DEVELOPMENT OF FUZZY SYLLOGISTIC ALGORITHMS AND APPLICATIONS DISTRIBUTED REASONING APPROACHES

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ABSTRACT

DEVELOPMENT OF FUZZY SYLLOGISTIC ALGORITHMS AND APPLICATIONS DISTRIBUTED REASONING APPROACHES

A syllogism, also known as a rule of inference or logical appeals, is a formal logical scheme used to draw a conclusion from a set of premises. It is a form of deductive reasoning that conclusion inferred from the stated premises. The syllogistic system consists of systematically combined premises and conclusions to so called figures and moods. The syllogistic system is a theory for reasoning, developed by Aristotle, who is known as one of the most important contributors of the western thought and logic. Since Aristotle, philosophers and sociologists have successfully modelled human thought and reasoning with syllogistic structures. However, a major lack was that the mathematical properties of the whole syllogistic system could not be fully revealed by now. To be able to calculate any syllogistic property exactly, by using a single algorithm, could indeed facilitate modelling possibly any sort of consistent, inconsistent or approximate human reasoning. In this work generic fuzzifications of sample invalid syllogisms and formal proofs of their validity with set theoretic representations are presented. Furthermore, the study discuss the mapping of sample real-world statements onto those syllogisms and some relevant statistics about the results gained from the algorithm applied onto syllogisms. By using this syllogistic framework, it can be used in various fields that can uses syllogisms as inference mechanisms such as semantic web, object oriented programming and data mining reasoning processes.

ÖZET

BULANIK TASIM ALGORİTMALARIN GELİŞTİRİLMESİ VE DAĞITIK ÇIKARSAMA YAKLAŞIMI OLARAK UYGULANMASI

Çıkarsama kuralları olarak bilinen tasımlar, iki önermeden sonuç çıkarmaya yarayan mantıksal bir kurallar bütünüdür. Tasım sistemi simetrik önerme ve sonuçlardan elde edilen figür ve modlardan oluşmaktadır. Tasım çıkarsamaları ilk olarak batı düşüncesinin önemli isimlerinden Aristo tarafından insan karar verme sürecini formel olarak tanımlamak için geliştirilmiştir. Tasımlar daha sonra sosyal ve matematik alanlarında araştırma yapan bir çok araştırmacı tarafından incelense de matematiksel olarak tasımların tüm arama uzayı tam olarak oluşturulmadan yapılan araştırmaların çoğu eksik kalmıştır. Tasım sistemini oluşturan tüm figür ve modların toplam arama uzayını elde edebileceğimiz bir algoritma ise bu alanda bize daha doğru istatistiksel bilgiler elde etmekte yardımcı olabilir. Bu çalışmada tasım sisteminin yapısı ve elde edilen istatistiki veriler bu amaçla geliştirilen algoritmadan oluşturulmuştur. Bunun yanı sıra bulanık tasım mantığı konusunda da bu verilerden yola çıkarak çeşitli sonuçlar elde edilmiştir ve gerçek yaşamdaki örnek bir uygulamada karar verme mekanizması olarak kullanılıp bu sonuçlar tartışılmıştır. Sonuç olarak ise tasımların istatistiki dökümleri, bulanık değerleri ve çıkarsama mekanizması olarak kullanabilirliği oluşturulan matematiksel uygulamalar elde edilmiştir.

to my beloved mother, Şafak Çakır and father, Mehmet Ahmet Çakır
whose invaluable effort and support has taken me to the present

sonsuz emegi ve destegiyle bugüne gelmemi saglayan
sevgili annem Şafak Çakır ve babam Mehmet Ahmet Çakır 'a

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CHAPTER 1

INTRODUCTION

The first studies on syllogisms were pursued in the field of right thinking by the philosopher Aristotle [1]. His syllogisms provide patterns for argument structures that always yield conclusions, for given premises. Some syllogisms are always valid for given valid premises, in certain environments. Most of the syllogisms however, are always invalid, even for valid premises and whatever environment is given. This suggests that structurally valid syllogisms may yield invalid conclusions in different environments. Given two relationships between the quantified objects P, M and S, a syllogism allows deducing a quantified transitive object relationship between S and P. Depending on alternative placements of the objects within the premises, 4 basic types of syllogistic figures are possible. Aristotle had specified the first three figures. The 4^{th} figure was discovered in the middle age. In the middle of the 19^{th} century, experimental studies about validating invalid syllogisms were pursued. For instance, reduction of a syllogism, by changing an imperfect mood into a perfect one. Conversion of a mood, by transposing the terms, and thus drawing another proposition from it of the same quality [2] [3].

Although shortly thereafter syllogism were superseded by propositional logic [4], they are still matter of research. Philosophical studies have confirmed that syllogistic reasoning does model human reasoning with quantified object relationships [5]. For instance, in a psychological study that used the full set of 256 syllogisms [6] [7] about different subjects (Two settings about choosing from a list of possible conclusions for given two premises [8] [9], two settings about specifying possible conclusions for given premises [10], and one setting about decide whether a given argument was valid or not [11]). It has been found that the results of these experiments were very similar and that differences in design appear to have had little effect on how human evaluate syllogisms [6]. These empirically obtained truth values for the 256 moods are mostly close to their mathematical truth ratios that are calculated with algorithmic approach in this study[12].

Although the truth values of all 256 moods have been analysed empirically, mostly only logically correct syllogisms are used for reasoning or modus ponens and modus tollens, which are generalisations of syllogisms [13]. Uncertain application environments, such as human machine interaction, require adaptation capabilities and approximate reasoning [14] to be able to reason with various sorts of uncertainties. For instance, we know that human may reason purposefully fallacious, aiming at deception or trickery. Doing so, a speaker may intent to encourage a listener to agreeor disagree with the speaker's opinions. For example, an argument may appeal to patriotism or may exploit an intellectual weakness of the listener. We are motivated by the idea for constructing a fuzzy syllogistic system of possibilistic arguments for calculating the truth ratios of illogical arguments and approximately reason with them [15]. In approximately reasoning the main difference is that the possibility values which enables vagueness of a value whereas in probabilty the likelihood of an event.

The aim of this thesis is to develop an algorithm in order to make syllogistic reasoning within a distributed environment and analyze the structural properties of syllogistic search space within the results gained. There are lots of studies in the area of syllogism but with this study the whole search sets were given so that these findings can be used in various fields that are related with Syllogisms such as physcology or mathematics. The study also deal with invalid syllogisms which is generally omited with classical approaches. With the use of fuzzy syllogisms, syllogisms can be analyzed more detaily since it is no more decided as valid and invalid but also some middle possibilistic values which order the syllogisms according to their validities.

CHAPTER 2

RESEARCH APPROACH

Reasoning is one of the core issues of artificial intelligence. It is still a matter of research since there are no intelligent agents that completely behaves as human inferences. Inference mechanisms needed to be developed in various fields to aid human inferences or to give decisions. The ability of machines to give accurate decisions is the main motivation of artificial intelligent so this study. In other words, intelligent inference mechanism according to Turing suggested "the "imitation game," now known as the Turing test: a remote human interrogator, within a fixed time frame, must distinguish between a computer and a human subject based on their replies to various questions posed by the interrogator. By means of a series of such tests, a computer's success at "thinking" can be measured by its probability of being misidentified as the human subject" [16].

Inferences are classified as deductive or inductive. In this study one of the deductive inference mechanisms syllogisms was used that is called syllogisms. The thesis started by the problem of formal representing of syllogisms to use them in an algorithm.

There are several ways to formal representation of syllogisms in literature like Euler Diagrams, Venn Diagrams and Triangular. In this study the Venn Diagram representation of syllogisms used as formal respresentation which will be disscussed detaily in next sections. After representing the syllogisms mathematically, the algorithmic study made to calculate syllogistic validity in figures.

The main contribution of the thesis is the results gained from the algorithm which displays the whole search space of syllogistic structure. And after that the fuzzy approach applied on to syllogisms to find possibilistic values of invalid moods in figures.

Last stage of this study was to develop a sample distributed syllogistic reasoning application and a real world example based on object oriented programming. Methodological approach can be found in Figure 2.1.

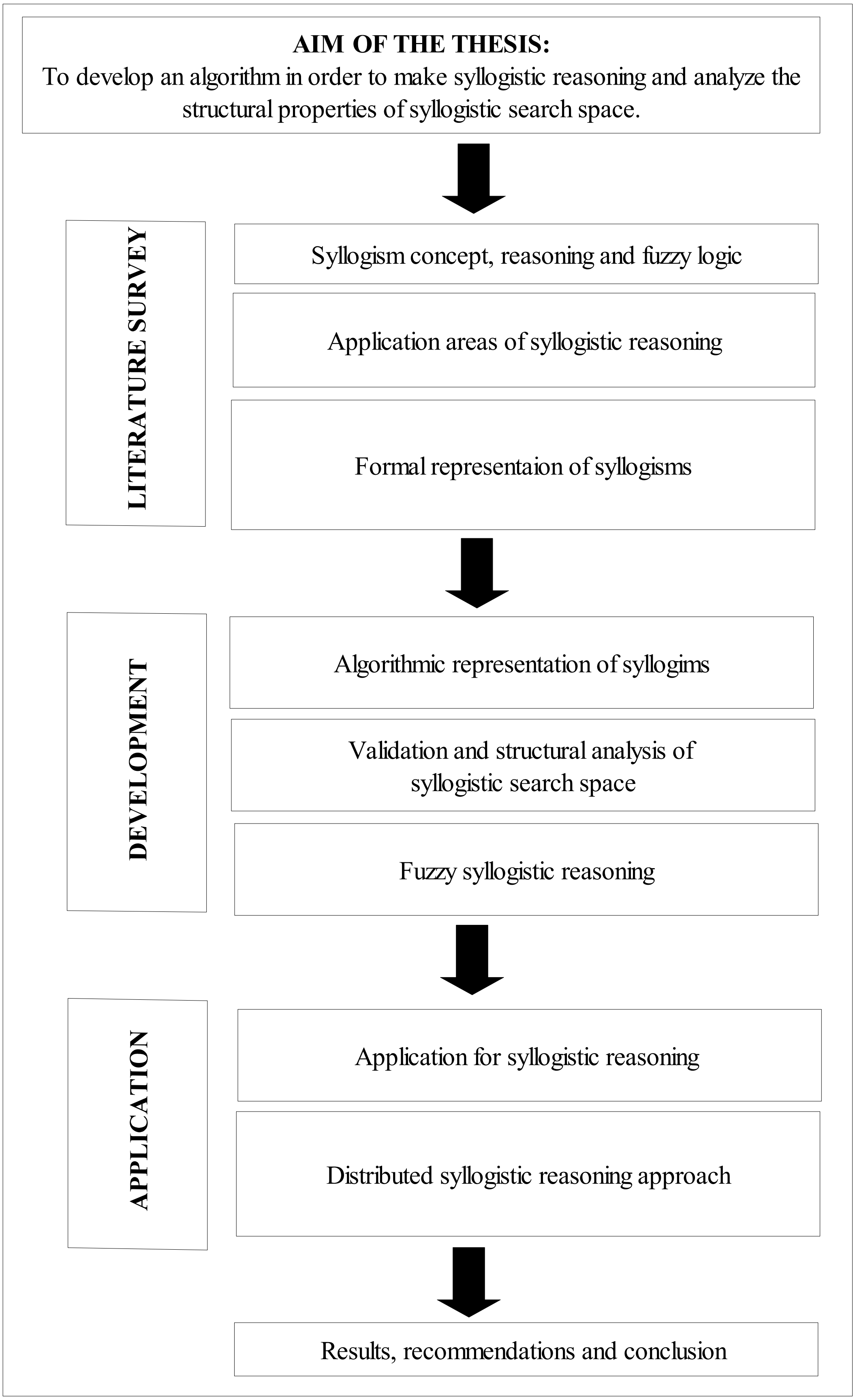


Figure 2.1. Methodological Approach

During development stage of the master thesis four papers accepted and published in conferences about artificial intelligence by the great contribution of supervisor of the thesis Assist. Prof. Dr. Bora İ. KUMOVA.

