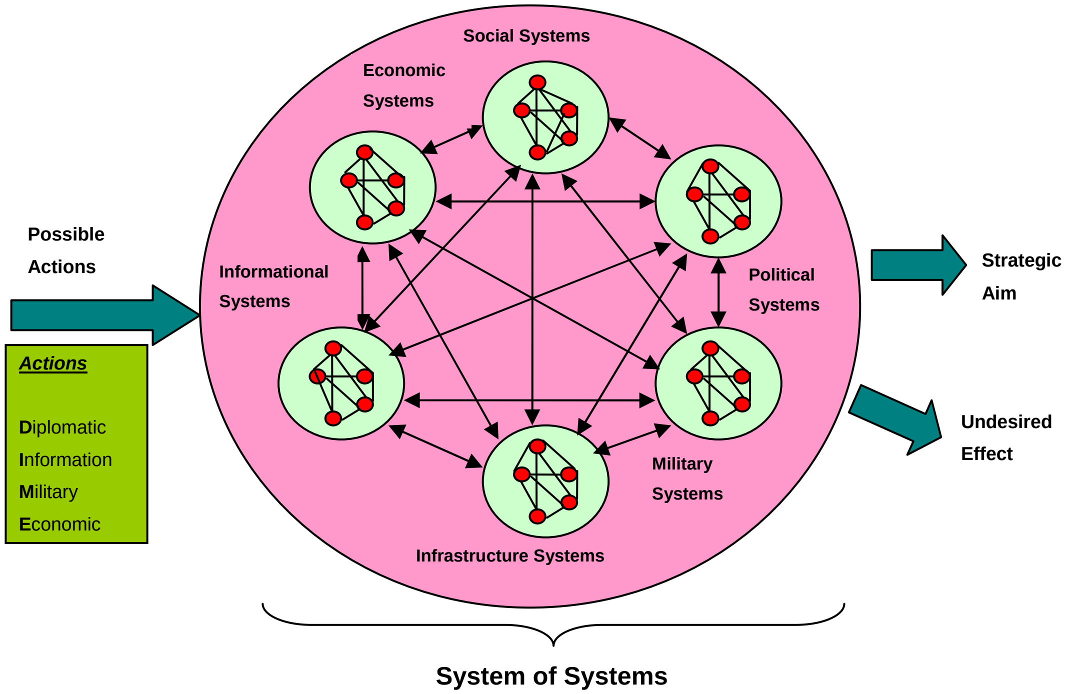

Figure 2.1. System of Systems Illustration of EBO for Military Operations

Although EBO is a military operation as stated in the definitions of it, it can be applied to other systems. For instance, for each system in different fields there is a desired situation which is a desired effect in EBO. For the systems which have complex adaptive environment it is better to focus on creating desired effects rather than focusing on system objectives. Since most complex adaptive systems are unpredictable and mysterious, there may be several ways to reach system strategic aim which is more general than system objectives. For those complex systems, strategic aim can be accomplished with choosing and applying right actions to each sub system of the system or each system of SoS in order to create desired effects. The need for assigning actions to reach desired effects rather than objectives is that a system or system of systems may achieve four main attributes of systems which are cost, performance, time and risk more effectively and efficiently. As a result, if EBO is redefined, it can be said that effects based operations are operations to produce influences on the long-term or short-term state of a system in order to attain desired effects-with different degree of probability utilizing the integrated application of all applicable instruments. These operations are concurrently planned, executed, assessed within a complex adaptive system view.

The term “effect” has been used most frequently in target-based operations to explain the results of military actions. As the EBO concept arises, the terms began to be used for “the outcomes or impacts of actions which are created by diplomatic, informational, military and economic powers” [1]. Moreover, it is crucial to note that such powers can be applied at any level of the concept such as tactical level, operational or strategic level. It is also important to notice that effects can be results of military power that does not aim destruction or they can be generated from the use of accumulation of other forms of power. For example, an effect can be just result of existence of military power on the operational area or it can be the result of both diplomatic and economic actions. The results of EBO can be “desired” effect or “undesired” effect. The main point in the EBO is to eliminate undesired effects. On the other hand, desired effects can be created by direct or indirect effects.

Direct effects can be physical, functional, psychological and collateral effects. They are results of actions which have no intermediate mechanism or effects between act and outcomes. They are easily recognizable and their effects occur immediately. However indirect effects mostly difficult to recognize and their effects usually delayed. Unlike direct effects, there is an intermediate effect or mechanism to create this kind of effects. Indirect effects are created by indirect actions and indirect actions may be result of previous direct effect. The type of effects is grouped in [10] as in the below.

Physical effects: They are the effects created by the direct impact of physical distortion on the object or system targeted by the application of EBO.

Functional effects: It is a result of a direct or indirect attack or operation to damage target system’s functional ability.

Psychological effects: The aim of actions to create this kind of effects is to influence emotions, motives, objective reasoning, and ultimately the behavior of target system.

Collateral effects: It is an unintended result of actions. These results may be either positive or negative to the original objective. Therefore, they may be indirect or direct effects which may cover wider array of possible results.

Cumulative effects: It is the outcomes of many direct and indirect effects. It may occur either at the higher level or at the same level as a contributing lower order effect.

Cascading effects: They are outcomes of actions which affecting other systems and damaging the nodes that are critical to multiple systems. Therefore, it is an indirect effect.

On the other hand, actions are defined in EBO as the events or the set of connected events which are exertions of different forms of power. Those actions can be grouped according to the nature of power for military EBO.

Diplomatic Actions: These kinds of actions are the events which international negotiations about peace-making, war, crisis, economics, trade, culture or law are conducted.

Informational Actions: Informational actions enable to convey the data to receiver. Effects of those kinds of actions depend to communication channels, media, control issues and perception of the information by receiver.

Military Actions: These are the actions to create desired effects with the application of appropriate armed forces and soldiery resources

Economic Actions: Economic actions are the actions which regulations about international trade, production, distribution, consumption of goods and services are conducted to create desired effect on adversary system.

This classification is done for military operations. In the literature, there is no classification for the resource of actions. For different systems in different fields, resource of action is varied. Therefore resource of action should be determined by system architect and system mangers in the effects based planning stage of EBO.

In addition to this resource of action classification, actions can be thought also in two group; behavioral actions and physical actions. The results of behavioral actions usually can not be observed immediately; however, the results of physical actions can be observed and their effectiveness can be assessed with quantitative methods easily. On the other hand, physical actions can create indirect effects after their applications and it can take much longer time than the physical actions with direct effects can [1].

2.2. EFFECTS-BASED OPERATION METHODOLOGY

The most important thing that effects-based approach brings to the field is changing the way the actors of EBO think. Planners and executers started to think that EBO environment is a system of systems and adversary system is just a reflection of their system. In order to change adversary system's behaviors, one should understand the environment and links and nodes in the environment. A key aspect is that deciding which links, nodes or actions are expected to bring success; thus, the aim of changing adversary system behavior into more amenable level can be succeeded with use of different forms of power. EBO approach shows that how adversary's system behaves and how it might be behave under various actions and conditions [1]. Moreover, it is understood that success comes when not only the actions are done right but also the right actions are done.

Although most systems in EBO environment are dynamic and it is difficult to define end state of the systems, EBO approach also brings significant level of prediction for certainty, precision and control. In addition to that, most EBO systems are also learning organizations which EBO evolves when opponent systems adapt to responses of each other. This reciprocity necessitates that cause and effect relationships in the environment are not linear and it is especially true for the systems which include human beings [1].

Since it is a global and competitive world and the enemy is intelligent and proactive, the EBO starts with assessment of complex adaptive environment. Then, desired effects are identified and actions to create these effects are assigned. Lastly, effects are executed and assessed. It is a reverse diagram of applying EBO. Since once the application of EBO is decided, first actions are done and then effects are created and objectives are reached at any level. In summary, the end of the operations should be understood well, before actions are generated. In the following sections, four important steps of EBO are described according to [10], [1] and [11].

2.2.1 Effects-Based Analysis (EBA). EBO starts with effects-based analysis because before deciding upon effects, the adversary system and the environment which encompasses both sides should be understood well. The environment is complex adaptive environment since it is *complex* in that it is diverse and made up of multiple interconnected elements and *adaptive* in that it has the capacity to change and learn from experience [1]. The main characteristics of complex adaptive environment are summarized from [12], [13], [14]:

- Connectivity and interdependency between elements
- Co-evolution
- Dissipative structures
- Exploration of the space of possibilities
- Feedback and path dependence
- Emergent behavior and self organization

Therefore, the first thing should be done in that stage is in-depth understanding of the strategic complex adaptive environment. To do that, all actors and linkages between them and all domains should be defined and analyzed. The relationships between actors provide to understand network between nodes and to select the best effects in other EBO stages. The relationships also provide to create positive indirect or secondary effects in different domains in the environment.

The biggest challenge of this stage is monitoring of global environment completely [1]. The environments of most EBO are very broad area and it is difficult to control all nodes and their interactions. Moreover, because of the importance of the EBO, operations require constant real-time monitoring. Predictive simulation of the environment as a complex adaptive system can be good idea but it is difficult to present the data about those huge environments [8].

In the work of Pollicott [2], it is stated that system of systems approach is useful when analyzing EBO. It provides enhanced understanding of the functioning of the system and an improved comprehension of the linkages. In this sense, it enables better awareness of secondary effects which is one of the challenges of EBO. A SoS in the EBO context is a macro system which encompasses political, social, economic, military, information and infrastructure systems and networks for military operations. For this reason, analysis should be performed on the macro system to assess the impact of removing or degrading components of the SOS to achieve a desired effect. The initial step is to understand the macro system's nature and structure; then form the macro system's behavior as wanted [2]. In military operations, macro system is an operational environment (OE). For other fields, macro system is the entire SoS. In order to define OE as a first of EBO, the geographic and non-geographic boundaries of the operation should be described. Then, boundaries for each system should be identified by commander's intent or system architect's intent. All information about entire SoS should be collected within the time available. Existent data bases can be also searched but knowledge about the OE should not be depend on the past record because it has dynamic nature and the other steps of EBO depend upon that information collection [10]. For example, common elements such as information about demographics, religions, political form of OE for military operations might stay unchanged and therefore, existent data can provide more time for other analysis.

The next step of EBA is describing effects on friendly system and adversary system. The result of OE investigation makes a contribution to define desired effects on each system. Besides desired effects, this process helps to identify potential undesired effects. At the end of the EBA stage, the system is ready to pass to the next step. The products of the stage are knowledge bases and dynamic modeling system.

2.2.2. Effects-Based Planning (EBP). Effects-based planning is an operational process to conduct EBO. EBP is result-based rather than attrition based [1]. Therefore, it focuses upon the linkage of actions to effects to objectives. The products of EBA are used to inform EBP. The EBP process can be seen in Figure 2.2.

Most EBO cases are conducted in an adaptive environment therefore the amount of available time becomes crucial for planning stage. Available time determines reliability of the following processes. Commander and his staff or system architect and management team should always revise their system analysis about OE through the operation. Plans should be well structured to adapt new OE.

This planning stage also requires collaboration of other systems, neutrals and allies. Since it is a stage the source, time, place and form of actions are identified, all actors related to each system should make a contribution. In an effects statement that provide common language for each system should be prepared in this stage. Effects statement shows the role of each system and potential actions in pending operations [10].

In this stage, first of all, target and target audience are identified by planner. Objectives and set of desired physical and cognitive effects are determined. These effects are listed in the priority effects list (PEL). Then, these effects should be linked to related nodes and measurement of effectiveness (MOE) and measurement of performance (MOP) should be created in order to assess their effectiveness. Then, the actions to achieve those effects are defined. When choosing actions, resources needed for actions are also considered [10]. It is important to foresee and mitigate undesired effects before EBP ends.

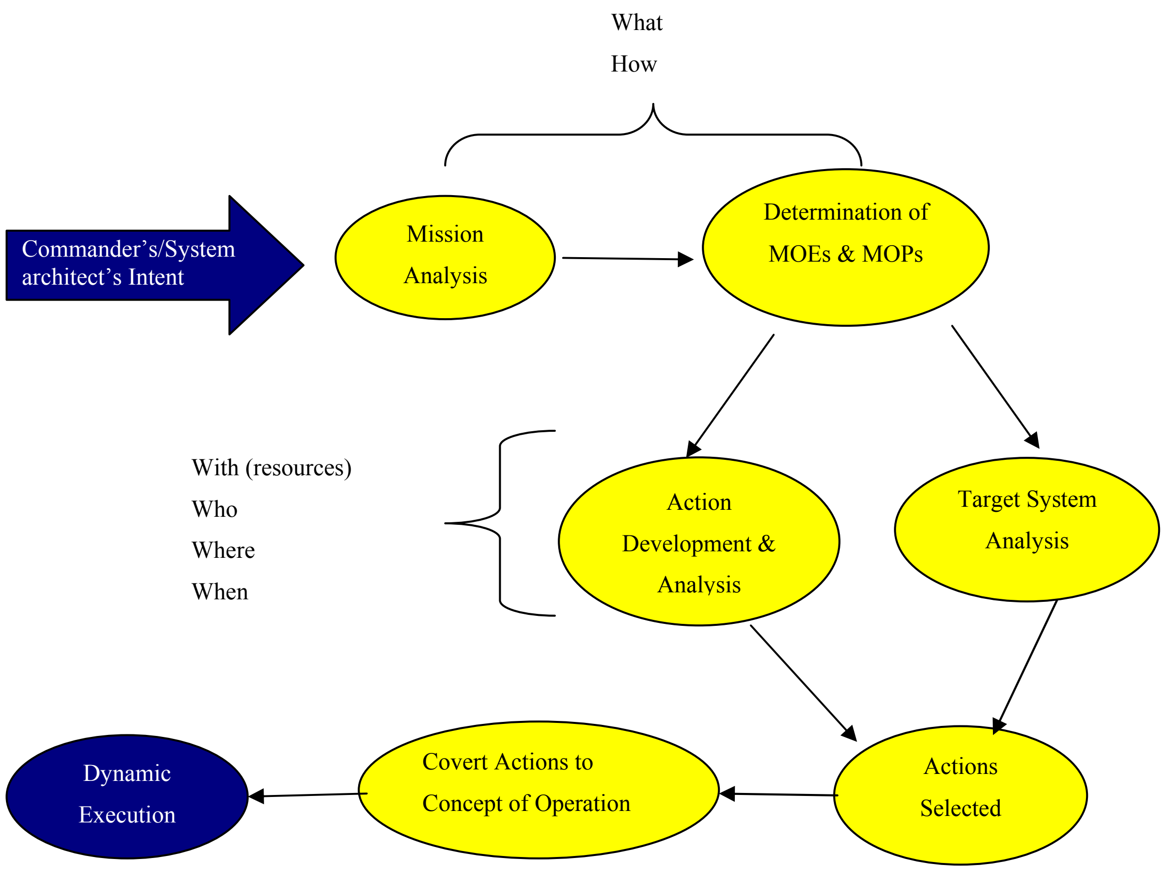

Figure 2.2. EBP Process

EBP is a top-down a commander / system architect centric process. However, the collaborative information capability at each level of operation and between commander and his staff or system architect and his team helps in planning process. Decisions are conveyed to vertical or horizontal node frequently.

2.2.3. Effects-Based Execution (EBE). It is described in [10] as a "collaborative orchestration and management of activity with the aim of realizing precise physical and cognitive effects in accordance with the output of EBP". Like EBP, it is also iterative and multi level process. MOEs and MOPs which are identified in EBP, provide input for feedback mechanism in EBE. EBE also requires very flexible tactical units with adequate equipment, procedure and training to adapt the current routine immediately.

In EBP resources for actions are identified; however, sometimes it may be more difficult to assign specific actions to resources. Therefore, the commander or the system architect uses effects tasking order to specify the actions' task, aim and desired effects. During execution, each resource undertakes its assigned missions. To attain desired effects, the commander and staff in military operations and system architects and his management team in other systems try to make best sequence and timing of actions by redirecting actions and resources as necessary. Resource allocation is crucial because spare resources which are allowed to act without integrating activities with planned actions may take resources away from critical actions. Therefore, spare resources do not have positive mean always; therefore, they should be avoided [10].

At this stage, head quarters (HQ) need to control execution process by collecting information about OE's current situation, reviewing subordinating tasks, assessing operations and making adjustments if necessary, recommending improvements for increase MOEs and MOPs, and providing necessary conditions to adapt new plans and orders [10].

2.2.4. Effects-Based Assessment (EBAS). It is a measurement of success of realizing effects. Quality of an action, level to which the desired effect relating to that action is realized and progress towards an objective are main criteria for this measurement [1]. It shows if there is any better opportunity and if there is any corrections to be made [10]. Actually, assessment starts from EBP and continues in EBE and it is also multi-level process. Tactical level assessments are usually about accomplishment rate of tasks; on the other hand, assessments in operational and strategic level focus on broader aspects of tasks, effects and objectives. Tactical level assessment also contributes the assessment of operational and strategic level operations. Tactical level assessments give information about capacity of friendly and adversary systems [1]. For example, usage rate of munitions, number of soldier or available aircraft. Strategic and operational level assessments can be done daily or weekly or sometimes monthly but all players and related staff should be involved into the assessment process [10].