The papers published are;

- Bora İ. Kumova and Hüseyin Çakır, "**Algorithmic Decision of Syllogisms**" .IEA-AIE 2010, The Twenty Third International Conference on Industrial, Engineering & Other Applications of Applied Intelligent Systems, Córdoba, Spain. [This research was partially funded by the grant project 2009-İYTE-BAP-11.]

  The first paper published about syllogisms during this study in "The Twenty Third International Conference on Industrial Engineering and Other Applications of Applied Intelligent Systems" at special session on Engineering Knowledge and Semantic Systems. The conference ranked 46 among 701 conferencesin the Computer Science Conference ranking and final copies of accepted papers for inclusion to the conference proceedings will be published in a bound volume by Springer-Verlag in their 'Lecture Notes in Artificial Intelligence' series.

  Briefly, in this paper the mathematical structure of syllogisms dicussed with a general view to fuzzy syllogisms. Also some statistics given that are about validating syllogisms.

- Hüseyin Çakır and Bora İ. Kumova, "Algoritmik Tasim Çıkarsamaları". ASYU 2010, Akilli Sistemlerde Yenilikler Ve Uygulamalari Sempozyumu (Symposium on Innovations in Intelligent Systems and Applications); 21-24 June 2010 Kayseri & Cappadocia, TURKEY.

  This paper is mainly about algorithmic representation of syllgistic system and some relevant statistics about results gained from algorithm. This conference was set of conferences parallel to International Symposium on Innovations in Intelligent SysTems and Applications.

- Bora İ. Kumova and Hüseyin Çakır, "**The Fuzzy Syllogistic System**". MICAI 2010, Mexician International Conference on Artificial Intelligence; November 8-13 Pachua, Mexico.

  This paper is about the fuzzy logic and its appliance on syllogisms. .The acceptance rate has been around 26% and conference is organized by the Mexican Society for Artificial Intelligence.

  And also there exits ongoing works about this study;

- Hüseyin Çakır and Bora İ. Kumova, "**Structural Analysis of Syllogistic System**". [Accepted but not published yet on International Joint Conference in Artificial Intelligence 2010, Barcelona, Spain]

This thesis consists of six main chapters in addition to appendices. Organization of the chapters are as follows;

Chapter 1, the brief introduction given that includes main motivation of the study. The former chapter that is current chapter, contains research methodology and explains the steps that built up the thesis.

In chapter 3 , the background view about syllogisms concept discussed mainly from the view of historical background and its relations with computer science.

Chapter 4 focuses on structural analysis of syllogims which composed of two main sections Syllogistic system and fuzzy syllogistic system. In syllogistic system section the formal representaion of syllogisms and algorithm developed for syllogistic reasoning explained. In last part the fuzzy syllogistic system defined with possibilistic values of syllogisms rather than classifying only as valid or invalid.

In chapter 5, the applications to represent the validty of algorithm is discussed. There is also an application that uses syllogistic algorithm created in this thesis to make inferences on object oriented programming relations.

And in last chapter, the contribution of this study on reasoning and recommendation for further studies discussed.

CHAPTER 3

BACKGROUND

The origin of the logic studies known goes among ancient Babylonian, Greeks, Indian, Chiese and Islamic cultures. However the first systematic study on logic seems to be done by Aristotle according to the surveys. Aristotle's theory of logic suggests that in some cases the answer (conclusion) is predictable based on earlier answers which called premises.

Aristotle's logical works are:

- **Categories**, which discusses Aristotle's 10 basic kinds of entities: substance, quantity, quality, relation, place, time, position, state, action, and passion. Although the categories is always included in the Organon, it has little to do with logic in the modern sense.
- **De interpretatione**, which includes a statement of Aristotle's semantics, along with a study of the structure of certain basic kinds of propositions and their interrelations.
- **Prior Analytics**, containing the theory of syllogistic.
- **Posterior Analytics**, presenting Aristotle's theory of "scientific demonstration" in his special sense. This is Aristotle's account of the philosophy of science or scientific methodology.
- **Topics**, an early work, which contains a study of nondemonstrative reasoning. It is a miscellany of how to conduct a good argument.
- **Sophistic Refutations**, a discussion of various kinds of fallacies. It was originally intended as a ninth book of the Topics.

There exists lots of researches on syllogisms in philosophy, mathematics and logic. The drawback of syllogisms mainly about dealing with invalid moods since they were generally ignored, so the new approaches evolve from his studies in the field of reasoining.

From computational view, Aristotle's syllogisms not analyzed much when compared to widespread use of predicate logic.

History of logic can be summarised as follows;

- Plato's Logic: Made contributions about philosophical formal logic. Work on defining true and false.
- Aristotle’s Logic: Introduced systematical analysis to logic.
- Kant: Made modifications to syllogism.
- Frege: Introduced method for representing categorical statements for representing human thought.

Aristotle's categories with his syllogisms for reasoning about them and Porphyry's tree for illustrating them dominated the field of logic for over two thousand years. Not until the nineteenth century did the new systems of symbolic logic become sufficiently expressive to replace the syllogism. In 1879, Gottlob Frege developed his Begriffsschrift (concept writing), which was a complete system of first-order logic (first-order predicate calculus) [21].

CHAPTER 4

STRUCTURAL ANALYSIS OF SYLLOGISMS

In this chapter, categorical syllogisms are discussed briefly. Thereafter an arithmetic representation for syllogistic cases is presented, followed by an approach for algorithmically deciding syllogisms and an application for recognising fallacies and reasoning with them. At the end of this section there is a part that explains the statistics about syllogisms and development of the fuzzy syllogistic system.

4.1. Categorical Syllogisms

A categorical syllogism can be defined as a logical argument that is composed of two logical propositions for deducing a logical conclusion, where the propositions and the conclusion each consist of a quantified relationship between two objects. A syllogistic proposition or synonymously categorical proposition specifies aquantified relationship between two objects. We denote such relationships with the operator ψ. Four different types are distinguished $\psi \in \{A, E, I, O\}$ (Table 4.1.1):

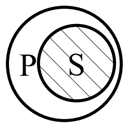
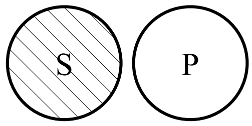
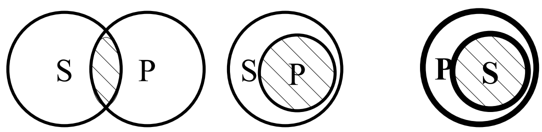
Table 4.1. Syllogistic Relationships

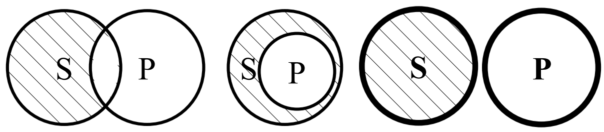
A is universal affirmative:	All S are P
E is universal negative:	All S are not P
I is particular affirmative:	Some S are P
O is particular negative:	Some S are not P

One can observe that the proposition I has three cases (a), (b), (c) and O has (a), (b), (c). The cases I (c) and O (c) are controversial in the literature. Some do notconsider them as valid [17] and some do [18]. Since case I (c) is equivalent to proposition A, A becomes a special case of I. Similarly, since case O (c) is equivalent to proposition E, E becomes a special case of O.

At this point we need to note however that exactly these cases complement the homomorphic mapping between syllogistic cases and the set theoretic relationships of three sets (Table 4.2.):

Table 4.2. Syllogistic Propositions Consist of Quantified Object Relationships

<table>
<tr><th>Operator ψ</th><th>Proposition Φ</th><th>Set-Theoretic Representation of Logical Cases</th></tr>
<tr><td>A</td><td>All S are P</td><td>
</td></tr>
<tr><td>E</td><td>All S are not P</td><td>
</td></tr>
<tr><td>I</td><td>Some S are P</td><td>

(a) (b) (c)</td></tr>
<tr><td>O</td><td>Some S are not P</td><td>

(a) (b) (c)</td></tr>
</table>

Any two of operators made up propositions and they can be listed as in Table 4.3.:

Table 4.3. Types of Propositions

Name	**Universality**	**Positivity**	**Symmetry**
A	Universal	positive	asymmetric
E	Universal	negative	symmetric
I	Particular	positive	symmetric
O	Particular	negative	asymmetric

A proposition can be called symmetrical if they are convertable, in other words they are equal if the terms are interchanged. After validating syllogisms three different types of categories received which are valid, invalid or weak moods. A valid mood called as weak syllogism if their conclusions are less extensive than the premises warrant. For example, in *Figure 1* AAI and EAO are weak valid since they are included in AAA and EAE.

4.2. Syllogistic Figures

A syllogism consists of the three propositions major premise, minor premise and conclusion. The first proposition consist of a quantified relationship between the objects M and P, the second proposition of S and M, the conclusion of S and P (Table 4.4.). Since the proposition operator may have 4 values, 64 ψ syllogistic moods arepossible for every *figure* and 256 moods for all 4 *figures* in total. For instance, AAA1 constitutes the mood MAP, SAM, SAP in *figure 1*. The mnemonic name of this moodis Barbara, which comes from syllogistic studies in medieval schools. Mnemonicnames were given to each of the in total 24 valid moods, out of the 256, for easier memorising them [17].

Table 4.4. Syllogistic Figures

Figure Name	I	II	III	IV
Major Premise Minor Premise —————— Conclusion	$M\psi P$ $S\psi M$ —— $S\psi P$	$P\psi M$ $S\psi M$ —— $S\psi P$	$M\psi P$ $M\psi S$ —— $S\psi P$	$P\psi M$ $M\psi S$ —— $S\psi P$

According to Aristotle's syllogistic inference structure the validity of syllogisms is done by patterns for argument structures that always yield conclusions, for given premises [10]. The 4 syllogistic *figures* combined with the 4 syllogistic propositions, draw 256 syllogistic moods in total. A particular mood has a fixed number of cases, which varies however from one mood to another, from 0 to 21 false and 0 to 21 true cases. The 256 moods have 2624 structurally true/false cases in total, of which 41 are distinct (Appendix B).

The rules that Aristotle discovered are:

- Inference cannot be made from two particular premises.
- Inference cannot be made from two negative premises.
- Conclusion must be positive if one premise is positive.
- Conclusion must be negative if one premise is negative.
- Middle term must be distributed at least once.
- Predicate distributed in conclusion must be also distributed in major premise.
- Subject distributed in conclusion must be also distributed in minor premise.

Aristotle had specified the first three *figures*. The 4th *figure* was discovered in the middle age. Valid moods in four *figures* according to these rules are:

Figure 1:

AAA, AAI, EAE, EAO, AII, EIO

Figure 2:

AEE, AEO, AOO, EAE, EAO, EIO

Figure 3:

AAI, EAO, AII, IAI, OAO, EIO

Figure 4:

AAI, AAO, AEE, AEO, EAO, EIO, IAI

As it mentioned above these valid syllogisms have mnemonic names to memorize some of them are:

- *Figure 1*: Barbara [AAA], Celarent [EAE], Darii [AII], Ferio [EIO]
- *Figure 2*: Cesare [EAE], Camestres [AEE], Festino [EIO], Baroco [AOO]
- *Figure 3*: Darapti [AAI], Disamis [IAI], Datisi [AII], Felapton [EAO], Bocardo [OAO], Ferison [EIO]
- *Figure 4*: Bramantip [AAI], Camenes [AEE], Dimaris [IAI], Fesapo [EAO], Fresison [EIO].

4.3. Syllogistic Fallacies

Invalid syllogisms are also one of the most important issue of syllogisms. Resulting from incorrect reasoning in argumentation. 7 syllogistic fallacies are known in the literature:

1. Affirmative conclusion from a negative premise:

    Logical fallacy: syllogism has a positive conclusion, but one or two negative premises.

2. Existential fallacy:

    Logical fallacy: two universal premises has a particular conclusion.

3. Fallacy of exclusive premises:

    Formal fallacy: syllogism has two negative premises.

4. Fallacy of the undistributed middle:

    Middle term must be distributed in at least one premiss.

5. Illicit major:

    Logical fallacy: major term is undistributed in the major premise but distributed in the conclusion.

6. Illicit minor:

    Logical fallacy: major term is undistributed in the minor premise but distributed in the conclusion.

7. Fallacy of necessity:

    Degree of unwarranted necessity is placed in the conclusion.

These fallacies can be occur exactly with the 7 rules for eliminating invalid moods, which were discovered already by Aristotle. Our objective is to use the whole set of 256 syllogistic moods as one system of possibilistic arguments for recognizing fallacies and reasoning with them.

There exits lots of work about reducing fallacies in the literature [2] [19]; Johnson-Laird [10] and Frege [4]. Their approach are different from Aristotelian logic. Johnson-Laird use conclusion type free in order (Instead of only S – P, it allows P – S in conclusion part) and allow weak syllogisms in his approach to increase the number of valid syllogisms. And his valid syllogisms are listed as:

Figure 1:

AAA, AAI, EAE, EAO, AII, EIO + ***AAE, IEO***

Figure 2:

AEE, AEO, AOO, EAE, EAO, EIO + ***OAO, IEO***

Figure 3:

AAI, EAO, AII, IAI, OAO, EIO + ***AEO, IEO, AOO***

Figure 4:

AAI, AAO, AEE, AEO, EAO, EIO, IAI + ***IEO, AAA***

Frege different from others allows weak syllogisms in his approach but not conclusion type free in order. And his valid syllogisms are listed as:

Figure 1:

AAA, AAI(invalid), EAE, EAO, AII, EIO + ***IEO***

Figure 2:

AEE, AEO, AOO, EAE, EAO, EIO + ***OAO, IEO***

Figure 3:

AAI(invalid), EAO(invalid), AII, IAI, OAO, EIO + ***IEO, AOO***

Figure 4:

AAI, AAO, AEE, AEO, EAO(invalid), EIO, IAI **+ *IEO, AAA***

So by their approaches later than Aristotle, they can get more valid moods from the syllogisms like Woodworth and Sells did in their researches. They construct two rules which are: A negative premise increases the chance of a negative conclusion and a particular premise is more likely to result in a particular conclusion.

Our approach is different from these ones, we try to make invalid moods valid by using a new conversion rule between A, I, E, O in the conclusion part of the moods.

Rule 1, "convert E into O since the information in O also contains the information in E". (Table 4.2.)

Rule 2 , "convert A into I since the information in A also contains the information in I". (Table 4.2.)

In fact, by using this method we can make moods more fuzzy in meaning and getting more valid syllogisms. Valid syllogisms from Aristotle and with conclusion premise change by using *Rule 1* and *Rule 2*:

Figure 1:

AAA, AAI, EAE, EAO, AII, EIO + ***EIE, AIA***

Figure 2:

AEE, AEO, AOO, EAE, EAO, EIO + ***AOE, EIE***

Figure 3:

AAI, EAO, AII, IAI, OAO, EIO + ***EAE, OAE, EIE, AAA, AIA, IAA***

Figure 4:

AAI, AAO, AEE, AEO, EAO, EIO, IAI + ***AAA, AAE, EAE, EIE, IAA***

When we used the two rules given above we get an increase in the number of valid states and a decrease in invalid states as the example graphic for *figure 3* below. Increase in valid states gray line represents initial which means before and black after conversion:

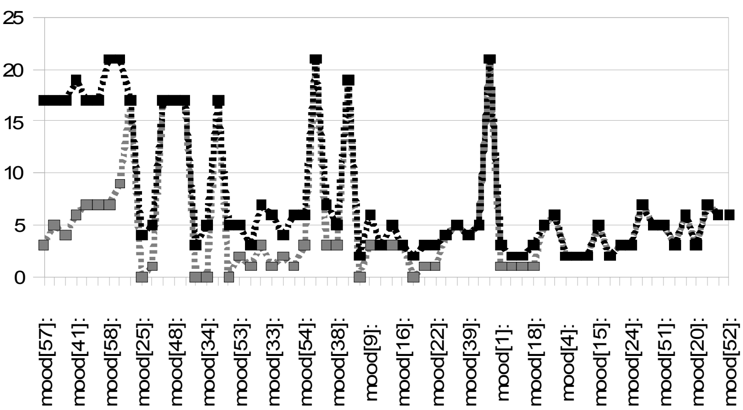


Figure 4.1. Decrease in Invalid States

When we used the two rules given above we get an increase in the number of valid states and a decrease in invalid states as the example graphic below:

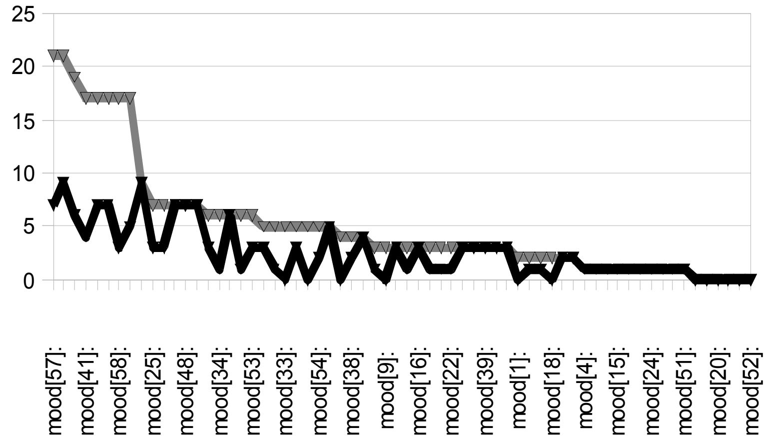


Figure 4.2. Increase in Valid States

More detailed graphs about increasing valid states of moods can be found in the Appendix B part of the thesis and also in fuzzy syllogisms part the fuzzy values for invalid moods.

4.4. Mathematical Representation and Algorithm

In this section, approach of the study for algorithmically deciding any given syllogistic mood is presented. Algorithmically analysing all 2624 truth cases of the 256 moods enables us to calculate all mathematical truth values of all moods, sort the moods according their truth values and define a fuzzy syllogistic system of possibilistic arguments.

For three symmetrically intersecting sets there are in total 7 possible sub-sets in a Venn diagram (Figure 4.3.). If symmetric set relationships are relaxed and the three sets are named, for instance with the syllogistic terms P, M and S, then 41 set relationships are possible. These 41 relationships are distinct, but re-occur in the 256 moods as basic syllogistic cases. The 7 sub-sets in case of symmetric relationships and the 41 distinct set relationships in case of relaxed symmetry are fundamental for the design of an algorithmic decision of syllogistic moods.

The 41 cases are exactly all possible combinations of the three syllogistic terms P, M, S. Any of these 41 set theoretic cases occurs at least once true and at least once false within the 2624 syllogistic cases. These results were found with an algorithmic solution for deciding all syllogistic cases for any given mood.

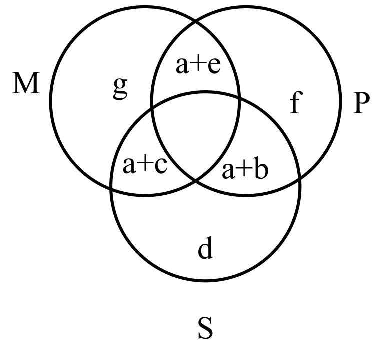


Figure 4.3. Mapping Sub-sets of the Symmetrically Intersecting Sets P, M and S onto Arithmetic Relations

We have pointed out earlier that, including the cases I (c) and O (c) of the syllogistic propositions I and O, is required by the algorithm to calculate correctly. Without these cases, the algorithm presented below, cannot decide some cases of some moods or cannot find valid moods at all (Table 4.2.).

For instance, as valid moods in *figure I*, only AAA, AAI, AII and EAE can be found by the algorithm, although EAO and EIO are also true. If the algorithm considers the cases I (c) and O (c), then all 6 valid moods of *figure I* are found. The reason for that is that the syllogistic propositions are basically a symmetric sub-set of the in total 12 distinct set relationships between two named sets. Therefore the cases I (c) and O (c) are required to complement the symmetric relationships between the syllogistic propositions. We shall denote a propositional statement with Φi, in order to distinguish between possibly equal propositional operators of the three statements of a particular mood, where $i \in \{1, 2, 3\}$. A further consequence of including the above mentioned cases I (c) and O (c) in our algorithmic approach is that the number of valid moods increases with AAO-4 from 24 to 25. Since no mnemonic name was given to this mood in the literature by now, name it here with "*anasoy*".

Based on theses 7 sub-sets, we define 9 distinct relationships between the three sets P, M and S. These 9 relationships are mapped homomorphically onto the 9 arithmetic relations, denoted with $\delta 1$, ..., $\delta 9$. For instance $P \cap M$ is mapped onto $\delta 1$=a+e and P-M is mapped onto $\delta 4$=f+b. These relationships can be verified visually in the Venn diagram.

One can observe that the symmetric relationship between the three sets (Figure 4.4.1) is preserved in the homomorphically mapped arithmetic relations (Table 4.5.).

Table 4.5. Homomorphism Between the 9 Basic Syllogistic Cases and 9 Arithmetic Relations

Sub-Set Number	$\delta 1$	$\delta 2$	$\delta 3$	$\delta 4$	$\delta 5$	$\delta 6$	$\delta 7$	$\delta 8$	$\delta 9$
Arithmetic Relation	a+e	a+c	a+b	f+b	f+e	g+c	g+e	d+b	d+c
Syllogistic Case	$P \cap M$	$M \cap S$	$S \cap P$	P-M	P-S	M-P	M-S	S-M	S-P

The above homomorphism represents the essential data structure of the algorithm for deciding syllogistic moods. The pseudo code of the algorithm for determining the true and false cases of a given moods is based on selecting the possible set relationships for that mood, out of all 41 possible set relationships.