As mentioned before in Section 2.2, EBAS measurement tools are established in EBP. Both quantitative and qualitative methods are used for EBAS. Estimations of overall effectiveness are done with the help of probability science. However, it is critical to have objective and quantifiable MOEs and MOPs. Although actions have both physical and behavioral effects and it is difficult to measure them, [2], [8] and [6] try to find some metrics such as time of effect, recuperation time, persistence of effect and secondary effects. Analysis of MOE trends enables to decide whether additional future missions will be required against a node [10].

2.3. CHALLENGES IN EFFECTS BASED OPERATIONS

The reason of why EBO is so difficult is that EBO are applied to complex adaptive systems. For instance, there are many actors in military EBO such as enemies, neutrals, allies and different form of actions such as diplomatic, informational, military and economic, and different kinds of effects such as desired, undesired, direct, and indirect. Three district areas of complexity are the main challenges for EBO [1]. Figure 2.3 presents EBO methodology and its challenges. It also summarizes the purpose of this thesis.

The first challenge of the complexity is determining and estimating direct and indirect effects of the planned actions. Unpredictability of these direct and indirect effects is dealt in the course of action development and analysis (COA) and target system analysis steps (TSA) of EBP. Many studies in the literature have been conducted to overcome this challenge. [5], [6] and [8] propose well-structured solutions in order to estimate the direct and the indirect effects of selected actions. However, these studies are not adequate. The EBO researchers have been investigating more robust solutions to overcome this challenge. The step of where this challenge is a main consideration is illustrated in the Figure 2.3.

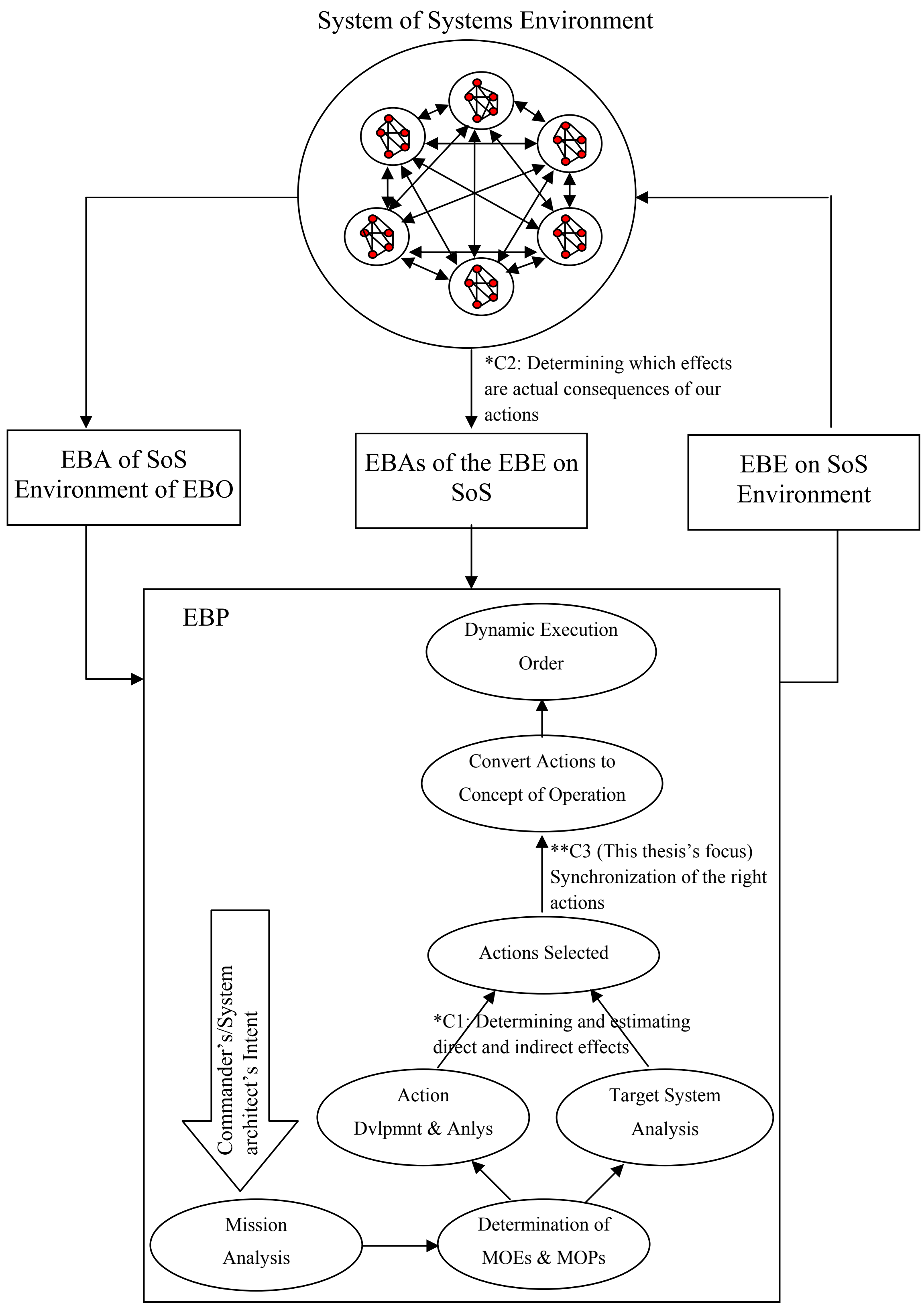

Figure 2.3. Effects Based Operations Methodology and Its Challenges

The second challenge of complexity is determining which effects are actual consequences of the executed actions. In EBO, an effect is created when an action is observed by an actor. The actor interprets his observation and assesses it by depending on his past experiences, cultures and mental models. Then, he starts a decision making process to react and create a response [1]. This is a simple description of the cycle which human beings involved several times and in a different level of the operations during EBO. An effect may be result of an intended action or may be created by other effects. They are often obscure. Moreover, there is no hierarchy in complex adaptive systems. Small actions at a micro level can have huge effects at macro level. In addition to these, even different scenarios for EBO are planned, they may occur at a variety of times and in a variety of orders. Furthermore, the systems-human beings have a dynamic nature and many of their changes are observed sometimes only indirectly and delayed. This challenge is the main problem of EBAS which is shown in Figure 2.3.

Finally, the last challenge which is the reason and motivation of this study is synchronization of the right actions to generate desired effects. Right actions are chosen after actions development and analysis step in EBP. The tools to choose right actions are presented by some researchers [5, 6 and 10]. However, the aim of this thesis is to orchestrate these selected right actions with modular architecting modeling methodology. Figure 2.3 shows EBO processes and it also points where this thesis will be useful. The most beneficial contribution of this thesis is in the process between action selection and converting actions to concept of operations. This step is illustrated in Figure 2.3 as C3. In the following section, the methodology used to overcome this challenge is described and in the fourth section methodology development is conducted.

3. MODELING METHODOLOGY

Modular architecting means that a design of any system composed of separate components can be connected together. The modular architecting enables the replacement or addition any module (component), without affecting the rest of the system [15]. The need to produce different types of products at the cost of mass production started the idea of modular architecting. In mass production, design for producing a single product minimizes the cost but many products do not meet the customers' requirements. On the other hand, modular architecting creates different types of products and reduces the cost of producing various products at almost the cost of producing a single product for all customers [16].

Low cost communication between firms and customers via internet, the production of customer-specific assemblies of components on IT-driven flexible assembly lines, and door-to-door distribution channels like Federal Express are three breakthroughs of information technology that enable mass customization [16]. However, those breakthroughs are just supportive issues for modular architecting. Only when a product architecture that will allow satisfying different requirements needed by customers is designed, the customization can be reached; otherwise, taking and mixing components without architecture can not meet customer preferences. Therefore, design processes must be changed. Furthermore, system development becomes creating a platform or in other words a modular architecture rather than creating a system. System development is not just a technical issue, but the notion of system architecture is a key point in it. In the business sector creating appropriate modular architectures to support new kinds of strategies is taking more attention. Creating system and system development architectures that are capable of providing the flexibility to customize systems for different customers is becoming a necessity for businesses. Also, because of improvements in information technologies, upgrading systems when better components come along is crucial.

As mentioned in [17] an architecture has a two-part definition: the first part of an architecture is a decomposition of the overall functionality of a product into a set of defined functions and the component parts of the product that are going to provide those functions. The second part of the definition is the specification of the interface between the components, in other words, how components are going to interact in the product as a system. Interfaces are important in flexible architecture because they allow the creation of component variations within a product without having to make changes in other components. Modular 5-kW power processing unit design can be given as a good example. In 2001 NASA Glenn Research Center developed a 5/10-kW ion engine for a broad range of mission applications. A 5-kW breadboard power processing unit was also deigned and fabricated concurrently. The modular design approach which includes a beam supply consisting off 1.1 kW power modules connected in parallel, equally sharing the output was embraced. A novel phase-shifted/pulse-width-modulated dual full-bridge topology was chosen for its soft-switching characteristics. The proposed modular approach allowed not only scalability to higher powers but also possibility of implementing an N+1 redundant beam supply. More than 96 percent efficiency was measured during testing of a breadboard beam power module. A specific mass of 3.0 kg/kW was expected for a flight PPU. This represents a 50 percent reduction from the state of the art NSTAR power [18].

As stated in [16], the notion of modular architecture is quite a challenge to system management. The first revolution, which is the industrial revolution, created enormous effects on business. The second revolution, which is the information revolution, caused unimagined dreams to come true. Lastly, the third revolution is the design revolution that will transform strategies and management processes. The idea under the design revolution is that there is no direct trade-off between system output variety and system cost, but very high levels of output variety can be achieved while at the same time low cost for development is accomplished via modularity [16]. The modularity approach has been changing the concepts of competition by pushing out productivity frontier in the system development. In these senses, many system stakeholders have been changing their many assumptions in management as an initial step for modular design. The more it is understood of how modularity can be applied to new markets and how a modular strategy can be implemented in a system, the more the system get close to win the competition.

The biggest change that is brought by modular architecture is that users can become the drivers of system output variety. The modularity design provides the focus of system description to shift from system architect to consumers [17]. The old way of system development was trying to guess system product variations or what kind of system functions, features and performance levels would be bought by consumers and offering those “guessed” system product types to the market and wait to see if it is guessed right. On the other hand, the modular architecting make it possible to have different strategies by defining architectures that will enable to have a range of component variations that provide different functions, features, and performance levels that supply a menu of choices to consumers.

A modular approach needs to have a different mind set on the systems. Modular architecting allows consumers to choose among component variation the way they want. However, the kinds and the extent of component variation to be designed into the architecture is still the system architect’s decision. Therefore, these skills in defining strategies become important for companies or systems to have a more competitive advantage. Applying modular architecting is not necessarily hard. Systems that have learnt how to do modular design are now taking advantage of the increased flexibility and reduced cost that they get from modular design approach.

Another new thing which is brought by modular architecting is the relationship with the system designer, system architect and system user. Although the greatest impact of modularity is on system management thinking; the modular approach that causes decision making process in system development should start from the beginning. It is asserted that a design process for creating a single product should be avoided and furthermore a platform approach for gaining broad market share should be considered during a decision making process [16]. This platform approach should also include future plans about the system which enable the upgrading of components when new technologies become available

Besides providing component variety; modular architecting also enables to have common or standardized interfaces which facilitate concurrent development of components [17]. The required outputs of the development process for a component are defined by those standardized interfaces. When the interfaces are defined from the beginning a lot of middle level management energy, time and cost in managing the process of component development can be saved. Modular development approach asserts that there is a need to move from flat or empowered organization structures to thin layers of middle management and a more strategic orientation in decision making of top management [16]. In a traditional system development process, engineers at technical working level decide the constraints on the flexibilities of the systems to meet diverse and changing requirements from system users without involvement of top management. On the other hand, modular system development process requires a top management to realize that such decisions can not be depended on the technical level because these decisions also form the strategies in the market. It can be clearly seen that decisions about interfaces are not a low-level engineering or technical decision. Decisions about interfaces or flexibility are the issues which define the success of the system. Interface specifications determine the flexibility of the system that will offer component variations, upgrades and technology improvements in the future. Also, these decisions must be strategic decisions not just a technical one because they set the future options of the system.

Another advantage of modular architecting is reusability. For instance, in the software industry, although technology improvements on a former design provide the best way forward, backward compatibility has been always a big problem for the producers. Compatibility is important for software industry because users have an installed base of equipments, programs or files that they do not want to sacrifice [17]. Those issues also can occur in other kinds of systems. At this point, modular architecting approach gives backward and forward compatibility to the system user and system producer can have many benefits. It can be used as a big advantage in the market. Since it facilitates a proprietary architecture strategy; only the system architect knows the critical interfaces which enable the plug and play compatibility. Moreover, a system architect also holds the fast upgradeability of a modular architecture advantage as a market strategy and the control of the market. With modular architecture, many benefits from configuration of products for variation and upgrades can be gained. Reusability is a main factor that provides these benefits. System users or consumers also save money from modular architecting. Therefore, reusability of components and processes has become a central issue for a lot of systems in their design strategies [17]. This situation may cause several results. For example, the relative cost of development versus production may shift greater investments in system development. If it is focused on one component design and if this component design can be used in a number of system variations or across system generations, then it is clearly seen that it can provide tremendous amounts of money in system development cost. Another great result is bringing improved system products based on selectively upgraded components can be faster than a traditional system design. Moreover, economies of learning and quality improvements at the component level because of reusability can be seen as another result. This last result brings another benefit with itself, reliability. Reliability is an issue which can be measured by reusability [17]. It is obvious that with time and experience, a component can be made better and cheaper. The more the component is reused and the more system architects work for improving the component and its process, the more reliable that component becomes.

In summary, modular architecting approach means having certain key components-around standardized interfaces. High reliability, performance of components, final product, and also low cost is desirable for both consumers and producers. This situation sometimes leads to have interface standards for that kind of a component so all systems in the field can use the same components [16]. Component producers can begin to think that as long as the component that they produce fits the interfaces, they can upgrade their product around that interface standards. When the interfaces are not standardized, there may be more component variations, but there may be many uncertainties about what the interfaces will be in the future. It may increase the risk and cost barriers for the component producers. On the other hand, the lack of standardized interfaces may limit the competition and component variation which is not good for both consumers and producers.

Those benefits of modular architecting and modular design are not limited in production systems. Modular architecting can be applied the entire systems engineering field. Systems engineering process starts with problem identification and continues with requirements and functional analyses, detailed design, element fabrication, integration, verification, validation, deployment, operation and support and finally disposal of the system. Modular architecting is achieved throughout the systems engineering process. Requirements are traced through levels of modular design. A design philosophy that emphasizes maintaining a systems perspective while utilizing a modular architecting are guided in every phase of the system development. In other words, system architecture is developed around modularity concepts and served as the framework for designing and integrating the many components required to make the complete system fulfill its mission and objectives. Modular design in systems engineering process enables system architects to gain many benefits mentioned above. The importance of system modeling in development of modular vehicle design is demonstrated in [19]. Their approach creates modular systems and optimized integration and interactions of the system elements. For the effects based operations (EBO), their approach which composes a requirement analysis, integration analysis, and design analysis is adapted in this research with a few changes. The modeling methodology for this thesis is shown in Figure 3.1.