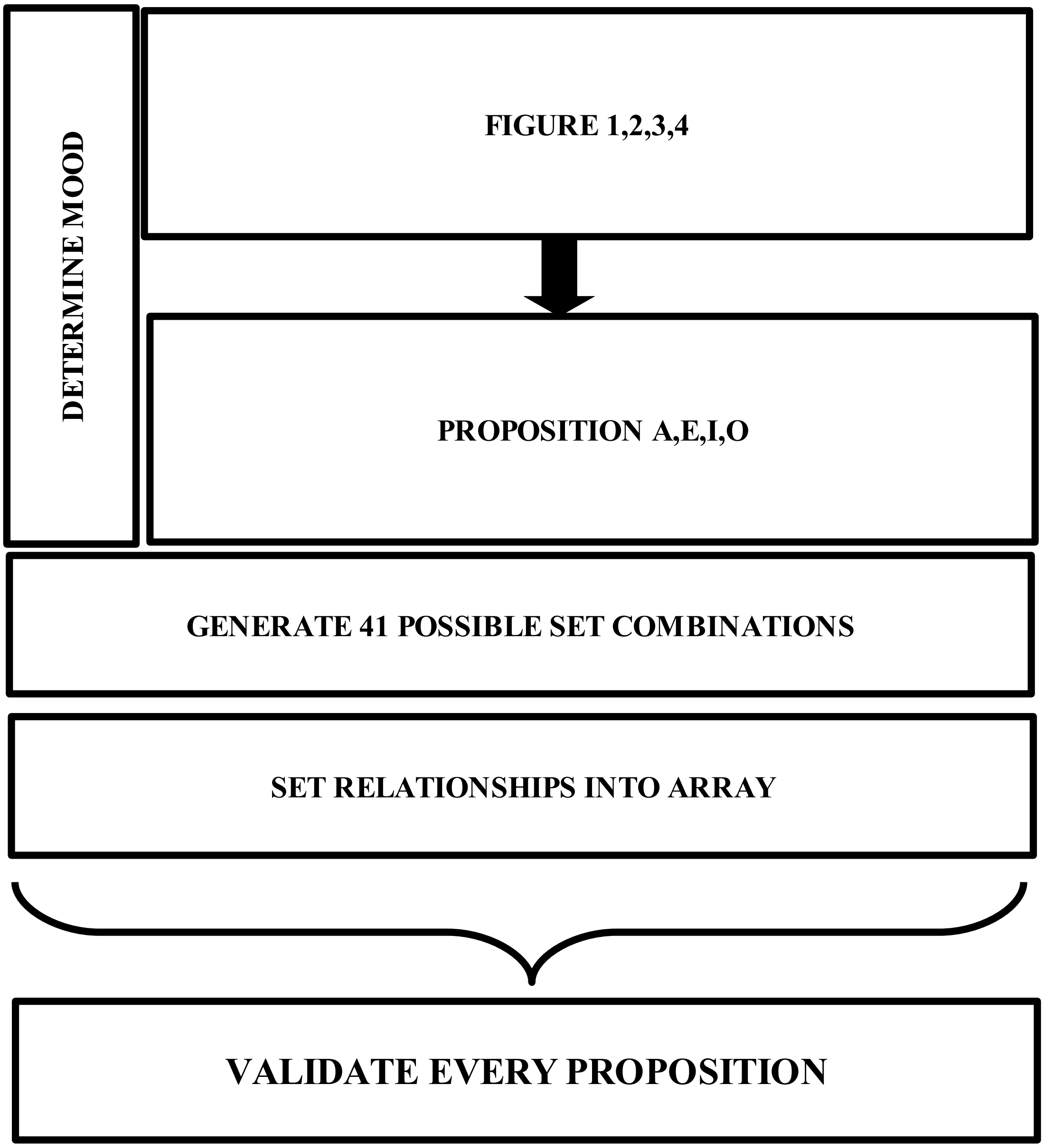


Figure 4.4. Pseudo Code of Algorithm

```
DETERMINE mood
               READ figure number {1,2,3,4}
               READ with 3 proposition ids {A,E,I,O}

GENERATE 41 possible set combinations with 9 relationships
into an array
               SetCombi[41,9]={{1,1,1,1,1,1,1,1,1}, ...,
{0,1,0,0,1,1,1,1,1}}

VALIDATE every proposition with either validateAllAre,
               validateAllAreNot, validateSomeAreNot or
validateSomeAre

DISPLAY valid and invalid cases of the mood

VALIDATE mood
                validateAllAre(x,y) //all M are P
                if(x=='M' && y=='P')

CHECK the sets suitable for this mood in setCombi
                if δ1=1 and δ2=0 then add this situation as
valid
                if(setCombi[i][0]==1 && setCombi[i][1]==0)
//similar for validateAllAreNot(),
validateSomeAre(),validateSomeAreNot()
```

The algorithm first generates set of all possible set situations and than validates the syllogistic moods.

In algorithmic representation of syllogisms the arrays used to represent sets and relationships. For instance a set situation 1 which is given in the figure below:

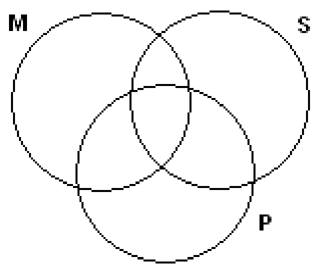


Figure 4.5. Sample Venn Diagram Representation

The array of the algorithm that respresents the set in Figure 4.5. is:

Table 4.6. Arithmetic representation of Figure 4.5.

Sub-Set Number	$\delta 1$	$\delta 2$	$\delta 3$	$\delta 4$	$\delta 5$	$\delta 6$	$\delta 7$	$\delta 8$	$\delta 9$
Arithmetic Relation	a+e	a+c	a+b	f+b	f+e	g+c	g+e	d+b	d+c
Syllogistic Case	$P \cap M$	$M \cap S$	$S \cap P$	P-M	P-S	M-P	M-S	S-M	S-P
Figure 4.4.3	1	1	1	1	1	1	1	1	1

All $\delta 1$ to $\delta 9$ is one since the set situation in Figure 4.5. contains all relationships such as $P \cap M$, $M \cap S$, $S \cap P$, P-M, P-S, M-P, M-S, S-M and S-P.

To be more precise, the Figure 4.4.4 has arithmetic relation Table 4.4.3:

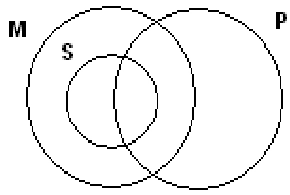


Figure 4.6. Sample Venn Diagram Representation

Table 4.7. Arithmetic representation of Figure 4.6.

Sub-Set Number	$\delta 1$	$\delta 2$	$\delta 3$	$\delta 4$	$\delta 5$	$\delta 6$	$\delta 7$	$\delta 8$	$\delta 9$
Arithmetic Relation	a+e	a+c	a+b	f+b	f+e	g+c	g+e	d+b	d+c
Syllogistic Case	$P \cap M$	$M \cap S$	$S \cap P$	P-M	P-S	M-P	M-S	S-M	S-P
Figure 4.4.4	1	1	0	1	1	1	1	0	1

After filling the arrays as the structure above, the algorithm validates each mood in a loop that checks every proposition by the functions validateAllAre(), validateAllAreNot(), validateSomeAreNot() or validateSomeAre().

4.5. Statistics about the Syllogistic System

The statistics in this section were generated to understand the structure of the syllogisms and make some logical inferences from them. These statistics gained from the algorithm mentioned in previous section. Some more improvements needed in our algorithm but for this study it successfully help to generate some beneficial results about structure of syllogisms. The introduced algorithm enables revealing various interesting statistics about the structural properties of the syllogistic system.

In this work Venn Diagram representation of syllogisms is used. According to the model there exists 11 distinct relations among Venn Diagrams that provide determining syllogisms. Every mood has 0 to 21 true and 0 to 21 false cases, which is a real subset of the 41 distinct cases. Interesting is also that for any given *figure* the total number of all true cases is equal to all false cases, ie 328 true and 328 false cases. Thus we get for all 4 syllogistic *figures* the total number of 4 x 2 x 328 = 2624 cases.

These relations provide all possibilities among three sets which makes 41 syllogistic subset situations. The algorithm that we used to determine valid/invalid syllogisms based on selecting the possible set conditions from all possible sets according to the *figure* selected. After that algorithm simply returns all valid and invalid sets for all 64 moods in the *figure* selected. This algorithm provides some beneficial statistics about syllogisms which enables understanding the structural behaviours of Syllogisms. When the algorithm applied for the 41 set conditions given in Appendix B we have seen that some set conditions appear more than others as valid and there exits also an symmetric distribution with respect to their appearances.

4.6. Fuzzy Syllogistic System

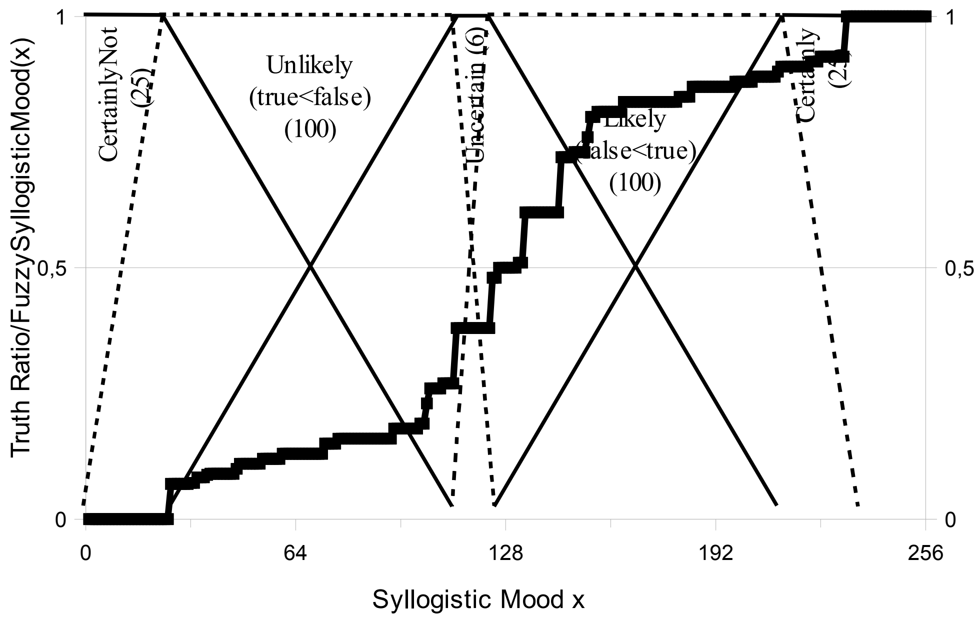


Figure 4.7. Fuzzy Syllogisms

The results discussed above used same approach as in Aristotle's, so it decides on syllogisms as valid or invalid which gives strict decisions on syllogisms either name them as true or false as in conventional computer systems. But since our objective is to utilize the full set of all 256 moods as a fuzzy syllogistic system of possibilistic arguments [14] [20], we have first calculated the truth values for every mood in form of a truth ration between its true and false cases, so that the truth ratio becomes a real number, normalized within [0, 1].

Figure 1 and *Figure 3*: Subset valid conditions other than 21 and 30 occurs 8 times, but condition 21 appears 21 times and 30 appears 4 times. [*Figure 1* Invalid: 13:6, 19:6, 21:12, 22:9, 29:6, 30:3, 39:6, 40:7 others 8] [*Figure 3* Invalid: 12:7, 13:6, 20:12, 21:12, 22:9, 29:6, 30:3, 36:7, 39:6 others 8]

Figure 2 and *4*: As it can be seen from above there are two conditions that have different occurrences, whereas in figure 2 and 4 all valid conditions appear 8 times. [*Figure 2* Invalid: 13:7, 19:7, 20:12, 22:11, 24:7, 29:6, 30:7, 37:7, 39:6, 40:7, 41:7 others 8] [*Figure 4* Invalid: 12:7, 13:7, 20:12, 22:11, 24:7, 28:7, 29:6, 30:7, 37:7, 39:6, 41:7 others 8].

256 syllogistic moods sorted in ascending order of their truth ratio true/false, if number of truth cases of a mood is true<false and false/true ratio, if false<true. Some examples of mapping fuzzy membership functions to syllogisms can be summarized as follows:

Quantification:
All, Most, Many/About Half, Few, No
Usuality:
Always, Usually, Frequently,Seldom, Never
Likelihood:
Certainly, Likely, Uncertain,Unlikely, Certainly not

256 syllogistic moods sorted in ascending order of their truth ratio true/false, if number of truth cases of a mood is true<false and false/true ratio, if false<true. Definition of the possibility distribution FuzzySyllogisticMood(x) with the linguistic variables CertainlyNot, Unlikely, Uncertain, Likely, Certainly and their cardinalities 25, 100, 6, 100, 25, respectively.

In this paper we used the fuzzy membership as:

Certainly:

All of the mood's subsets are true

Likely:

Most of the mood's subsets are true

Uncertain:

Many/About half of the mood's subsets are true

Unlikely:

Few of the mood's subsets are true

Certainly Not:

None of the mood's subsets are true

Based on the structural properties of the syllogistic system, we elaborate now a fuzzified syllogistic system. One can see (Figure 4.7.) that every syllogistic case is now associated with an exact truth ration. We utilise the symmetric distribution of the truth ratios, for defining the membership function FuzzySyllogisticMood(x) with a possibility distribution that is similarly symmetric (Figure 4.7.). The linguistic variables were adopted from a meta membership function for a possibilistic distribution of the concept likelihood [20]. The complete list with the names of all 256 moods is appended. Since our objective is to utilise the full set of all 256 moods as a fuzzy syllogistic system of possibilistic arguments, we have first calculated the truth values for every mood in form of a truth ration between its true and false cases, so that the truth ratio becomes a real number, normalised within [0, 1]. Thereafter we have sorted all moods in ascending order of their truth ratio.

Note the symmetric distribution of the moods according their truth values. 25 moods have a ratio of 0 (false) and 25 have ratio 1 (true). 100 moods have a ratio between 0 and 0.5 and 100 have between 0.5 and 1. 6 moods have a ratio of exactly 0.5 . Every mood has 0 to 21 true and 0 to 21 false cases, which is a real subset of the41 distinct cases.

The total number of true or false cases varies from one mood to another, from 1 to 24 cases. For instance, mood AAA1 has only 1 true and 0 false cases, whereas mood OIA1 has 3 true and 21 false cases. Hence the truth ratio of AAA1 is 1 and that of OIA is 3/21=1/7.

After fuzzifying Syllogisms to check whether the values assigned to moods are valid we make a comparison these values with empirical studies done about Syllogisms before. For instance, a comparison between the studies of Chater and Oaksford and our given in the figure below:

Table 4.8. Comparison with Empirical Studies

	A	I	E	O
AA-1	90	5	0	0
AA-2	58	8	1	1
AA-3	57	29	0	0
AA-4	75	16	1	1
AI-1	0	92	3	3
AI-2	0	57	3	11
AI-3	1	89	1	3
AI-4	0	71	0	1

Table 4.9. Fuzzyfied values for the Table 4.8

	A	I	E	O
AA-1	Certainly True	Certainly True	Certainly Not	Certainly Not
AA-2	Unlikely	Likely	Unlikely	Likely
AA-3	Unlikely	Certainly True	Certainly Not	Likely
AA-4	Certainly Not	Certainly True	Certainly Not	Certainly True
AI-1	Uncertain	Certainly True	Certainly Not	Uncertain
AI-2	Unlikely	Likely	Unlikely	Likely
AI-3	Uncertain	Certainly True	Certainly Not	Uncertain
AI-4	Unlikely	Likely	Unlikely	Likely

As it can be understood from this example moods above our fuzzy values for Syllogistic moods also are logical with respect to empirical studies done on this field. [There are also other studies which our results can be compared like L.Dickstein 's.]

Fuzzy Syllogistic can be used to make inference about traffic lights with respect to the traffic statistics collected before. So the statistics collected for the X road for long time and concluded the statistics below:

07:00 – 08:30	Very Crowded
08:30 – 09:00	Crowded
09:00 – 10:30	Free
10:30 – 12:00	Crowded
12:00 – 18:00	Free
18:00 – 21:00	Very Crowded

The statistics above can provide an intelligent traffic light system can be made for road X by using fuzzy syllogistic algorithm.

Ex: Logical Situations

[#1]

Road X very crowded between 07:00 and 08:30.

The time is 07:30 traffic lights at X should be shortly stay in red.

[#2]

Road X free between 12:00 and 18:00. The time is 17:30.

Traffic lights at X should work as normal.

So when we applied this scenario to syllogisms we have the following results:

M: Crowded

P: Time is between 07:00 and 08:30

S: Traffic lights at X stay short in red

Valid Cases with respect to Syllogisms *Figure 1*:

AAA-1: [Valid]

ALL road crowded between 07:00 and 08:30

ALL lamps at X should stay short in red when crowded

ALL lamps at X should stay short in red between 07:00 and 08:30

AAI -1: [Valid]

ALL road crowded between 07:00 and 08:30

ALL lamps at X should stay short in red when crowded

SOME lamps at X should stay short in red between 07:00 and 08:30

AII -1: [Valid]

ALL road crowded between 07:00 and 08:30

SOME lamps at X should stay short in red when crowded

SOME lamps at X should stay short in red between 07:00 and 08:30

EAE -1: [Valid]

ALL road NOT crowded between 07:00 and 08:30

ALL lamps at X should stay short in red when crowded

ALL lamps at X should NOT stay short in red between 07:00 and 08:30

EAO -1: [Valid]

ALL road NOT crowded between 07:00 and 08:30

ALL lamps at X should stay short in red when crowded

SOME lamps at X should NOT stay short in red between 07:00 and 08:30

EEO -1: [Likely]

ALL road NOT crowded between 07:00 and 08:30

ALL lamps at X should NOT stay short in red when crowded

SOME lamps at X should NOT stay short in red between 07:00 and 08:30

EIE -1: [Unlikely]

ALL road NOT crowded between 07:00 and 08:30

SOME lamps at X should stay short in red when crowded

ALL lamps at X should NOT stay short in red between 07:00 and 08:30

Our algorithmic approach for calculating the truth ratios of syllogisms has enabled to reveal all structural properties of the complete syllogistic system. On top of the syllogistic system study proposed a fuzzy syllogistic system that consists of possibilistic arguments. This approach can prove a practical approach for reasoning with inductively learned knowledge, where P, M, S object relationships can be learned inductively and the "most true" mood can be calculated automatically for those relationships.

CHAPTER 5

APPLICATIONS FOR SYLLOGISTIC REASONING

During this study various applications developed to check validty of algorithm. These applications includes graphical interfaces that draws Venn diagrams of the moods. In this section these applications and distrubuted reasoning approach to syllogistic reasoning is discussed. Moreover a sample application for distributed reasoning is given. And in the last section, there is a part that focus on the fields that can use the distributed syllogistic reasoning. In previous sections, the algorithmic approach was introduced as pseudo codes and its results. To be more precise, in this section the applications that reveals the correctness of the study analysed.

5.1. Mathematical Applications

As the research began about syllogisms after arithmetic representation, first an application that lists all the valid/invalid sets developed as in Figure 5.1..

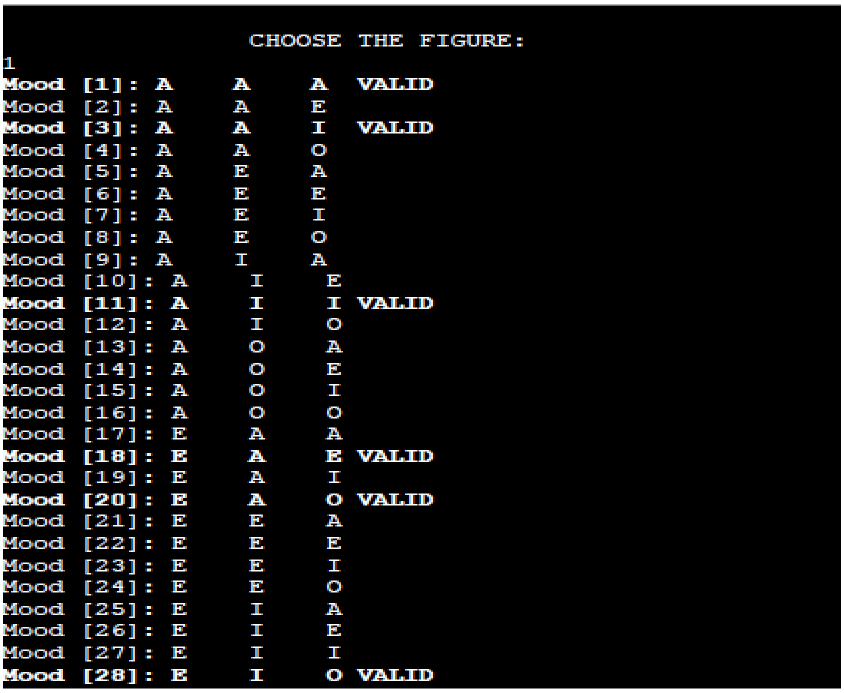


Figure 5.1. Application Lists Validity

After listing all validies of moods, an application developed to show the set situations of the moods as in figure 5.2..