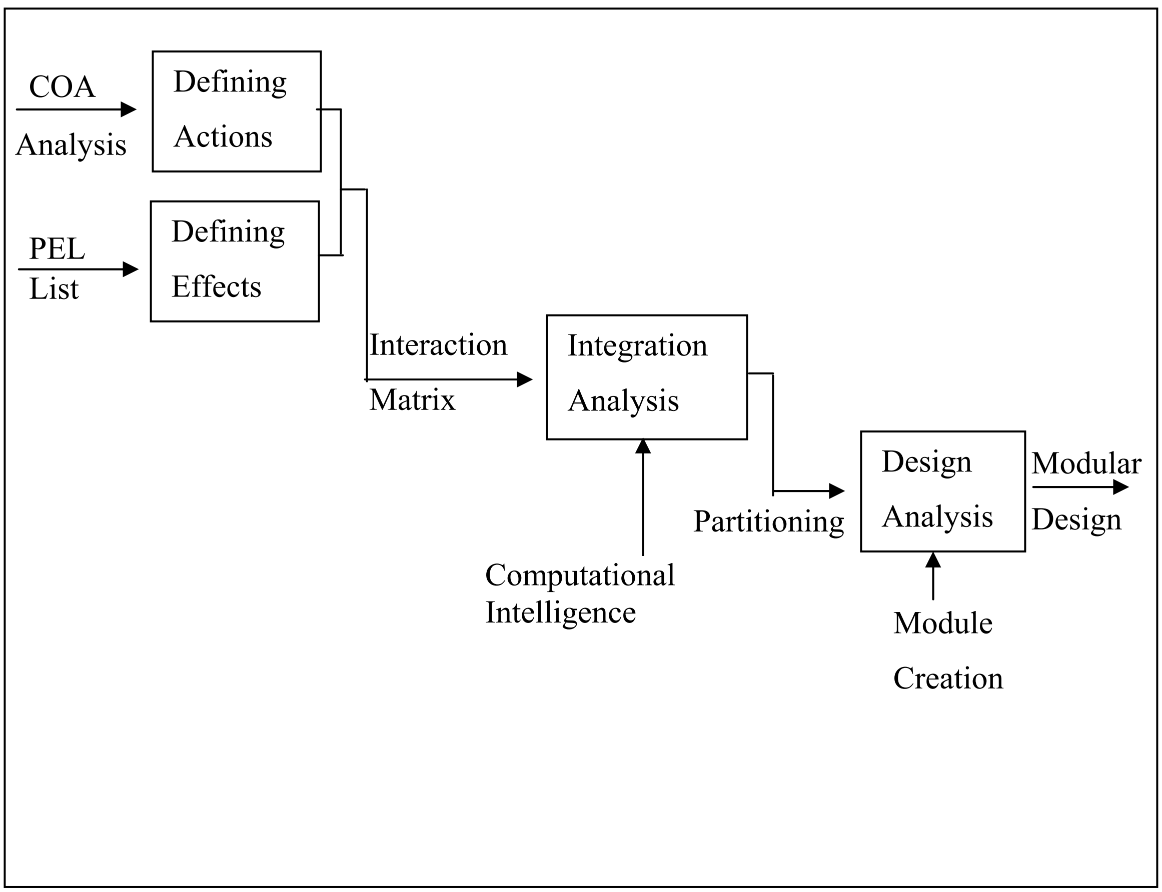

Figure 3.1. Modular Design Methodology for Synchronization of the Right Actions

The first step of the modeling methodology is defining effects and actions by using inputs from the result of COA analysis and PEL. The next step is applying computational intelligence models for integration analysis. The reason for choosing computational intelligence, which is neural network models in this thesis, lies in the fact that they can be used to infer a function from observations. Also neural network models are particularly useful in applications where the complexity of the data or task makes the design of such a function by hand impractical like in EBO. Rather than applying traditional statistical models, neural network models are chosen to solve the complexity challenge of non-linear and adaptive EBO. In the last section of the modeling methodology the design analysis is completed by using the output of the integration analysis. Each step will be explained next.

3.1. DEFINING ACTIONS

The explanations in the previous chapters make it clear that military EBO is a process in which the actions and effects in question are interrelated across tactical, operational, strategic level and across four national powers; namely, diplomatic, informational, military, and economic powers are cumulative over time. It is apparent that the actions which are used in crisis or peace time to create desired effects can be nearly infinite. As stated in the previous sections those actions can be perceived differently from one observer to another. If the past wars and crisis are considered even the best commanders accepted the fact that there is uncertainty in every action-effect relationship. Inducing desired behavior for an adversary system involves many complexities that are mentioned in the previous sections. It seems better that the starting point for a study about effects based operations should be to understand and to define actions, effects and their relationships.

At this point, the first thing that should be done is describing actions. The most critical thing in this phase is setting particular variables in order to limit the infinity of actions. Setting variables should be done in a way that everybody can observe, interpret and understand it. The defining process begins with the question of “what is done?” and then continues with the question of “with what?” for the actions. These actions may be destruction of the forces and capabilities or it may be the action without destruction such as being in the right place or taking the right economic decisions. The actions can be the answer of "what is not done?" such as not providing financial funds to an adversary system. "What?" questions provoke series of shaping questions for the decision makers such as "what was the last action?", "what was destroyed?" and "what can affect adversary?". The third question that should be asked is "how can it be done?". The answer of this question is the result of choosing resources to undertake the action. In the example of this thesis, planned actions are diplomatic, informational, military or economic actions (DIME). These are main action varieties and they can be also used under different names. In addition to these, the answer can be moved one step forward with defining sub-kinds of actions. For example, what kind of military force will be used or what kind of economic action will be done. Another variable for defining action is scale of the action. The scale of the action is the effort to do the action and also the measurement of the impact of the action. It means that when scaling the action, the effort and the impact both should be considered. It is obvious that the effect of five ships for five different targets and five ships for one target would not be same. The next variable for actions is to define the scope of them. The scope of an action can be geographic which defines the battle space or it can be an operational scope which defines the environment of the battle space such as air, undersea, etc. Timing is another variable for actions which has three dimensions: speed, duration, and synchronicity. Speed is the measurement of execution of the actions. Duration is another concept where whether the action will be initiated once or be repeated is decided. Synchronicity is the ability to do actions in the right order and in the right time to achieve desired effects. The last variable is the visibility of the action that provides control of what is observed and when it is observed [1].

This six attributes for actions are defined in the COA development and analysis phase. It is important to note that these attributes form the aspects of actions that may be synchronized so as to create desired effects and shape the adversary's behaviors. Those variables also provide quantitative measurement for assessment of the actions that have done to provide feedback for future actions. In COA development and analysis phase, after actions are defined, the next step is choosing the right actions. Choosing right actions can be done in several ways such as war gaming, cellular automata, or agent based modeling and there is still a need for more tools to choose right actions.

3.2. DEFINING EFFECTS

In the previous sections, desired effects are defined as "the consequences or outcomes of actions which can be created by any national power." One of three main complexities of EBO is synchronization of the actions to create very specific effects. EBO approach is built on the assumption of a casual link between a given action and a given effect or stated differently between an action and a reaction. Moreover, it is almost impossible to predict the relationship between actions and effects at any level of EBO and across any system. Furthermore, interactions between effects and actions change dynamically during EBO. The relationship between an effect and an action can be never reduced a simple linear cause and effect relationship and there are too many variables such as perception of the action, human decision making process, invisible factors, and physical and psychological domains where effects can occur. The only thing that can be done for the EBO planning is to bound the problem of a potential infinite number of effects. Desired effects are the sub-branches of strategic aim which is a commander's or system architect's intent. Therefore, desired effects can be defined by interpreting a commander's or system architect's intent and by analyzing each system and node to attain those desired effects.

3.3. INTEGRATION ANALYSIS

The need for integration analysis phase is to understand complex interactions between the elements of a design. The first step of this phase is describing interactions between the elements. The second step is trying to find best architecture for the specific case. The last step is clustering the elements into modules. By conducting the integration analysis, system developers can better understand the complex interactions within the design; thus, simplifying the design process for large and complex cases such as EBO.

After defining effects and actions, the next step is determining how these effects and actions might interact. First of all, all interactions between each action and each effect are defined. Determining interactions between effects and actions is important because it allows an understanding of the needs for coordination in the later design analysis. Once the interactions between actions and effects are identified an effect-action matrix which shows the interfaces is developed. The matrix of the interactions between effects and actions captures the current level of knowledge about the design. To develop a matrix for systematically identifying and describing interactions, one could begin by considering categorizing of interactions. The grouping method can be chosen applicable for the modeling architecture. This interaction matrix can be restructured using cluster analysis techniques to obtain the groups. The interaction matrix can be in both binary form and decimal form.

Cluster analysis is concerned with the grouping effects and actions into similar clusters. Although action generation is an important part of synchronization of the right actions complexity challenge, the real reason which creates complexity is organization of the actions. The effect-action interaction matrix in this thesis can be generated with different effects and actions. However, the most important thing is to orchestrate them.= The most critical part of the model development phase for EBO is this phase. Once the effect-action interaction matrix is generated, the most suitable algorithm which can provide a useful solution to deal with the complexity is selected. It is obvious that the clustering algorithm for EBO should be appropriate for non-linear and adaptive to the nature of EBO. Data clustering algorithms can be hierarchical or partitional [21]. Since the hierarchical algorithms use previously established clusters, the partitional clustering, where all clusters are determined at once, is preferred. Among many partitional clusters such as k-means, fuzzy c-means from the field of statistics, Kohonen's Self Organizing Maps (SOM) and Adaptive Resonance Theory I (ART1) from the field of artificial neural network have been chosen for the integration analysis. Artificial neural network architectures give more satisfactory results in adaptive non-linear systems where the complexity of systems is very high such as EBO. Another reason for choosing these architectures is in their ability of unsupervised and competitive learning process which helps in categorizing the actions and effects without any prior knowledge. The algorithms can also deal with large databases. Determining a suitable algorithm for a clustering analysis also depends on the aim of the analysis. Since the aim of this thesis is creating useful modules to solve one of the challenges of the EBO complexity, the help of these selected algorithms in visual interpretation of the clusters is another reason for selecting them.

The building blocks (called modules) which result from integration analysis can be used to define the design phase. Choosing the right architecture among its alternatives to cluster the matrix is crucial because not also the complexity problem starts after action and effect generation but also it affects quality of the design analysis. Moreover, other steps of EBO which depend on design analysis results can be affected by the integration analysis architecture.

3.4. DESIGN ANALYSIS

In this phase modular design is completed. The modules, which are the results of the modeling architecture, are identified and designed in order to solve synchronization of the right actions challenge of EBO. The design analysis is important because it requires lots of efforts for coordination of each sub system, actor, or player. For example, to create a desired effect in military EBO, coordination of economic system players and military system players may be more important and may require a more intense relationship for that specific desired effect. Since these types of interactions involve tremendous coordination efforts, modular design is proposed to execute actions in modules to increase the quality of effects and to reduce time for coordination of the actions.

4. MODEL DEVELOPMENT

The model development in this section demonstrates the application of the modeling methodology described in the previous section. Since many EBO are conducted for defense of a country, it is almost impossible to reach military data about past applications of EBO. Moreover, dealing with other steps and challenges of EBO which have been researched by many authors is, behind this study. A military EBO for defense of a hypothetical country in order to defeat a terrorist country is used in this thesis. The basic information about the steps of methodology was obtained from a deep literature review about military EBO.

4.1. DEFINING ACTIONS

In this study, actions associated with a hypothetical example of defense system of a country for a terrorist adversary system are stated in the below. It is assumed that actions are already chosen to create desired effects as a result of COA analysis and development phase. Since this is a military operation, actions are grouped according to their source of national power (DIME). Defining each variable for each action is beyond of this study and the actions have limited scalable attributes.

Diplomatic Actions:

1. Mild contribution of NATO
2. Long-term over-flight authority from many countries
3. Receiving grants for landing rights from majority of coalition
4. Having granted bed-down and basing authority from some part of coalition
5. Agreement with some part of coalition on hosting forces on their land
6. Employing hundreds of officers for investigations
7. Mild supply of new investigative tools to law enforcement and national security agencies
8. Severe strengthening legislation to combat terrorism
9. Anti-terrorism acts among many countries

10. Aeronautics act among some countries in order to maximize effectiveness of aviation security system
11. Severe cooperation between the police and the justice departments of the coalition countries
12. Creation of an adequate infrastructure for supply and exchange info among some countries
13. Severe border monitoring

Informational Actions:

14. Frequent radio broadcasting
15. Gaining deep knowledge about enemy people, culture, religion and language
16. Training several number of officers about enemy system in psychological operations
17. Dropping thousands of leaflets to OE
18. Knocking out huge percentage of enemy's radio capability
19. High level usage of graphics on leaflets
20. Applying higher level disinformation rarely
21. Making propagandas daily
22. Aggressive advertising and PR campaign
23. Releasing a few number of video cassettes about enemy leader

Military Actions:

24. Providing a few number of C-130s for strategic and tactical airlift
25. Designating thousands of troops which includes naval, air and land personnel to OE
26. Employing plenty of aircraft for long flight hours for hundreds of missions with airbus and helicopters
27. Mild increase in number of armored reconnaissance vehicles to detect nuclear, biological and chemical contamination
28. Mild increase in flight hours of carrier battle group to support combat operations
29. Providing a few number of frigates to support maritime surveillance

30. Deploy a few number of KC-135 to provide aerial refueling and re-supply
31. Mild increase in number of mine clearing vehicles in the OE
32. Mild increase in number if engineering companies in the OE
33. Drastic increase in number of missile salvos and flown sorties to support aircraft strike
34. Moderate increase in number of munitions storage facilities
35. Designating severe number of C-160 and C-130 aircraft for human aid
36. Providing moderate number of F-16 in an air to ground role

Economic Actions:

37. Freeze hundreds of terrorist bank accounts
38. Severe attitude toward disrupting fund raising and recruitment
39. Moderate intend to create a unit for the surveillance of suspicious financial flows
40. Severe protection for money laundering with using electronic data processing systems
41. Mild intention to create a centre for overseeing financial transactions and payments
42. Immediate action to issue order in order to freeze enemy assets
43. Moderate changes in regulation of trade practices
44. Providing severe money aid to OE
45. Providing severe food aid to OE
46. Providing utility aid to OE

4.2. DEFINING EFFECTS

In this section, the question of “to do what?” is answered. Since the example in this study is a military operation, desired effects will affect political, military, economic, social, informational, and infrastructure (PMESII) systems. Effects can be created on one or more than one of a PMSEII. It is difficult to categorize the effects according to the systems that they occur. This happens because of the complex adaptive nature of EBO. However, in this step for the simplicity it is assumed that the effects can be grouped under the one of the PMESII systems. The first step is to define strategic aim which is "peace and stability in the region". It is assumed that this strategic aim is described by a commander. Secondly, the end state of the operational environment for each PMESII system is explained. Descriptions of these end states for each PMESII system are assigned below. The aim of this thesis is to assist the effects based planning stage where the synchronization of the right actions challenge occurs. In this study, the effects are defined according to literature review in [8]. Davis stated in his research nine main effects wanted to be created in every military EBO. These nine effects are decomposed under PMESII systems.

Strategic Aim: Peace and stability in the region

End State:

Populace obeys civil authority **– Political Systems**

Stop fighting; prevent future attacks and terrorists leave the country – **Military Systems**

Economic welfare in the region **– Economic Systems**

Increased life standards for the populace **– Social Systems**

Independent media operations **– Informational Systems**

Finished reconstruction of the region **– Infrastructure Systems**

Desired Effects:

Political Systems

1. Support of neighboring countries for the central government
2. Reconciliation of central government with insurgents
3. Help of central government to bring terrorists to justice
4. Increase in number of surrendered terrorists
5. Elimination of international political support (security issues) for terrorist system
6. Increase in number of new parties
7. Local governmental control

Military Systems

8. Dismantling the organization

9. Taking out leadership
10. Elimination of capabilities of armed forces
11. Destroying terrorist training camps
12. Confusing/diverting enemy commanders
13. Destroying safe havens and sanctuary
14. Identifying, locating, eliminating man power
15. Destroying production, storage, maintenance and distribution centers
16. Weaken internal security in adversary's military systems

Economic Systems

17. Decrease in production which helps terrorist systems
18. Decrease in demand for exports
19. Increase in demand for imports
20. Elimination foreign aids
21. Elimination foreign investments
22. Minimization commercial interaction during war
23. Increase in consumption in domestic markets
24. After war, expanding cross-border commerce to pre-war level

Social Systems

25. Resistance of population to insurgent influence
26. Increase in good image of friendly system
27. Creation of social disapproval for terrorism
28. Protection of religion, culture, history of the nation
29. Increase in social welfare after war
30. Improve in education and health care services
31. Voting of populace for against adversary's political parties
32. Start in population to form new political parties
33. Decrease in trust to enemy commander

Informational Systems

34. Control of lines of command and communication by coalition forces
35. Media control in region
36. Decrease in support to terrorism via media

37. Limit in access to world wide web
38. Increase in enlightenment of populace

Infrastructure Systems

39. Limited or no access to utilities during war
40. Controlling or destroying transportation channels during war
41. Controlling heavy and light manufacturing
42. Minimization physical destroy in public facilities
43. Exceed in utility output pre-war levels
44. Prevention international transportation
45. Reducing hazards for civilians
46. Increase in reconstruction after war

4.3. INTEGRATION ANALYSIS

Effects and actions can be decomposed into PMESII systems and DIME actions according to the previous sections. It is impossible to decompose all possible actions and effects, but the aim of this study is beyond of defining actions and effects. The relationships between actions and effects, which are based on logical and historical examples, are attained. This study assumes that the relationships may be assigned differently. In a real EBO study, effect action matrix should be created after COAs are decided and a priority effects list is prepared. The hypothetical example and relationships of effects and actions can be seen Figure 4.1.

As an integration analysis, two architectures are proposed to solve the problem of modular design of effects and actions in this study. The first neural network architecture is Adaptive Resonance Theory I (ART1) and the second is Kohonen's Self Organizing Maps (SOM) architecture. In the literature, Kohonen's SOM and Adaptive Resonance Theory I architectures have been compared, concluding that the later are to be preferred. However, in this thesis, the use of ART1 and Kohonen's SOM for modular architecting of effects and actions highlighted different a result. It is concluded that ART1 is not adequate, whereas Kohonen's SOM provide completely satisfactory results including visually effective representation of clusters.