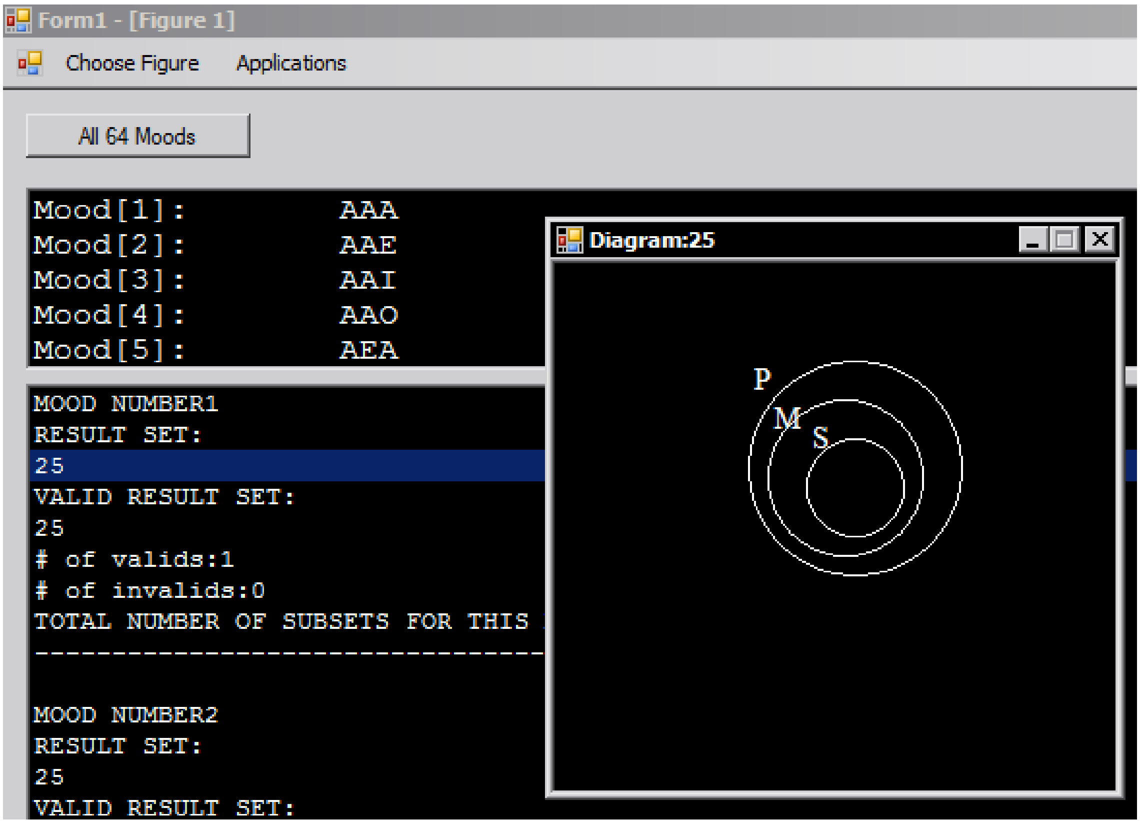


Figure 5.2. Application Draws Set Situations

Application that lists all moods done by using C++, but application that draw set situations are developed by using Mono, which is a open source .Net platform that works on multiple platforms [25].

And during other stages of moving from theorotical approach to application environment, a new neccesities emerged. For instance, to use algorithm in application area sets used to represent moods needed to take elements inside. In figure 5.3. an application example about this issue is given.

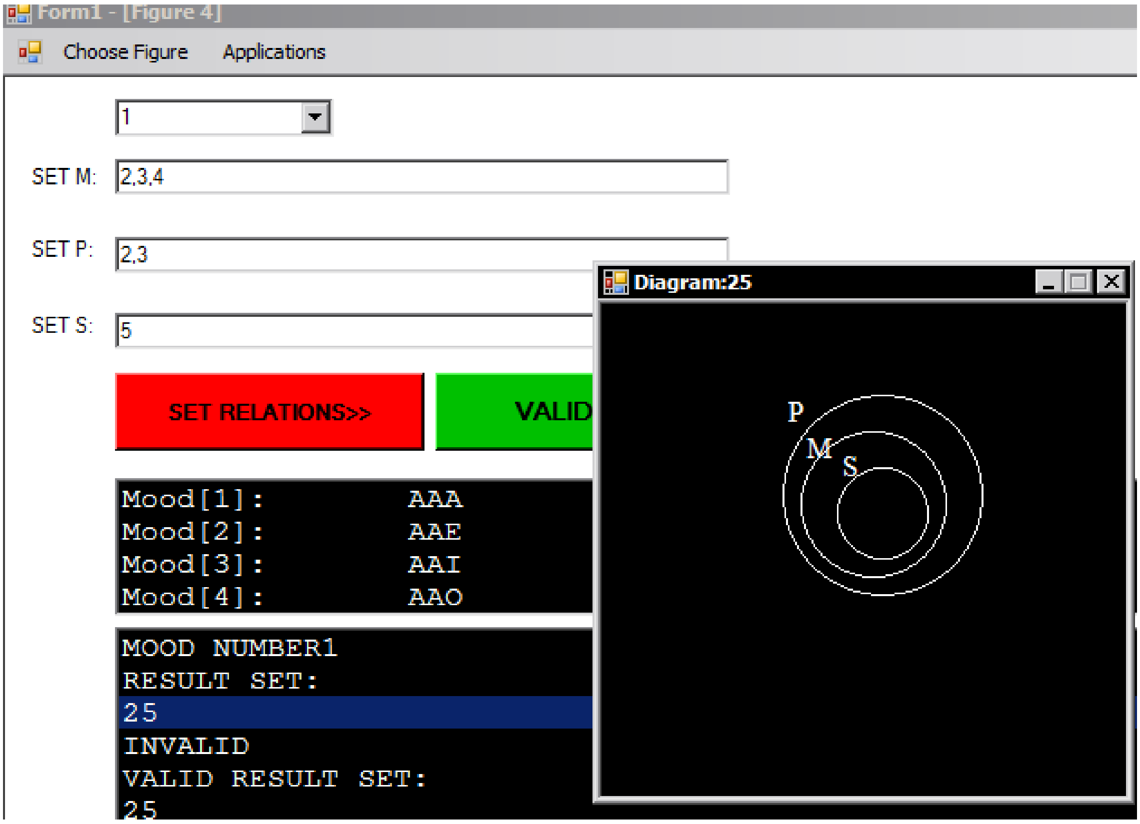


Figure 5.3. Application Take Set Elements

5.2. Distributed Reasoning Application

Up to this stage, all applications dicussed above developed to show the accuracy of the algorithm. But as mentioned before, one of the main contributions of this study is to adopt distributed reasoning to the syllogistic reasoning.

To make syllogistic reasoning distributed, a sample scenario created. In this scenario, the system composed of two intelligent agents that use syllogistic reasoning on mathematical sets (Figure 5.4.).

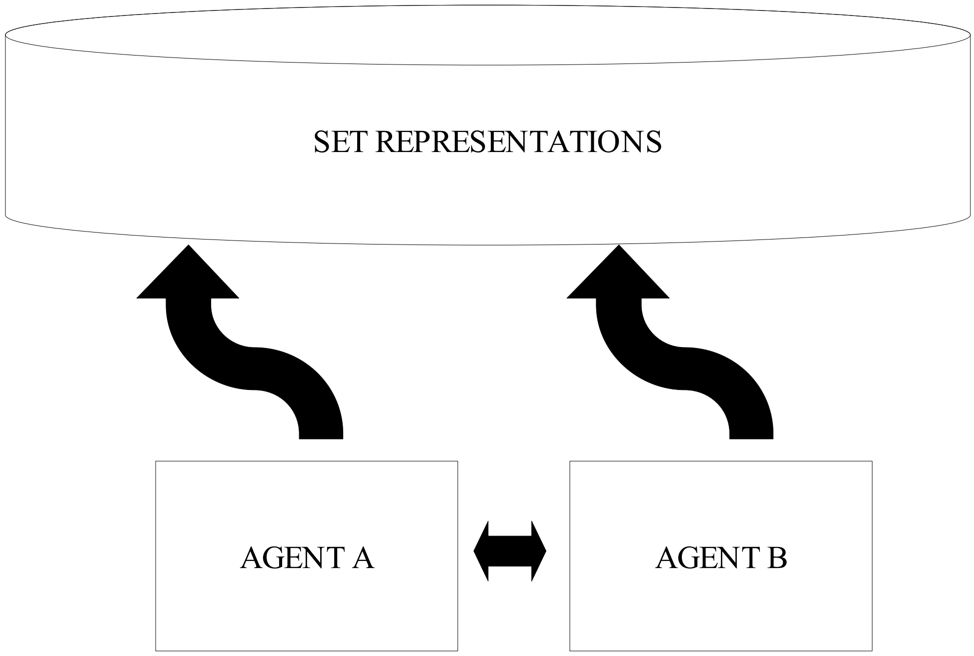


Figure 5.4. Scenario for Distributed Syllogistic Reasoning

Scenario:

AGENT A make reasoning about sets:

M:{2,3,4}

P:{2,3}

S:{2}

AGENT B gets directly the inference that AGENT A made if same set situations given, but make reasoning and send results to AGENT A if different situations entered. To accomplish the scenario above two AGENTS developed as seperate programs that communicate with each other by the use of TCP. They simply communicate over TCP to inform each other about inferences they made.

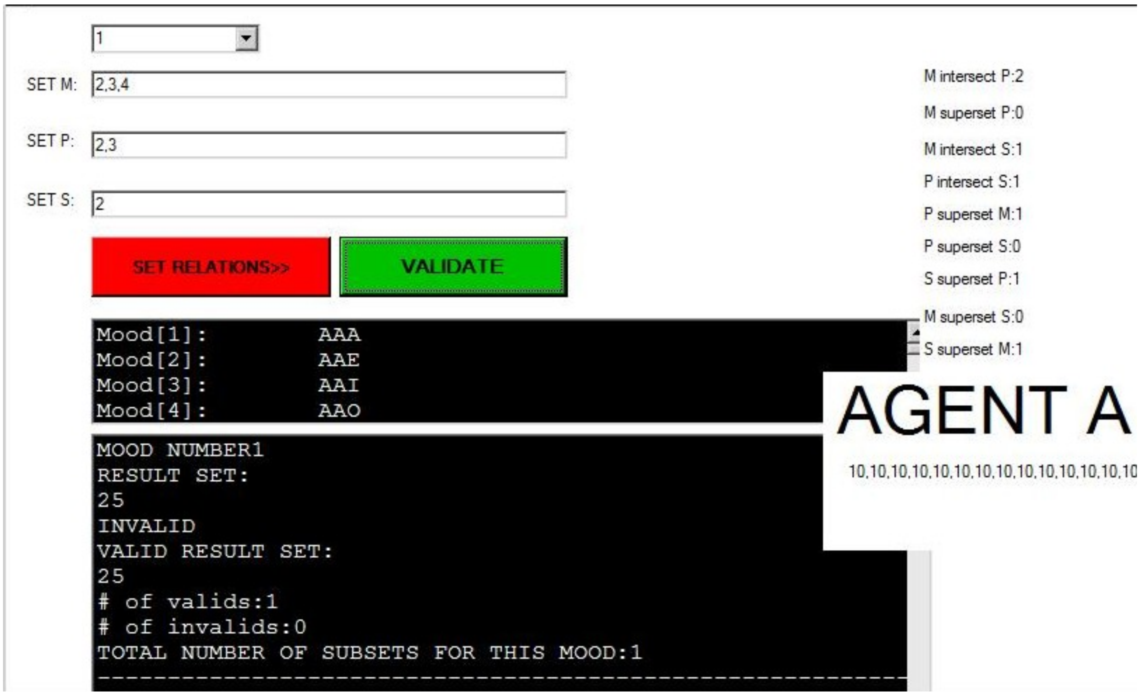


Figure 5.5. AGENT A

AGENT A make syllogistic reasoning on the sample sets M, P and S. And lists the valid set situations and send message to the messaging server that states that AGENT made a reasoning with the sets M:2,3,4 P:2,3, S:2 and get the valid set as VALID:10.