Effects/Actions	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46
Support of neighboring countries	1		1	1	1			1	1	1	1	1												1	1	1																				
Reconciliation with insurgents						1	1	1	1	1	1																																			
Bring terrorists to justice						1	1	1	1	1	1	1																																		
Increase in number of surrendered terrorists	1					1	1	1	1	1	1	1								1				1	1	1		1	1							1										
Eliminate international political support (security issues)			1	1				1	1	1	1	1																												1						
Increase in number of new parties														1		1	1		1		1	1	1																							
Local governmental control														1	1	1	1				1	1																								
Dismantling the organization	1	1	1	1	1	1	1	1	1	1	1	1						1		1	1	1	1	1	1	1		1	1	1						1		1			1					
Taking out leadership	1	1	1	1	1							1						1		1	1	1	1	1	1	1																				
Elimination of capabilities of armed forces	1	1	1	1	1																			1	1	1		1	1	1			1	1		1										
Destroying terrorist training camps	1	1	1	1	1																			1	1	1		1		1			1	1		1										
Confusing/diverting enemy commanders	1				1							1						1		1			1	1	1	1		1	1								1			1	1	1				
Destroying safe havens and sanctuary	1	1	1	1	1																			1	1	1		1	1	1			1	1		1										
Identifying, locating, eliminating man power	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1		1	1	1		1	1	1			1	1		1										
Destroying production, storage, maintenance and distribution centers	1	1	1	1	1																			1	1	1		1	1	1			1	1		1										
Weaken internal security in adversary's military systems	1	1	1	1	1			1			1	1						1		1				1	1	1			1	1																
Decrease in production which helps terrorist systems																																					1	1	1	1	1	1				
Decrease in demand for exports													1																										1				1			
Increase in demand for imports													1																								1		1			1	1			
Elimination foreign aids																																					1	1	1	1	1	1				
Elimination foreign investments																																					1	1	1	1	1	1				
Minimization commercial interaction during war																																					1	1	1	1	1	1	1			
Increase in consumption in domestic markets																																							1		1		1			
After war, ezpanding cross-border commerce expands to pre-war level																																1			1								1			
Resistance of population to insurgent influence														1	1	1	1		1		1	1	1																							
Increase in good image of friendly system														1	1	1	1		1		1	1	1				1				1	1			1								1			
Creation of social disapproval for terrorism														1	1	1	1		1		1	1	1																							
Protection religion, culture, history of the nation	1												1	1	1		1		1		1	1	1		1	1	1				1	1			1								1			
Increase in social welfare after war	1												1											1	1	1	1				1	1			1								1			
Improve in education and health care services	1																							1	1	1						1			1											
Voting for against adversary's political parties														1	1	1	1		1		1	1	1																							
Start in population to form new political parties														1	1	1	1		1		1	1	1																							
Decrease in trust to enemy commander														1	1	1	1		1		1	1	1																							
Control of lines of command and communication	1																	1						1	1	1																				
Media control in region by friendly system	1																								1																					
Decrease in support to terrorism via media														1			1		1		1	1	1																							
Limit in access to world wide web																		1																												
Increase in enlightenment of populace														1	1	1	1		1		1	1	1																							
Limited or no access to utilities during war	1																							1	1	1																				
Controling or destroying transportation channels during war	1	1	1	1	1																			1	1	1		1	1	1			1	1		1										
Controling heavy and light manufacturing						1	1	1	1	1	1																												1	1	1					
Minimization physical destroy in public facilities	1													1	1		1		1	1	1				1		1				1	1			1											
Exceed in utility output pre-war levels																															1	1			1								1			
Prevention international transportation						1	1	1	1	1	1																																			
Reducing hazards for civilians	1												1	1	1		1		1	1	1			1	1		1				1	1			1											
Increase in reconstruction after war	1																								1	1					1	1			1								1			

Figure 4.1. Effect-Action Interaction Matrix

The first step in the integration analysis phase is to build effect-action interaction matrix. The effect-action interaction matrix allows one to identify and understand interactions between effects and actions better. The matrix represents the flow and transformation of national power (DIME) within the matrix. While the rows of the matrix represent effects for each system, the columns represent the actions which are necessary to achieve those effects. Since the first attempt is clustering the effects and the actions with using ART1, this effect-action interaction matrix is prepared as binary input which means having only two states. While "1" means that there is a relationship between the effect and the action, the blanks represent that there is no relation between the action and the effect. After creating the matrix, actions and effects are initially clustered by using ART1. In this modeling architecture, the first aim is grouping the actions from the ones have more interactions with effects to the ones have fewer interactions. The second step is to cluster the actions which are columns first. Clustering of effects is the next step in this architecture. These last two steps are repeated until desired modules are created. The ART1 algorithm and its results are explained in the next section.

Since the use of ART1 algorithm did not provide a satisfactory result to create modules, Kohonen's SOM is applied as a modeling architecture for the example in this study. The working principles of Kohonen's SOM and its results are illustrated in the following sections.

Although two different architectures are used in this study, the aim grouping similar actions and effects and creating action modules which can be used in different strategic aims is the same. Moreover, grouping actions and effects can provide better results for the actions in each module. As a last step, design analysis begins and modules are developed in order to synchronize the actions for all PMESII system of systems.

4.3.1. Modeling with ART1. In the previous phases, the interactions between PMSEII and DIME actions are identified for the example in this thesis. Once the interactions among the actions and systems are identified, an effect-action matrix of the interfaces is developed. An effects-action matrix $[a_{ij}]$ includes "1" and "blank" entries, where an entry "1" indicates the information as material or energy link between effects i and actions j, and the direction of the link is from $j \rightarrow i$.

An effect-action matrix can be restructured using neural network to obtain the clusters in the binary interaction matrix and create action modules. Neural networks are parallel computer algorithms that are able to learn from experience and the capability to generalize, adapt, approximate given new information and provide reliable classification of data [22, 23]. Each node in the network has high connectivity with each other and has similar operational manner. The logic under the algorithm is that each node receives an input and uses this information to generate an output which is also an input to other nodes in the network. The power of the neural network depends on the interaction between nodes and learning rules that alter the strength of the interaction between nodes [22]. Neural network has been used for many applications from manufacturing systems to financial systems.

During the clustering of the effect-action interaction matrix, the only inputs provided to the network are the vectors representing the relationships between the effects and actions. Ideal or expected input is not available. As a result, the neural network must be self-organizing and perform in an unsupervised manner. ART1 architecture can be applied directly to the problem. In the literature, the ART1 paradigm has not been applied to the EBO. Impletion of ART1 for effect-action interaction matrix requires the recognition of resemblance between actions that are selected in COA analysis development phase. This would allow for correct classification of the actions which can create identical effects or that are applied in a similar sequence. There are several techniques to identify similarities between actions. However, the best way is to use classification and coding techniques in order to minimize human error by coding the individual attributes of each action. The following step is to perform computational method based on those codes for the actions.

Representation of the information that is sent to a neural network is a pattern. Each node includes a representation of previously stored patterns that fit the category associated with that node. If a new pattern is supplied to the ART1 network, a competition starts between nodes to make a match with the new pattern. The most relevant match wins the competition. Then, if the match is good enough, the input pattern is grouped into that node's part; on the other hand, if it is not good, a new node for the pattern is created. To do this comparison, different thresholds can be used. For each threshold, different degree of clustering can be obtained because threshold determines the number of groups. The sensitiveness to the threshold value is very high for ART1 algorithms [22].

During clustering of the effect-action interaction matrix, the column vectors representing actions are first classified by the ART1 to obtain a series of action groups. Similar columns are grouped into adjacent areas within an intermediate matrix. This begins the clustering of the “1” elements of the matrix next to each other. The effect row vectors are then classified and clustered in a similar manner to obtain the effect groups. The grouping of the rows and columns can occur simultaneously. The main advantage of the ART1 architecture is the ability to allow new effects and actions to be classified.

Firstly, the ART1 architectural model is conducted with choosing vigilance 0.8. Vigilance is a parameter in ART1 which should be defined between 0 and 1. For the realistic results vigilance should be higher than 0.5. However, ART1 with 0.8 vigilance did not enable to create modules for actions. The result can be seen in Figure 4.2. Therefore, ART1 has been run with different vigilance parameters. The Figure 4.3 is another result of ART1 model with vigilance 0.2.

Figure 4.3 shows that the ART1 paradigm as described above is not an effective technique for clustering effect-action interaction matrix. It has a few drawbacks which need to be improved. In the example the matrix is 46x46 and enough to show how ART1 works in EBO. If the more input vectors are applied to the network, the stored pattern grows sparser. In order to minimize this drawback of ART1, the vigilance parameter of the network can be adjusted for the different runs of the program to obtain set of different solutions. In the first attempt, vigilance parameter is chosen as 0.8 and the result is stated. After a different attempt, the vigilance parameter 0.2, which is far way from normal, is used. However, the results show that ART1 is not a satisfactory architecture to cluster effect-action interaction matrix. In addition to these, the clustering still becomes difficult as the number of the input pattern increases. Another problem is being dependent on the order in which the input vectors are applied. It is also obvious that as the number of input vectors increases, the representation grows sparse and vectors with most number of 1’s will not be classified into existing groups and will create a new category. It means that if higher vigilance parameter is used, the number of groups (number of modules) increases.

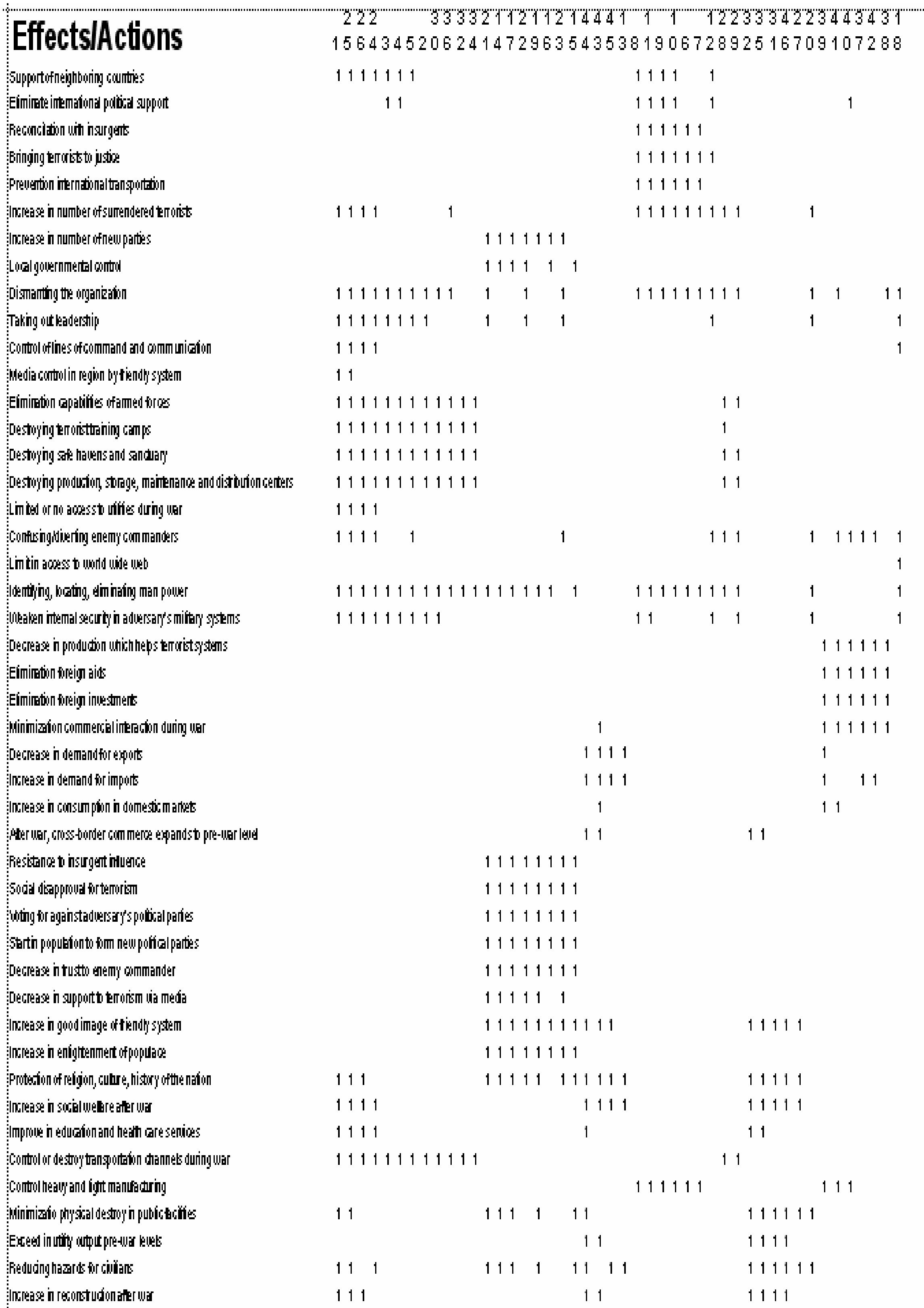

Figure 4.2. Modularity Matrix (Vigilance 0.8)

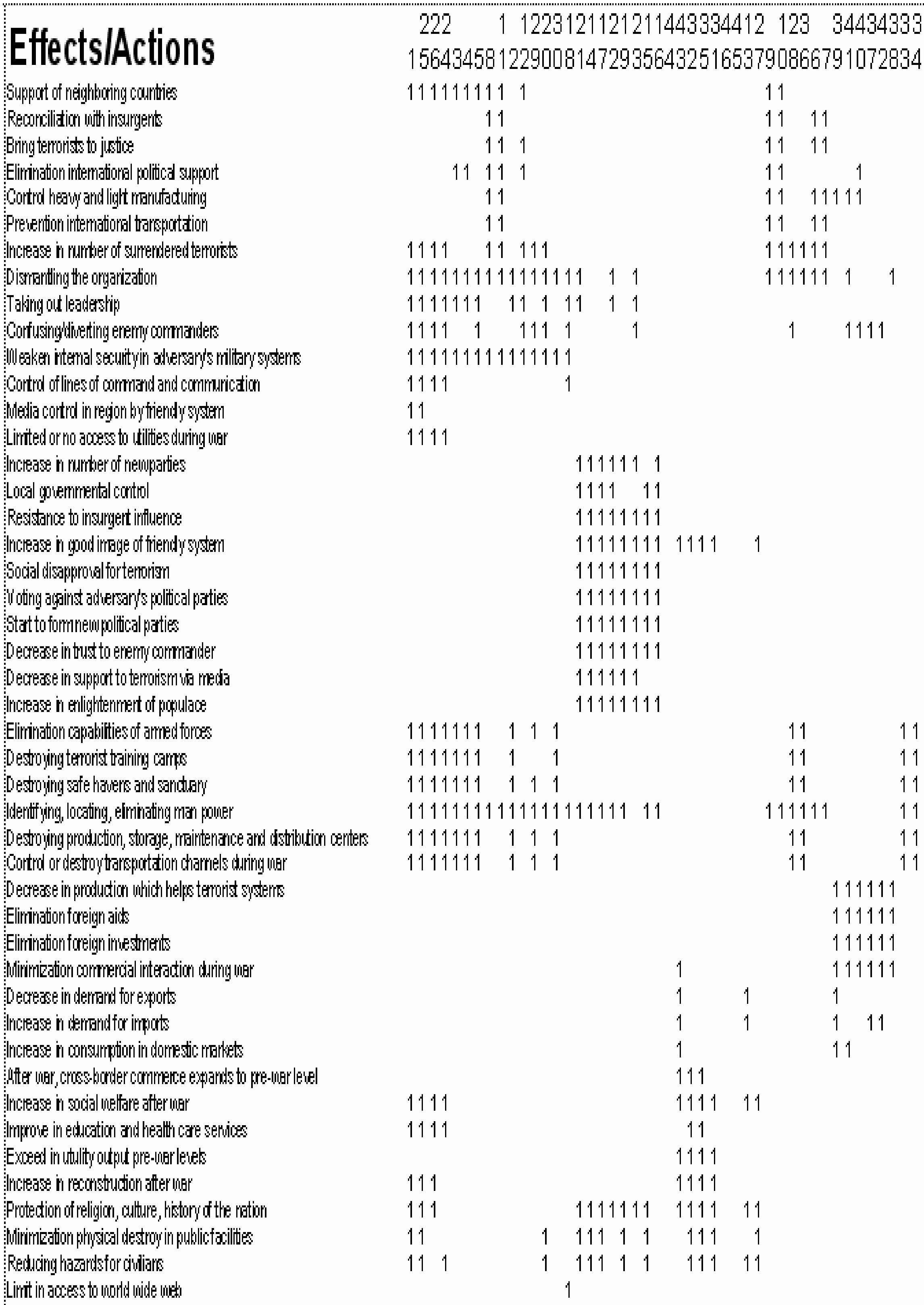

Figure 4.3. Modularity Matrix (Vigilance 0.2)

The further attempt with ART1 is clustering actions and effects together. To do this, effect-action interaction matrix is rearranged in a way that the action input vectors are dependent on not only the effects but also the actions. The new matrix is a 92x46 matrix, columns are actions and rows are both actions and effects. Original 92x46 matrix is reordered with the most number of 1's rule as in the previous attempt with ART1. The architecture is trained with vigilance 0.8. The result of it can be seen in Figure 4.4. In the figure, actions are numbered according to the action list in Section 4.1. If the action is nth action in the list, that action is named as A(n). Effects are also named according to their place in the desired effects list in Section 4.2. So, if the effect is nth effect in the desired effects list, it is stated as E(n). Since the results in Figure 4.4 with vigilance 0.8 is not a good solution for modularity, ART1 architecture is trained with different vigilance parameters. The result of ART1 with vigilance 0.2 can be seen in Figure 4.5. The investigation for creating modules with vigilance 0.2 also does not provide a satisfactory output for design analysis. Therefore, a solution for clustering will be investigated in the next section by another neural network model; namely, Kohonen's SOM.

4.3.2. Modeling with Kohonen's SOM. Since ART1 algorithm has not provided a satisfactory classification for the example, Kohonen algorithm has been chosen to group effects and actions. Kohonen nets are neural networks in which the idea of neighborhood is introduced. Each node in the network has a set of neighbors. Also, each node has a weight vector which enables to adapt the network in response to the input signals as the main feature of any self organizing map. In the Kohonen networks, the winner node changes its weight vector to become more similar to the input vector. Moreover, all neighbors of winner node which are in predefined distance to winner node, also change their weight vectors to the direction of the input vector. Therefore, the weight vectors of the neighboring nodes also become similar to the input data vector. As the learning process ends, neighboring nodes have similar values regarding the original data space [24]. The training process starts with the nodes placed on a plane initially. These nodes are attracted by the data vectors that are close to them during the training process. All data nodes are presented to the network repeatedly. The nodes take place in the region with high data density. If there are a large number of nodes, the location of it is called reference vectors. At the end of the training process, plain data surface becomes sculpture

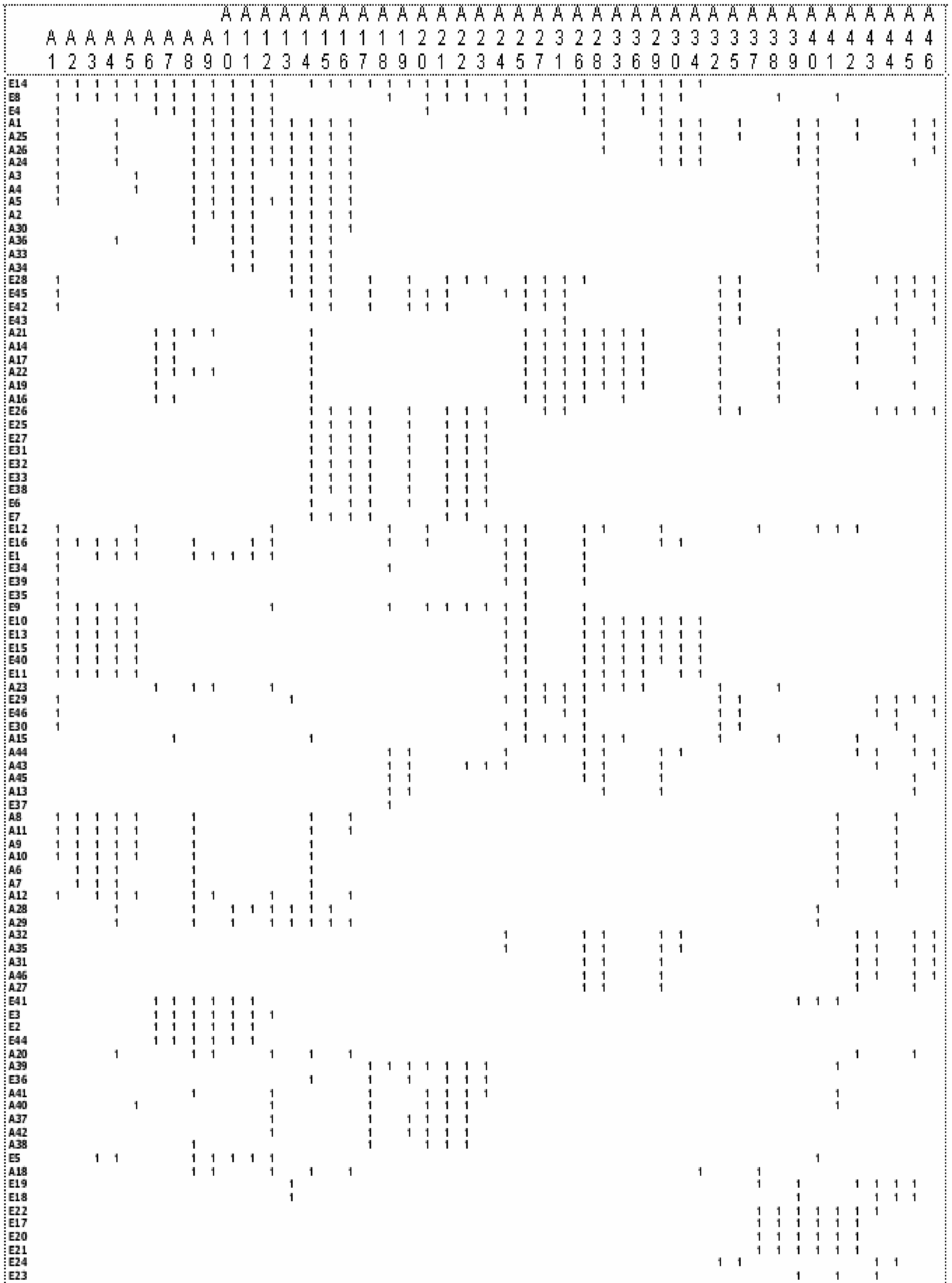

Figure 4.4. Modularity Matrix for Combined Effect-Action Input (Vigilance 0.8)

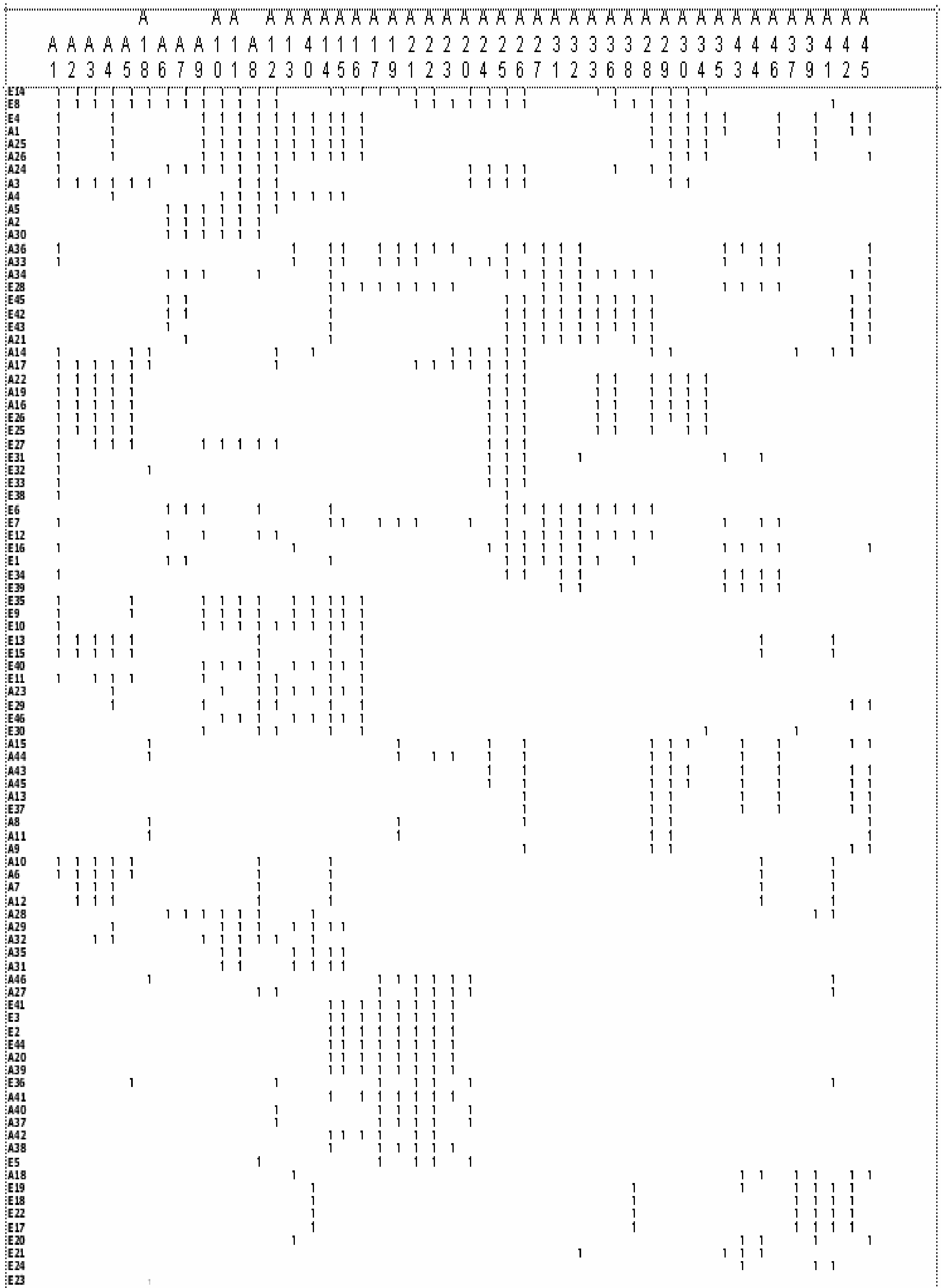

Figure 4.5. Modularity Matrix for Combined Effect Action Input (Vigilance 0.2)

of the output. Furthermore, a reference vector can be grouped with its neighboring nodes which represent a dense and connected data region. Boundaries between clusters are established if two neighboring nodes are different from each other. The boundaries can be modified by changing the threshold. Each component related to the reference vector can be also visualized in Kohonen networks, so it enables a comparison of the components with each other. Besides these, the capability of searching best matching node is crucial for many applications of Kohonen networks. During matching a data record is assigned to the node which has smallest computed distance. On the other hand, there are several parameters which affect the training process. First one is the number of nodes which has an impact on the duration of the training process and the flexibility for the map of data distribution. The next one is the format of the map which can be defined by the user. The last one is the tension which affects the strength of the interactions among neighboring nodes. If the tension is high it means that it averages the distribution of most data regions; on the other hand, if it is low, the map is adapted to fine details. In this study, the Viscovery SOMine which uses Kohonen algorithm is chosen. Viscovery uses these parameters which can be defined by the user. However, there are a few parameters which influence the training process of Kohonen networks and are also predefined by Viscovery SOMine such as minimum map height, map scaling factor, tension of intermediate maps, number of batches, wegstein factor and batch size. The advantage of Viscovery SOMine is speeding up the training process by batch SOM algorithm which does not require a learning factor. A node is updated by setting it to the mean value of all data vectors that are matched to that node and its neighboring nodes.

The input for the Kohonen's SOM is almost the same matrix which is used in ART1 algorithm. The difference is in the order of the columns and rows of the vectors. In ART1 algorithm, the input vectors are provided to the network from the one which has large amount of "1" to the fewer one. Unlike ART1, input vectors are used as in the order of original effect-action interaction matrix in Figure 4.1. The input data for Kohonen's SOM is arranged in a way to cluster similar actions. Therefore, each row represents a data record of that action. Components for those data records are the effects which are listed before. They are represented in the columns. Viscovery SOMine which is used to run Kohonen's SOM can read data from Microsoft Excel workbooks and text files. The quantity of the data in Kohonen's SOM depends on the maximum number of rows and columns in Excel 95. In the file for the example of this study, the headlines for component names are stated as E (n) while n represents nth effect in the desired effects list in Section 4.2. Therefore the file has 46 components. Each cell in the file contains the value of one component. Actions are also named as A (n) depending on the action lists in Section 4.1. The file also includes the data section which is organized in rows and columns and holds the data. Like modeling with ART1 architecture, the variables are in binary form as in the ART1 example. While "1" shows the existence of relationship between the effect and the action, "0" states that the desired effect cannot be created by that specific action.

As a first attempt, the training for creating action clusters is conducted. When the training process is started, map creation parameters are asked by Viscovery SOMine. For the example in this thesis, Target Map page is presented in Figure 4.6. The default number of nodes is specified as 2000. Map ratio is defined as 100:75 for the example, and the tension which influences the strength of the interactions among neighboring nodes is defined as 0.5, normally a good choice. Training has been repeated in the following training schedules: fast quick mode, normal quick mode, accurate quick mode, fast exact mode, normal exact mode and accurate exact mode. The best results have been achieved by using normal exact mode. The input file used for this training is shown in Figure 4.7.

The training parameters for the different input files for Kohonen's SOM architecture are illustrated in Table 4.1.

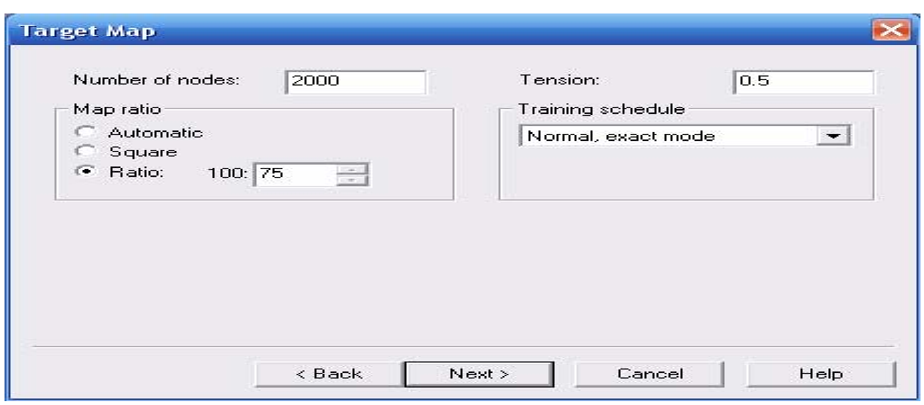

Figure 4.6. Screenshot from Viscovery SOMine of Target Map Window

E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	E13	E14	E15	E16	E17	E18	E19	E20	E21	E22	E23	E24	E25	E26	E27	E28	E29	E30	E31	E32	E33	E34	E35	E36	E37	E38	E39	E40	E41	E42	E43	E44	E45	E46	NAME
1	0	0	1	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	1	1	0	0	0	1	1	0	1	0	0	1	1	Diplomatic Action 1
0	0	0	0	0	0	0	1	1	1	1	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	Diplomatic Action 2
1	0	0	0	1	0	0	1	1	1	1	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	Diplomatic Action 3
1	0	0	0	1	0	0	1	1	1	1	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	Diplomatic Action 4
1	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	Diplomatic Action 5
0	1	1	1	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	Diplomatic Action 6
0	1	1	1	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	Diplomatic Action 7
1	1	1	1	1	0	0	1	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	Diplomatic Action 8
1	1	1	1	1	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	Diplomatic Action 9
1	1	1	1	1	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	Diplomatic Action 10
1	1	1	1	1	0	0	1	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	Diplomatic Action 11
1	0	1	1	1	0	0	1	1	0	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Diplomatic Action 12
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	Diplomatic Action 13
0	0	0	0	0	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	1	1	1	0	0	1	0	1	0	0	0	1	0	0	1	0	Informational Action 14
0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	1	1	1	0	0	0	0	1	0	0	0	1	0	0	1	0	Informational Action 15
0	0	0	0	0	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	1	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	Informational Action 16
0	0	0	0	0	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	1	1	1	0	0	1	0	1	0	0	0	1	0	0	1	0	Informational Action 17
0	0	0	0	0	0	0	1	1	0	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	Informational Action 18
0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	1	1	1	0	0	1	0	1	0	0	0	1	0	0	1	0	Informational Action 19
0	0	0	1	0	0	0	1	1	0	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	Informational Action 20
0	0	0	0	0	1	1	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	1	1	1	0	0	1	0	1	0	0	0	1	0	0	1	0	Informational Action 21
0	0	0	0	0	1	1	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	1	1	1	0	0	1	0	1	0	0	0	0	0	0	0	0	Informational Action 22
0	0	0	0	0	1	0	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	1	1	1	0	0	1	0	1	0	0	0	0	0	0	0	0	Informational Action 23
1	0	0	1	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	1	0	0	0	0	1	1	0	0	0	0	1	0	Military Action 24
1	0	0	1	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	1	1	0	0	0	1	1	0	1	0	0	1	1	Military Action 25
1	0	0	1	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0	1	Military Action 26
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	Military Action 27
0	0	0	1	0	0	0	1	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	Military Action 28
0	0	0	1	0	0	0	1	0	1	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	Military Action 29
0	0	0	0	0	0	0	1	0	1	1	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	Military Action 30
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	Military Action 31
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	Military Action 32
0	0	0	0	0	0	0	0	0	1	1	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	Military Action 33
0	0	0	0	0	0	0	0	0	1	1	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	Military Action 34
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	Military Action 35
0	0	0	1	0	0	0	1	0	1	1	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	Military Action 36
0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Economic Action 37
0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Economic Action 38
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	Economic Action 39
0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	1	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	Economic Action 40
0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	1	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	Economic Action 41
0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Economic Action 42
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	1	1	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	Economic Action 43
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1	0	1	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	Economic Action 44
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	Economic Action 45
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	Economic Action 46

Figure 4.7. The Input File for Kohonen's SOM

Table 4.1. Training Variables

Trainings \ Training Variables	Number of Nodes	Map Ratio	Tension	Training Schedule	Training Duration (sc)	Cycle of Training	Minimum Cluster Size	Cluster Threshold	Cluster Size
Action Clusters Figure 4.10	2000	100:75	0.5	Normal, Exact Mode	33	40	8	30.022	6
Effect Clusters Figure 4.12	2000	100:75	0.5	Normal, Exact Mode	28	40	8	25.555	9
Adapted Action Clusters Figure 4.13	2000	100:75	0.5	Normal, Exact Mode	42	40	8	25.555	9
Combined Effect-Action Clusters Figure 4.14	2000	100:75	0.5	Normal, Exact Mode	59	40	8	31.939	9
Combined & Prioritized Effect-Action Clusters Figure 4.15	2000	100:75	0.5	Normal, Exact Mode	61	40	9	29.5	10

While tension is set to 0.5, the number of training cycles is calculated as 40. Viscovery SOMine can estimate the time of the training process and for this example it is estimated as 213 minutes. When the process starts, the training process window appears on the screen which shows the progress in creating the map. The training process window for the example is illustrated in Figure 4.8.