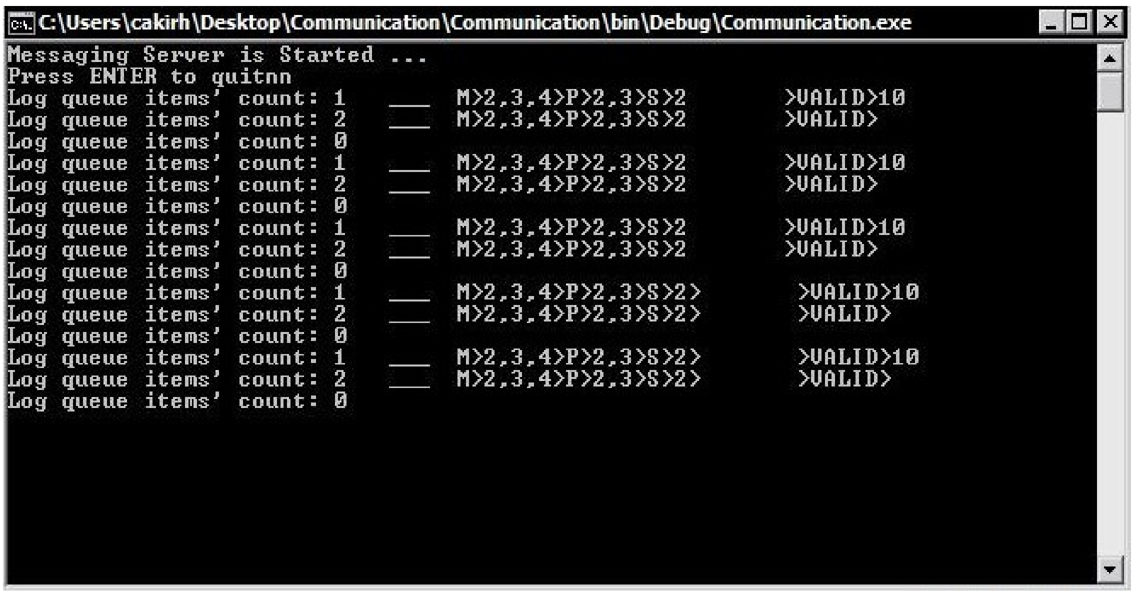


Figure 5.6. Messaging Server

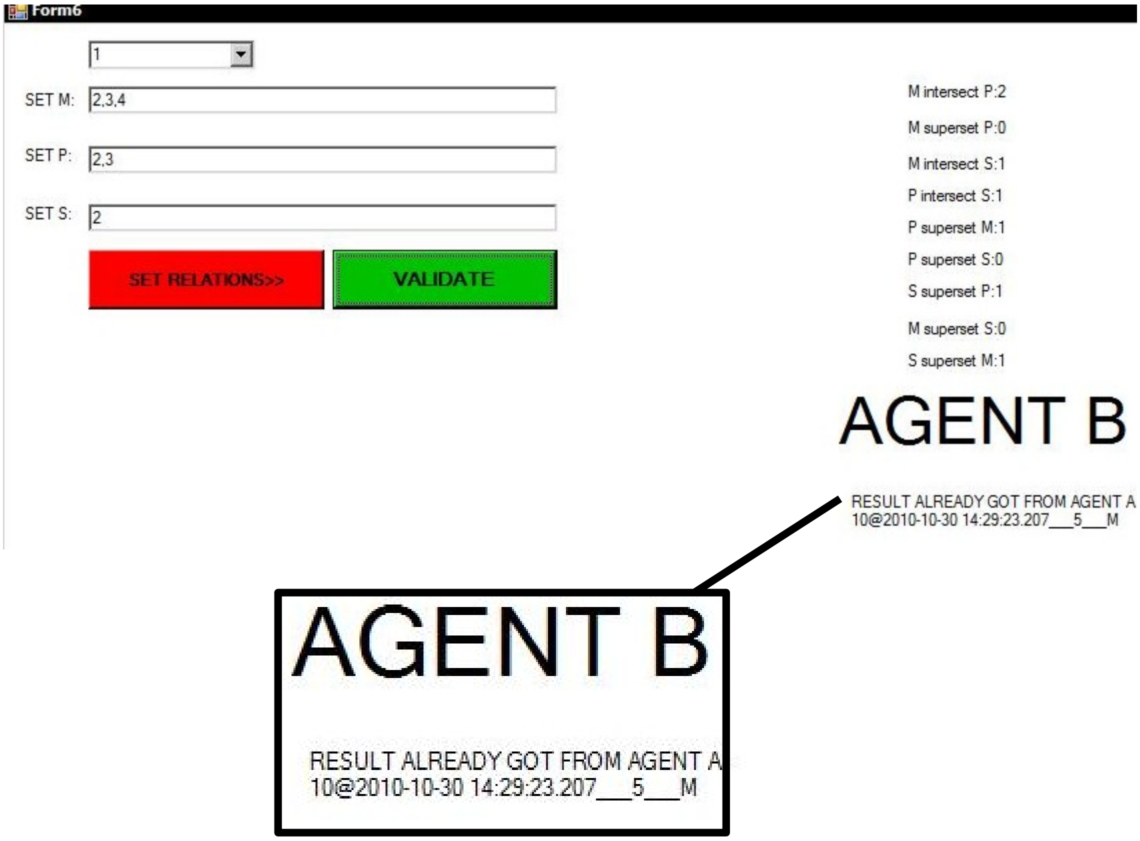


Figure 5.7. AGENT B

In conclusion, AGENT A make a syllogistic reasoning for the sets from 256 syllogistic moods made up 2624 cases which is a huge search space to validate. So to make it more useful a distributed system developed to make agents communicate with each other not to make huge calculations every time but if new validation needed.

In this system;

Each agent acts as a problem solving entity,

Make reasoning on shared knowledge [syllogistic moods],

Sample coordination between the agents.

The aim was to create coordination between agents as;

Direct messages to do the desired task,

Each agent can also reason without communication with other agents,

Processed information can also passed on between entities.

5.3. Sample Application for Syllogistic Reasoning

The application area chosen for this study is object-oriented programing because of its similarity with syllogisms. There exists researches on literature about the syllogistic structure of object-oriented programming that attract our interaction in applying syllogistic reasoning to the real life examples. In some works they design editors that uses sylllogisms to aid programmers about finding relations between entities.

The sample application just takes a sample text file that includes a object-oriented class structure and simply parse the classes to make syllogistic reasoning on them to draw a simple Venn diagram that shows relations between them like in UML diagrams.

Briefly; object-oriented programming is attempt to make programming more closely the model the way people think to deal with the world. In object-oriented programming instead of tasks in traditional programming the aim is to find objects.

The main concept used in this work about object-oriented programming is encapsulation and inheritance. Inheritance is developing collections of attributes called objects which could use previously created objects. Encapsulation is make package of an object's variables within the protective set of its methods.

The first example in this section deals with inheritance which is simple to reason from a source code whereas in later example the encapsulation discussed.

The example class structure:

```
struct Person
{
        public int SSNbr;
        public string FirstName;
        public string LastName;
        public string Address;
        public string Phone;
        public string Mail;
        public string Work;
        public double CreditCardNbr;
        public string ExpirationDate;
        public string FrequentFlyerNbr;
        public string TaxNumber;
        public int AgentID;

}
struct Customer
{
        public int SSNbr;
        public string FirstName;
        public string LastName;
        public double CreditCardNbr;
        public string ExpirationDate;
        public string FrequentFlyerNbr;
}

struct TravelAgent
{
        public int SSNbr;
        public string FirstName;
        public string LastName;
        public string TaxNumber;
        public int AgentID;
}
```

The sample application takes the class structure and parse to the frame that the syllogistic algorithm could understand and then finds relationships among class entities. Then validate the set situations to generate a venn diagram representation.

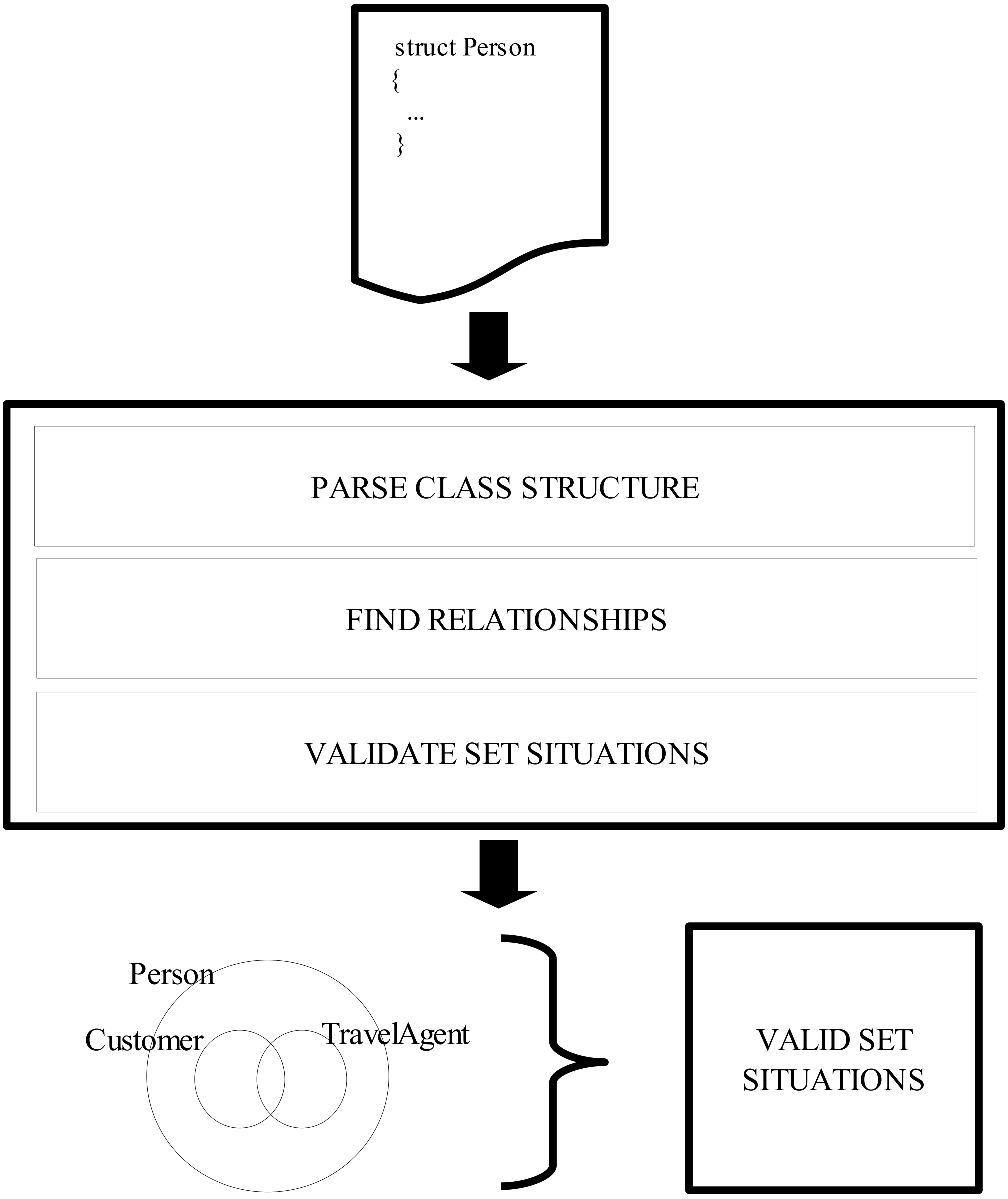


Figure 5.8. Sample Algorithm Steps

Figure 5.9. Sample Application for Syllogistic Reasoning

Classifying is a central activity in object-oriented programming and distinguishes it from procedural programming.