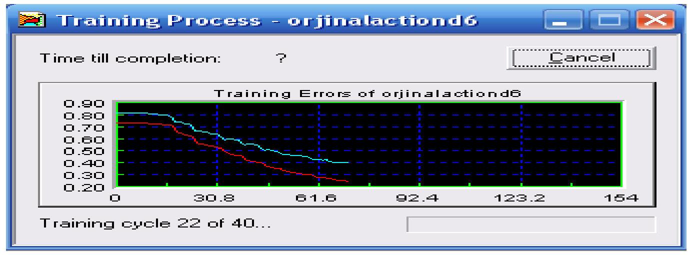

Figure 4.8. Screenshot from Viscovery SOMine of Training Process Window

The time for training process depends on the speed of the hardware. It took 33 seconds for the first attempt. Once the process has finished, the clusters window appears. The unchanged result of the training process is presented in Figure 4.9.

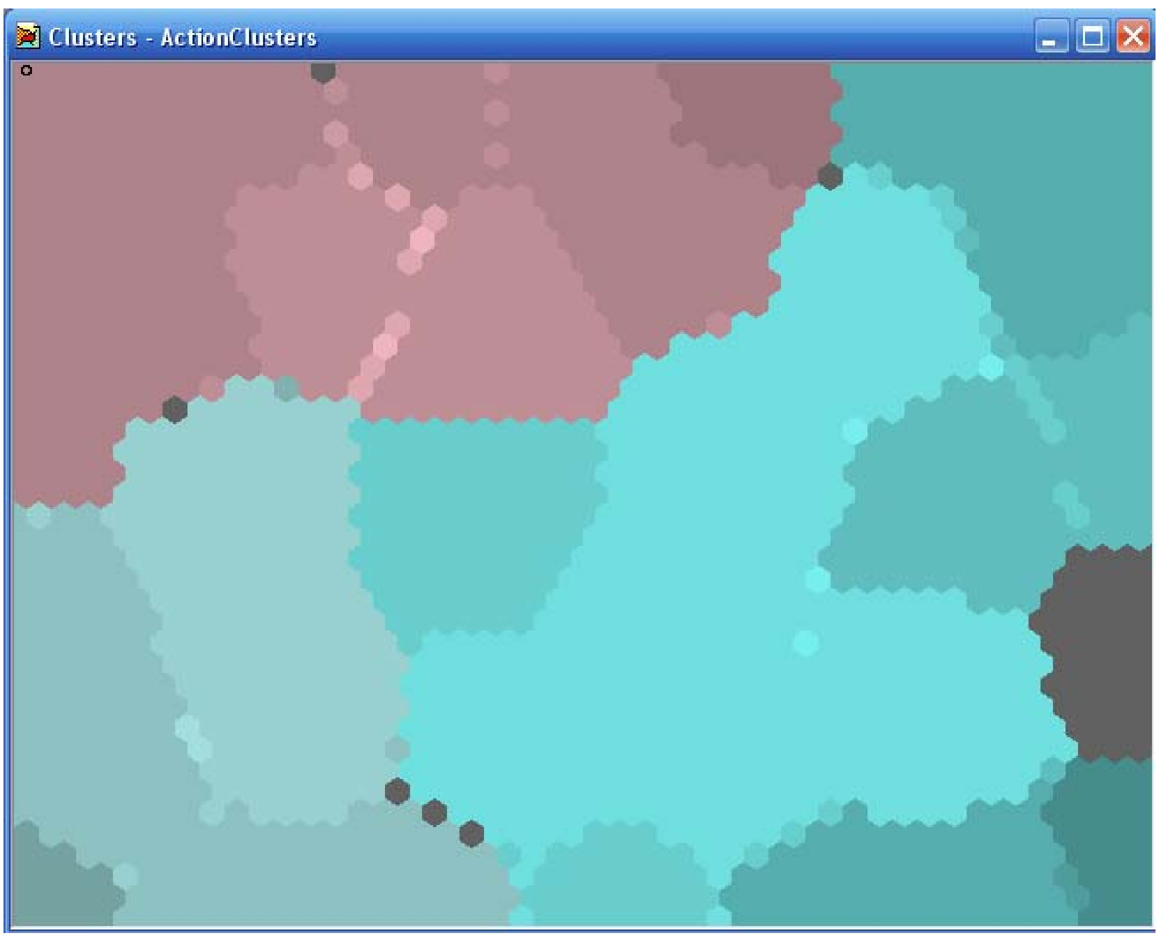

Figure 4.9. Screenshot from Viscovery SOMine of Unchanged Result of the Training Process

As seen in Figure 4.9, the hexagonal units are nodes. Each color represents a cluster. After the map has been created, the map is investigated by adjusting its tuning parameters. The purpose of it is to gain more insight about source data set which is actions. One of the parameters is cluster threshold. Cluster threshold enables to draw a line between two clusters. If the distance between two nodes is greater than the threshold, the line is drawn. This line is called a separator and it can be seen in Figure 4.10. For better granularity of the map, the cluster threshold is determined to be 30.022 by using clustering significance graph. This graph is helpful in finding the cluster threshold and the minimal cluster size depending on the total required number of clusters. It is defined as 6 in this example. The minimum cluster size is specified as 8.

In Figure 4.9, the nodes within a cluster are similar. These similar nodes have a center in their region. The shades are used to represent the distance of a node to the center of the cluster. Although shading provides better understanding of the global properties of the data, in Figure 4.10 the nodes take base color of their clusters. Therefore, the boundaries of each cluster can be illustrated in a clear way.

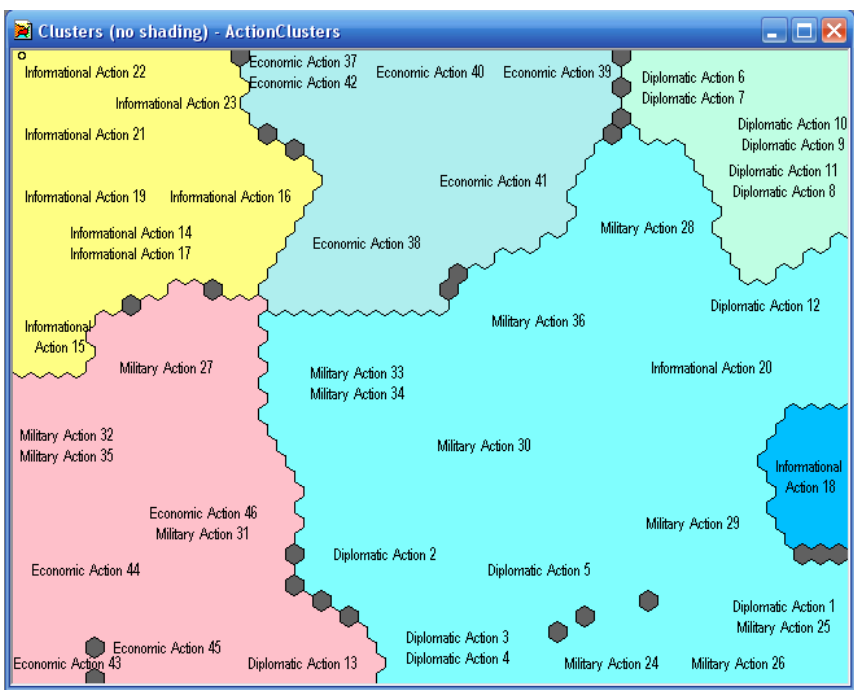

Figure 4.10. Screenshot from Viscovery SOMine of Illustration of Action Clusters

The dark gray nodes are clusters containing fewer nodes and they are unified in the separating areas. Since the data records have been labeled in the input file, the actions in each clusters can been seen in Figure 4.10.

The component maps can also be created in Viscovery SOMine. A component map represents the component value at each node in a certain color. For the illustration purpose, Political Effect 6 and Economic Effect 22 are chosen and stated in Figure 4.11. The scale below the maps describes the relationship between colors and component values.

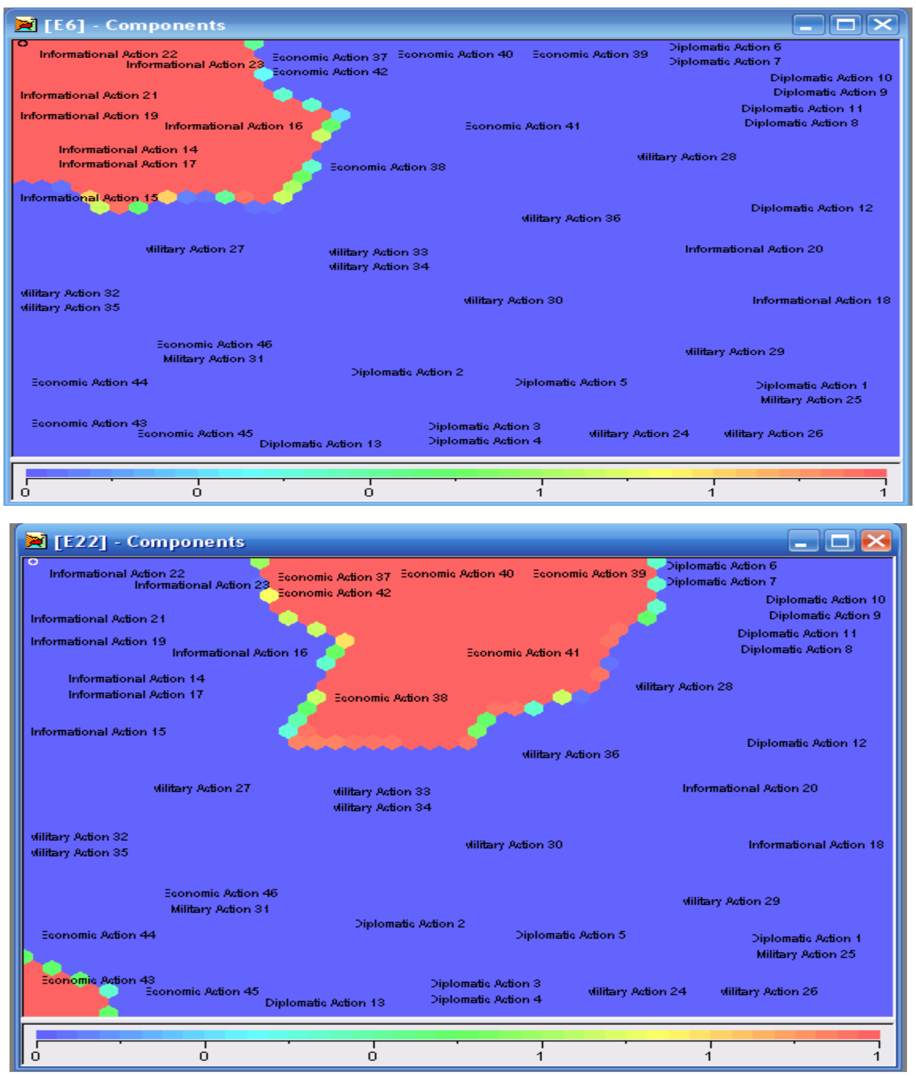

Figure 4.11. Screenshot from Viscovery SOMine of Map of Component Political Effect 6 and Economic Effect 22

Viscovery SOMine also enables the investigation of frequency, curvature and quantization error maps. These maps are illustrated in Figure 4.12 which is stated below.

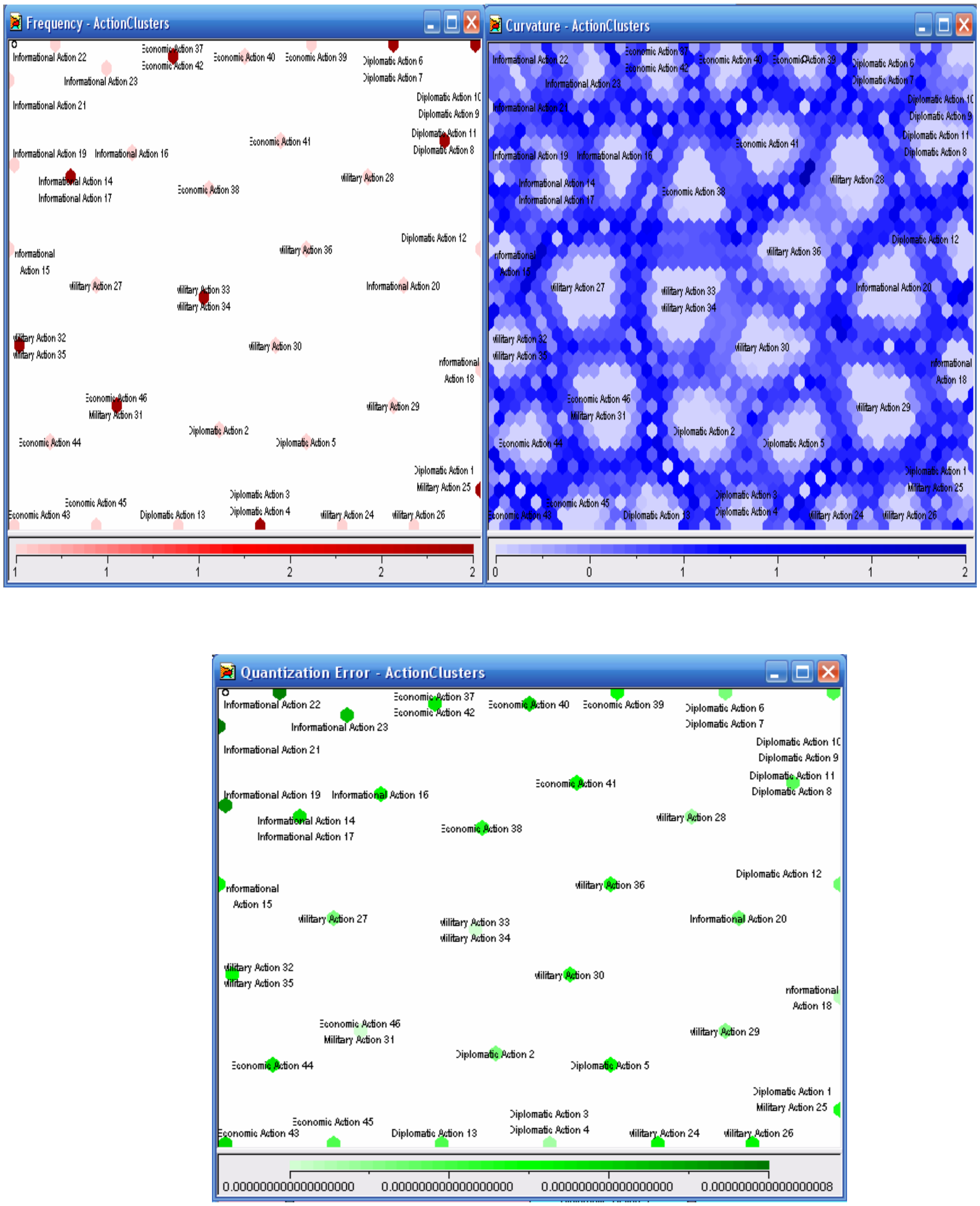

Figure 4.12. Screenshot from Viscovery SOMine of Frequency, Curvature and Quantization Error Maps

Another helpful result from Viscovery SOMine, is that the statistical results of the current clustering can be used to classify the data. The input data is read and each record is matched into some cluster. Statistical values for each component are computed. These evaluations provide quantitative measurement for the data relations.

After classification of the actions, the same process with Kohonen's SOM architecture can be applied to cluster the effects. The map without shading for this training result can be seen in Figure 4.13.

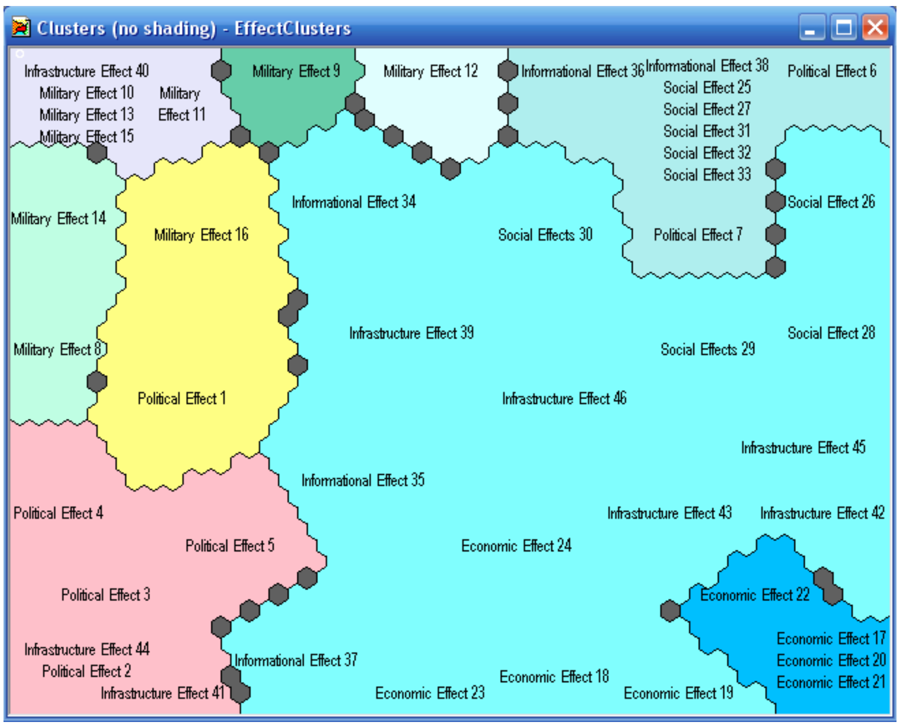

Figure 4.13. Screenshot from Viscovery SOMine of Illustration of Effect Clusters

In order to provide input file for classification of the effects, actions are replaced into columns of new input file. The effects become the data records. The training threshold is chosen as 0.5, the map ration is again 100:75 and number of nodes are 2000. Normal exact mode is used to create the clustering map. After 40 cycles of training, which takes 28 seconds, the map is created. The following changes have been conducted for the example. Eight effects groups are intended to be generated, so the clustering threshold is redefined as 25.555 by using clustering significance graph, while minimum cluster size is 8. The iso-contours are replaced to have a better understanding about cluster boundaries.

The original effect-action interaction matrix in Figure 4.1 is ready to be clustered and reordered. After each clustering for the effects and the actions are completed, members of same action cluster are replaced in the columns of the matrix subsequently. Also the effects within the same clusters are replaced into the rows of the matrix consecutively.

The next step is to create another input file whose columns and rows of the input vectors are adjusted to new action-effect interaction matrix. The reason for doing this is to give the final shape for the clustering maps. Figure 4.14 illustrates new action clustering map which is the same with the effects clustering map in Figure 4.13.

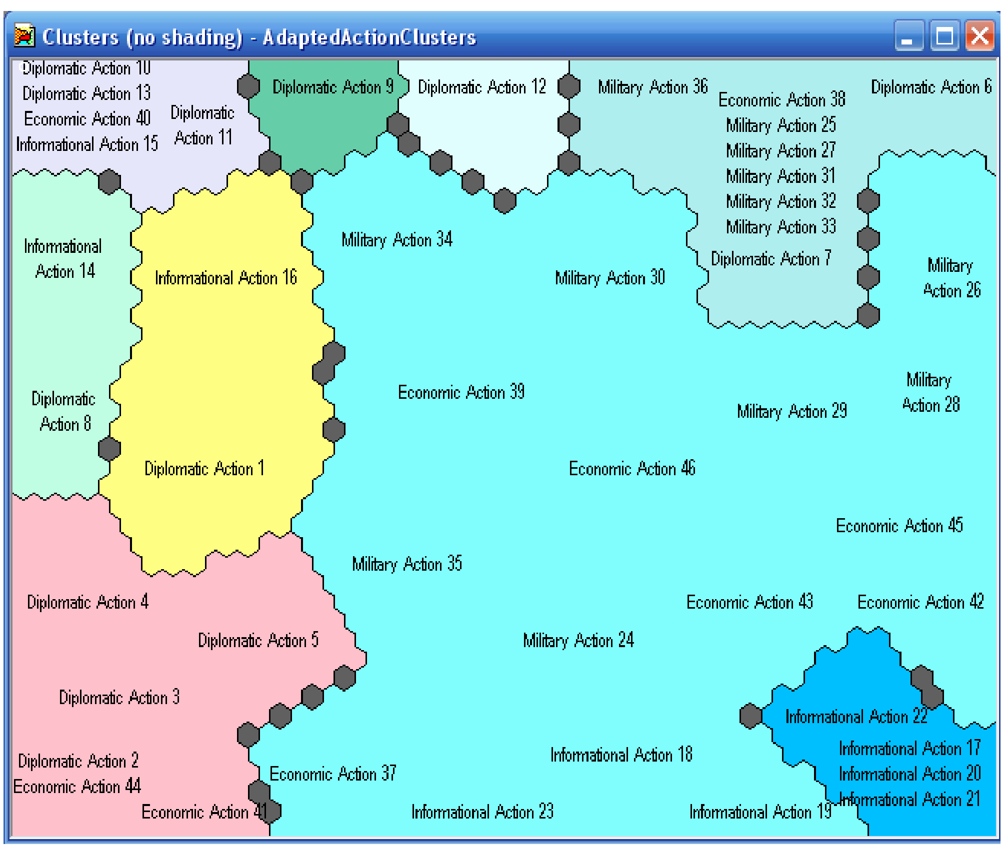

Figure 4.14. Screenshot from Viscovery SOMine of Illustration of Adapted Action Clusters

The map in Figure 4.14 and its similarity with Figure 4.13 lead to creating the effect and the action clustering at the same time with Kohonen algorithm. In order to accomplish this task, a new input file which includes effects as components, actions as data records and also actions as components while effects are data records, is prepared. The training parameters are also chosen, as same with other application of Kohonen algorithm in this thesis. In order to create 9 groups, the clustering threshold is chosen as 31.939, while 8 is determined as minimum cluster size from the clustering significance map. The Kohonen map for both the effect and the action clustering can be seen in Figure 4.15.

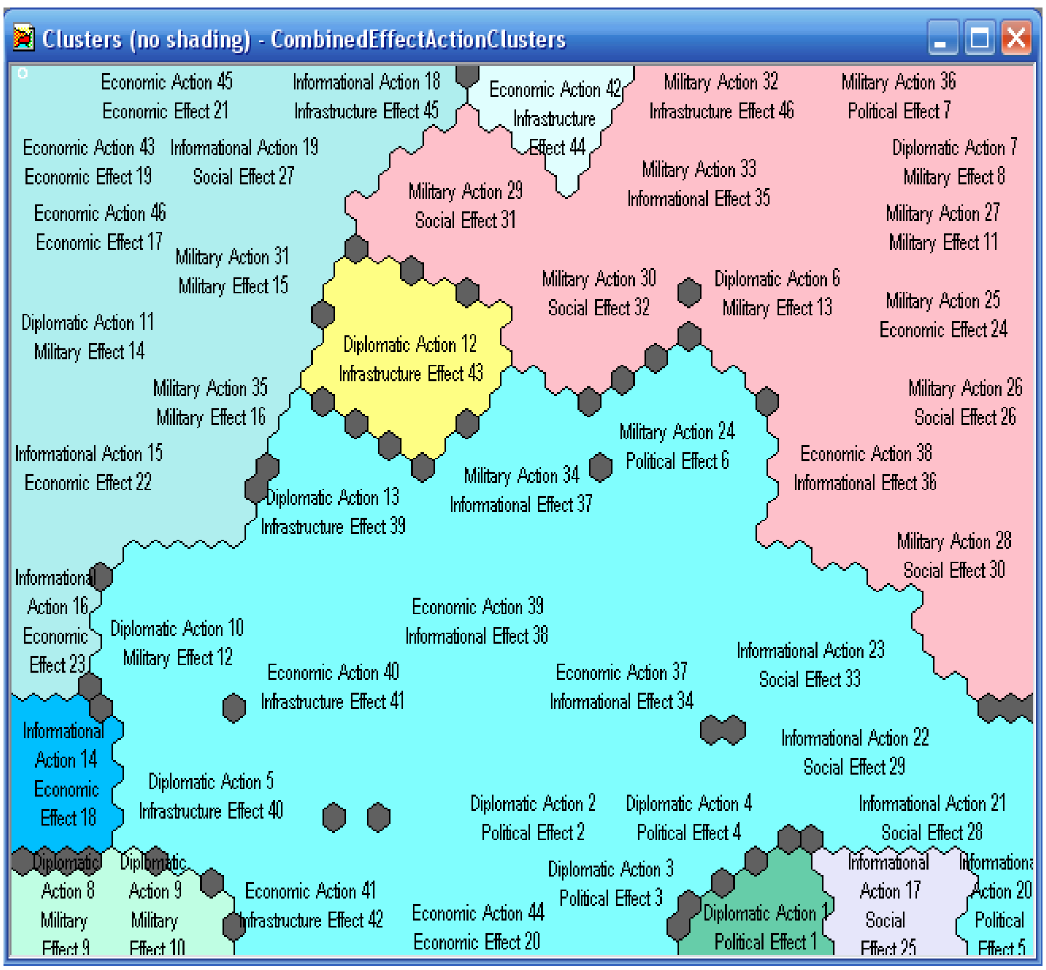

Figure 4.15. Screenshot from Viscovery SOMine of Illustration of Clustering of Combined Effects and Actions

The further capability of Viscovery SOMine is allowing investigation of dependencies between components which are effects and actions in the example. It also enables to set priority factors for each component. After determining priority factors for each desired effect, new map is created for combined effect and action clusters. The action clusters with given prioritized desired effects component is shown in Figure 4.16. The priority which is assigned to each desired effects can be seen in Table 4.2.

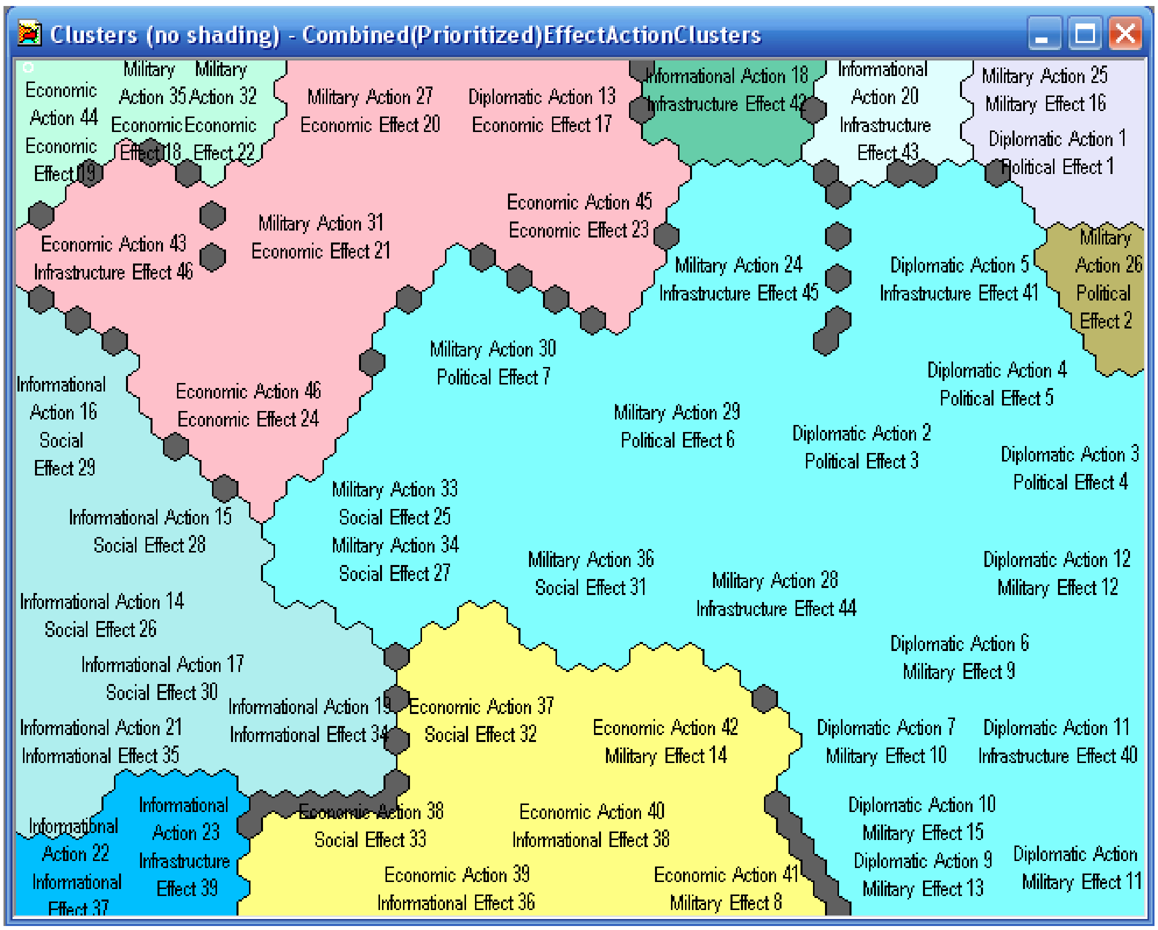

Figure 4.16. Screenshot from Viscovery SOMine of Combined Effect and Action Clusters with Prioritized Desired Effects Components

The training parameters which are number of nodes, map ration, tension, and the mode of training are the same with previous applications. The cluster threshold is 29.5 for 10 groups of actions while minimum cluster size is 8.

Table 4.2. Priorities of Desired Effects

Support of neighboring countries	1	Expanding cross-border commerce	2
Reconciliation with insurgents	2	Resistance to insurgent influence	1
Bring terrorists to justice	1	Increase in good image	2
Inc. in nmbr of surrendered terrorists	3	Social disapproval for terrorism	1
Eliminate international political sprt	2	Protection religion, culture, history	3
Increase in number of new parties	2	Increase in social welfare after war	3
Local governmental control	1	Improve in education and health	3
Dismantling the organization	3	Voting for against adversary	1
Taking out leadership	3	Start to form new political parties	1
Elimination of cap. of armed forces	2	Dec. in trust to enemy commander	2
Destroying terrorist training camps	1	Control of lines of C2	3
Confusing/diverting enemy leader	2	Media control in region	2
Destroying safe havens and sanct.	1	Dec. in spprt. to terrorism via media	2
Identify, locate., elimin. man power	2	Limit in access to world wide web	2
Destroying pro., stor.,main.,dis. cnt.	1	Inc. in enlightenment of populace	1
Weaken internal security	3	Limited or no access to utilities	2
Decrease in production which helps	1	Controlling transportation channels	2
Decrease in demand for exports	1	Control. Heavy and light mnfg	2
Increase in demand for imports	1	Min. physical destroy in public	3
Elimination foreign aids	2	Exceed in utility output	3
Elimination foreign investments	1	Prevention intl transportation	1
Minimization commercial interact.	2	Reducing hazards for civilians	3
Inc. in consumption in dom. Mrkt	1	Increase in reconstruction after war	2

In conclusion, ART1 and Kohonen's SOM have been selected as a modeling architecture in the integration analysis phase of the model development. The results of both show that although ART1 is suitable for the non-linear and adaptive nature of EBO, Kohonen's SOM provides more useful outputs for clustering of actions. The deficiency of ART1 is that the number of its output clusters is not directly determinable. In order to obtain specific number of clusters over the actions, prior knowledge of distribution of the data set is required to suggest a proper vigilance parameter. In modeling with ART1 architecture section, different vigilance parameters are selected. Although, the input matrix is run with 0.2 vigilance parameter which provides good clusters in many cases, the output of it can not be grouped into logical clusters. Furthermore, the combined effect-action input which is grouped satisfactorily with Kohonen's SOM also cannot be clustered with different parameters in ART1 architecture modeling. The results can be seen in Figure 4.4 and Figure 4.5. Another difference between ART1 and Kohonen's SOM is being dependent of order of the input vectors. In ART1, if order of the input vectors changes, the actions are also grouped in a different way. However, the output of Kohonen's SOM does not change with the order of input vectors. Furthermore, the ability of Kohonen's SOM in visually effective representation of the clusters, the results of Kohonen's SOM, make the interpretation of action the cluster analysis easier. Therefore, Kohonen's SOM outputs are selected to be used in the design analysis. After successfully completing clustering of both the effects and the actions with Kohonen maps, modules are described through interpretation of Figure 4.16. In the following section, the solution for synchronization of the right actions challenge, will also be explained.

4.4. DESIGN ANALYSIS

In this phase, the modular design is completed. Kohonen's SOM outputs have been developed to allocate actions and effects to the clusters identified in the previous section. In this phase, modules are created depending on the map in Figure 4.16, which shows both the action and the prioritized desired effect clusters.

It is shown in Figure 4.16 that the application of Kohonen's SOM resulted in ten action modules which provide accomplishment of the entire desired effects. The ten action modules are shown in the action module diagram in Figure 4.17 and as follows:

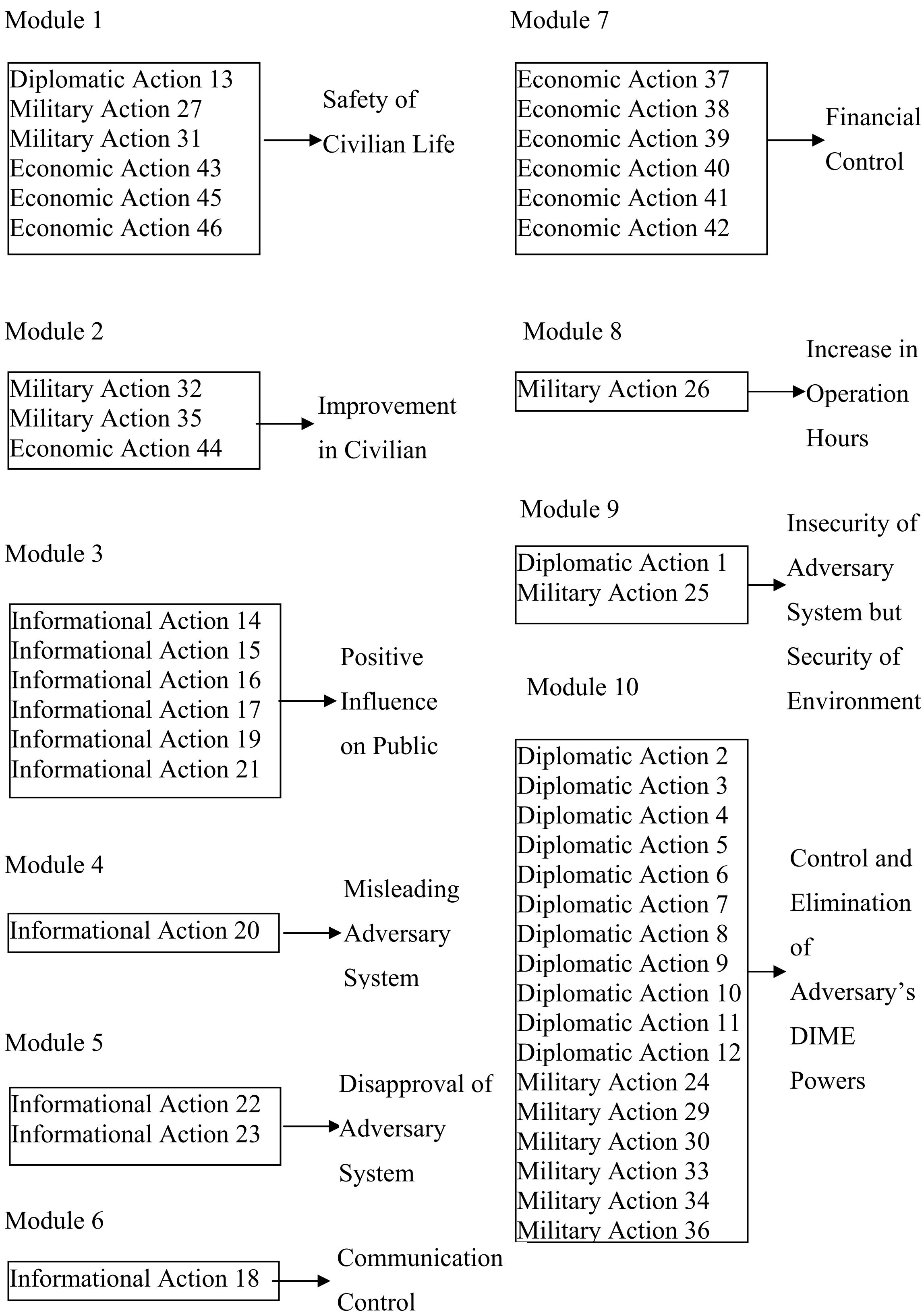

Figure 4.17. Action Modules

1. Safety of civilian life module
2. Improvement in civilian life module
3. Positive influence on public module
4. Misleading adversary system module
5. Disapproval of adversary system module
6. Communication control module
7. Financial control module
8. Increase in operation hours module
9. Insecurity of adversary system but security of environment module
10. Control and elimination of adversary's DIME powers module

Each module in Figure 4.17 has particular actions to create that module's objective. There are several benefits of this modularity approach for EBO. First of all, modules can be used in different combinations depending on which effect or effects wanted to be created. Hence combination gives variation to EBO, these modules also enable to serve for different strategic aims. For different strategic aims, there may be a few common desired objectives to accomplish that strategic aims via standardization of the actions. Modularity approach can provide different strategic aims with using common modules. Moreover, using common modules ensures economy of DIME national powers, for the example. Furthermore, for other systems, action resources may vary and the modularity also applies for them and can provide economy of action resources, which are used in EBO.

The second interpretation from Figure 4.17 is that modularity opens a door for the challenge of synchronization of the right action. It is easily understood from the Figure 4.17 that if the actions within a module are applied consecutively, there is a high possibility to achieve the module's desired objective. In other words, the actions within a module should be done consecutively. There is still a challenge about order of the application of the modules; on the other hand, modularity gives a solution at least the actions within a same module. Modules should be applied in order of which desired effects should be created first. When it is decided, it facilitates the achievement of orchestration of the right actions. For the example above, if the Module 7- financial control module is wanted to be created before the Module 6- communication control, the actions in the module 6 should be done after the actions within module 7.

There is another interpretation that can be gained from Figure 4.17. This result is related to communication channels and interfaces in the SoS environment of EBO. There are actors which are responsible for doing the right actions at the right time in EBO. The actions within a module and the actors of those actions should communicate and work closer to achieve that module's objective. This means that there should be intense interactions within a module while the interactions between modules are continuously loose. For example, two of the actions in the module 9 in Figure 4.17 are mild contribution of NATO (A1) and designating thousand of troops which includes naval, air and land personnel to OE (A25). The actors which are responsible for the actions may political actors who are related to NATO and military actors who can give the order of Military Action 25 should be in strong communication in order to achieve insecurity of the adversary's system objective. Modularity approach provides efficiency in communication by eliminating time consuming communication between actors and concentrating on interactions within a module.

Further analysis of the Kohonen's SOM in integration analysis phase lead to building the diagram in Figure 4.18. Figure 4.18 illustrates the interconnection between modules. The actions within a module may contribute to achieve another module's objective. Since the aim is creating desired effects in order to accomplish strategic aim, the connection between actors should not be dependant on only communications within the modules. In other words, while Figure 4.17 shows the necessary communication within a module, Figure 4.18 focuses the interactions between modules. In Figure 4.18, it is also emphasized that which module may provide necessary input to achieve another module's objective.

Same modeling methodology may be used for different case studies and for different strategic aims; hence, common modules that support various platforms can be used. The modules provide both variation and standardization. Standardization solves one of the main problems of EBO complexity which is synchronization. The modules also show that if the actions within a module applied together, it increases the possibility of reaching desired effects in that module. As a result, modular architecting provides synchronization of the actions and decisions, makes strategic aim consideration easier, and also provides efficiency in the cases where there are multiple strategic aims; therefore, it facilitates the achievement of economy of action resources.

This section highlighted the modeling architecting approach for effects based operations. It defined a methodology to build modules in order to solve stated challenge. The next section concludes the research work and provides some inputs for future work.

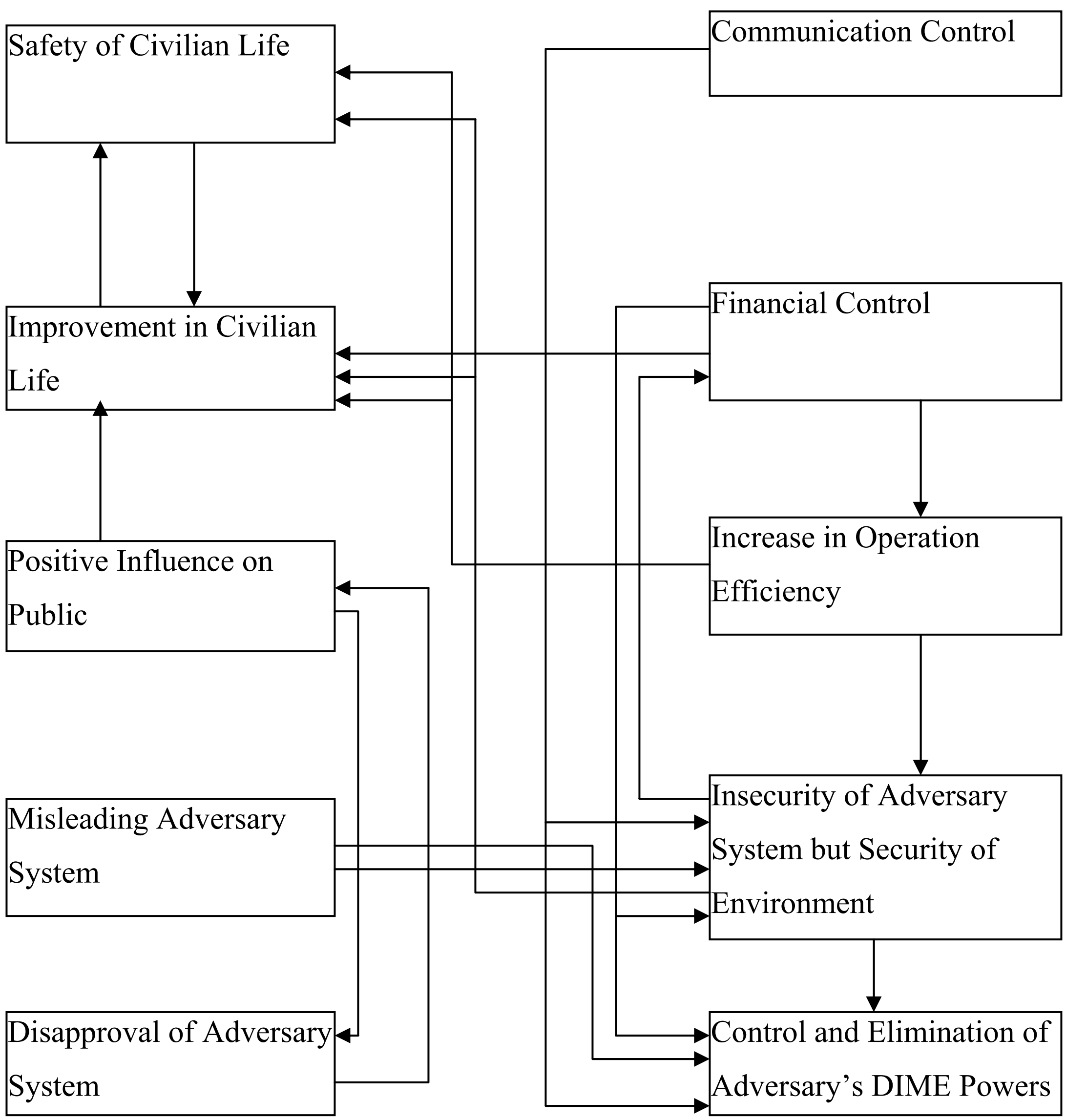

Figure 4.18. Effect Action Interconnect Diagram

5. CONCLUSIONS AND FUTURE WORK

This research proposed a modular architecting approach to design effects based operations. The effects based planning stage where this thesis is helpful is illustrated and explained. The methodology used in this research is similar to the one used in [19], but the further steps of the approach is adapted to design EBO. Its feasibility and advantages have been demonstrated using a hypothetical example which is EBO for defense of a country against a terrorist country. This methodology should be able to generalize and apply to a broad range of EBO design which may be conducted for systems in different fields. A particular clustering method for modular design has been proposed in [19, 20] but we have applied different clustering approach which is suitable for adaptive, non-linear and emergent nature of effects based operations. Instead of hierarchical clustering methods, computational intelligence clustering architectures have been chosen to fulfill the requirements of the EBO environment. The advantages of using neural network architectures instead of clustering effect-action interaction matrix are also put forward. ART1 architecture and Kohonen's SOM have been investigated to specify the modules for the EBO. The outputs of each architecture with different parameters and input vectors have been demonstrated. Since Kohonen's SOM architecture provides more useful outputs to achieve the aim of this thesis along with enabling effective interpretation of its outputs visually, Kohonen's SOM results have been selected to conduct the design analysis of the modeling methodology. The drawbacks and advantages of each modeling architecture for modular design of the EBO have been described. The modules for desired effects and actions have been demonstrated in the design analysis of the methodology. In this thesis, the advantages and benefits of modular design of the EBO have been presented and explained. It is illustrated with diagrams that the most crucial benefit of modular architecting for the EBO is opening a door for the challenge of synchronization of the right actions. The interconnect diagram and the module figure are developed to show communication interfaces within the EBO. The diagram and the figure help in building necessary relationships between nodes and actors in the EBO, and it aids in decreasing unnecessary and resource consuming communications within a system which EBO are held. The advantages of modular architecting in defining role of each actor and understanding complex relationships between nodes are also explained. That modular architecting for the EBO makes strategic aim consideration easier by both variation and standardization of the actions is asserted with the example. Moreover, the further benefit of the approach is enabling the achievement of the economy of national powers for military EBO is concluded and explained. It is also emphasized that benefits and advantages of modular architecting for the EBO can contribute to improve the possibility and effectiveness in reaching desired effects. Therefore this thesis brings a way not only to solve one of three main complexity challenges of the EBO, but also to provide a model which can increase effectiveness and efficiency of the EBO.

This thesis shows its advantages on a hypothetical defense related example scenario. The next step would be to conduct modular architecting approach used in this thesis upon different EBO examples in different fields. Furthermore, in this thesis only two neural network architectures have been investigated and subsequently validated for the aim of the study. In the next step, other computational intelligence architectures applicable to EBO can be conducted and the results of alternatives based on same input vectors can be compared. The further clustering algorithms for modular modeling architectures can be found in [25]. Moreover, as input 46x46 matrix is used in this thesis for the demonstration purpose. In the further researches, larger data sets can be used and they can provide insights for more developed and scalable modeling methodology for modular design of EBO. The necessary time to complete the trainings of very large data sets would be one of the main considerations for future works. Demonstration of the modular architecture with appropriate clustering algorithm is more important for the purpose of overcoming synchronization of the right action challenge. There are undesired effects that may be caused by these right actions. Another further step of this thesis would be to include undesired effects into effect-action interaction matrix for eliminating them. By assigning priority numbers to undesired effects, they can be added to the effect-action interaction matrix and the model can be redesign with modeling architectures. This will help in modeling the entire EBO in a way that it can overcome both eliminating undesired effects and orchestration of the right action challenges. Similarly, if the model is developed with a new effect-action interaction matrix, not only will the modules change, but also the interconnect diagrams will need to be rearranged. As a result of such studies, the modular architecting approach for the EBO become ready to serve more robust solutions for the challenge.

APPENDIX

COMMANDER’S HANDBOOK FOR AN EFFECTS-BASED APPROACH TO JOINT OPERATIONS

“Commander’s Handbook for an Effects-Based Approach to Joint Operations” is presented by the U.S. Joint Warfighting Center. It provides insights about the EBO. The EBO methodology used in this thesis is adapted by their research. In order to gain more information about the EBO methodology, the reference handbook can be found on the website that stated below.

For the document please visit:

http://www.dtic.mil/doctrine/jel/other_pubs/eb_handbook.pdf

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