Ex:

All mammals nurse their young. <<**Major Premise**>>

All humans are mammals. <<**Minor Premise>>**

Therefore, all humans nurse their young.

Major Premise In object-oriented programming, properties are expressed as either fields or methods. A method is most appropriate for this property, as it is an activity that the subject performs:

class Mammal { void nurse() {} }

Minor Premise Classification is often referred to as inheritance in object-oriented programming; in Java it is signified primarily with the extends keyword:

class Human extends Mammal {}

A Line of Code With the above considerations under our belt we may now examine a line of imperative code:

static void baby(Mammal mother) { mother.nurse(); }

However, in programming we name things with words that have meaning to the programmer (although not to the machine) [24].

So for object-oriented programming a class sturucture like in exaple below will be more relevant;

```
// Accessing base class members

using System;
public class Person
{
     protected string ssn = "444555666";
     protected string name = "Huseyin Cakir";
     public virtual void GetInfo()
     {
          Console.WriteLine("Name: {0}", name);
          Console.WriteLine("SSN: {0}", ssn);
     }
}
lass Employee: Person
{
     public string Employeeid = "1234567890";
     public override void GetInfo()
     {
          // Calling the base class GetInfo method:
          base.GetInfo();
          Console.WriteLine("Employee ID: {0}",
Employeeid);
     }
}
class Customer: Person
{
     public string CreditCardNumber= "444555444555";

}
```

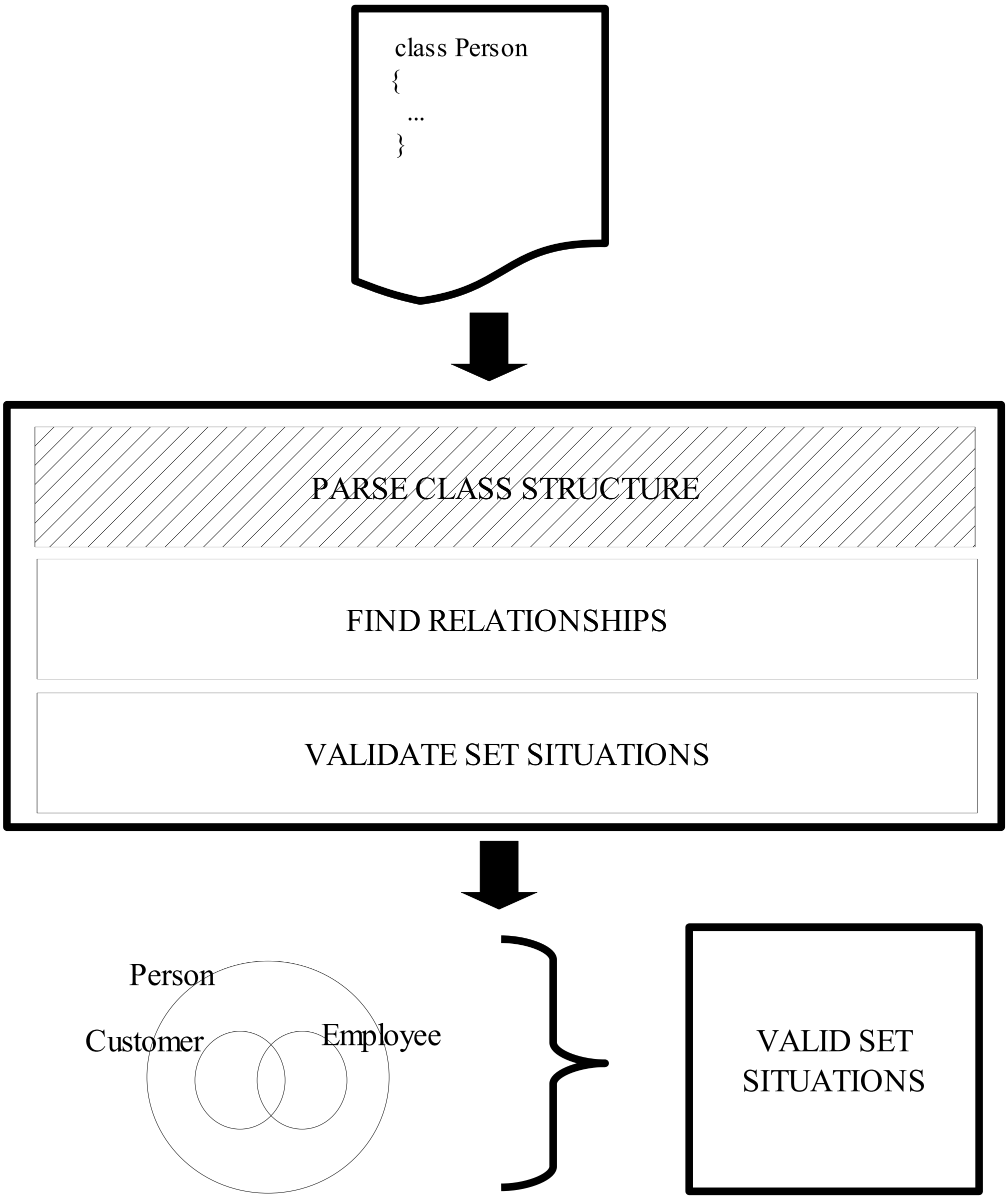


Figure 5.10. Sample Algorithm Steps

5.4. Application Areas for Syllogistic Reasoning

Syllogisms can be used in various fields as discussed before but generally it is used as a source of theoritical works. In this part, the list about use of syllogistic structure in practical ways given to show that the syllogistic reasoning framework devaloped in this study can be used in those fields as an inference mechanism.

Ontologies and Semantic Web: The Semantic Web is a vision for the future of the Web in which information is given explicit meaning, making it easier for machines to automatically process and integrate information available on the Web. Ontologies are designed for applications that need to process the content instead of just presenting information to humans [22].

There is a discussion about syllogisms if they can be used as reasoning in ontologies for AI systems. According to some works, the semantic web is a machine for creating syllogisms, on the other hand others claim that syllogisms could not be source of reasoning in semantic web since they are deductive.

Object Oriented Programming: Recent works show that there is a strong connection between object-oriented programming and syllogism [23]. As programs get larger the relations between entities get more important in software. And like in section 5.3 syllogisms can be used as a programmer aid for object-oriented programming.

CHAPTER 6

CONCLUSION

Syllogism is one of the most well-known form of deductive reasoning. In this thesis mathematical properties of the whole syllogistic system are fully revealed in detail including applications and statistics. These statistics can be used in various fields that use syllogistic reasoning. In this paper as consistent to the goal, an algorithm was developed to determine valid/invalid syllogisms and the results were analyzed in addition to the previous works in the literature.

It is believed that this thesis has two contributions to the literature, specifically to the search space of syllogisms and to the fuzzification of syllogistic values.

Contributions:

1. The algorithm that shows whole search space of syllogisms including invalid situations.
2. An approach to fuzzy syllogistic reasoning given with graphical explanations.

The principles that have been developed in this thesis work can be used as a reference in developing some applications about syllogistic reasoning. The developed applications in this thesis work do not give exact usage but they give a guidance to the people who want to use syllogistic reasoning for their application areas. Therefore, this thesis work provides a reference to the syllogistic reasoning from computational view.

The reason why it contributes to syllogistic reasoning field is that it shows the whole validity values for all moods in all *figures*. Moreover, fuzzified values given according to the possibilistic approach rather than strict rules to be more realative to human tought in reasoning. The another contribution of this work is that it not only deals with known valid moods but also invalid situations of syllogisms that made up syllogistic anomalies.Also, as a future work of this thesis work, application about the tools of object-oriented programming aid developed in this thesis work. A computer software, that provides the necessary aid to the programmer as software editor can also be developed as a future work as well. This will enable the syllogistic reasoning used in applications which will make remarkable contribution to syllogistic reasoning approach.

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APPENDIX A

FUZZY SYLLOGISTIC VALUES

The table shows the 256 moods in 5 categories with truth ratio normalised in [0,1]. False, undecided and true moods are not sorted. Unlikely and Likely moods are sorted in ascending order of their truth ratio. The table also shows the possibility distribution of the membership function FuzzySyllogisticMood(x), with x ∈ {CertainlyNot, Unlikely, Uncertain, Likely, Certainly}, defined over the truth ratios of the moods.

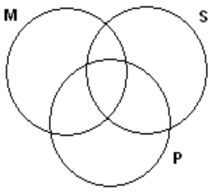
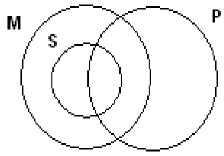
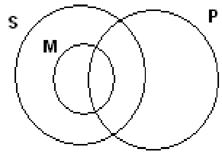
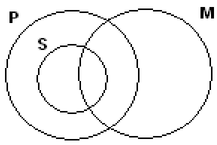
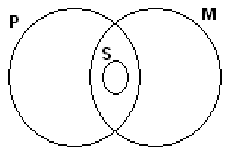
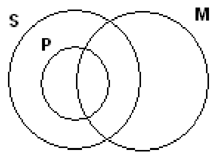
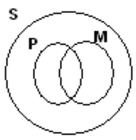
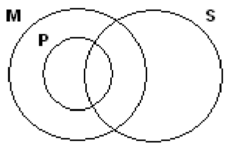
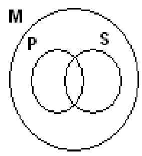
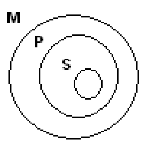
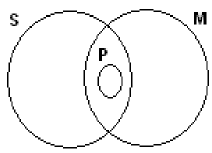
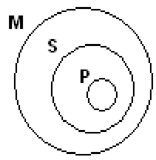
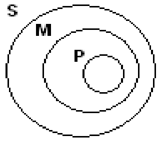
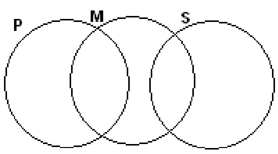
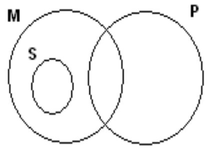
Table A.1. Possibility distribution FuzzySyllogisticMood(x) over the Syllogistic moods in increasing order of truth ratio of the moods.

Linguistic Variables	Sum	Moods
CertainlyNot; false; ratio=0	25	AAE-1, AAO-1, AIE-1, EAA-1, EAI-1, EIA-1, AEA-2, AEI-2, AOA-2, EAA-2, EAI-2, EIA-2, AAE-3, AIE-3, EAA-3, EIA-3, IAE-3, OAA-3, AAA-4, AAE-4, AEA-4, AEI-4, EAA-4, EIA-4, IAE-4
Unlikely; rather false; 0<ratio<0.5	100	EIE-1, IEE-1, EIE-2, IEE-2, EIE-3, IEE-3, EIE-4, IEE-4, AOE-2, OAA-2, OAE-2, AOA-1, IAA-1, OAE-1, OEE-1, IAA-2, EOE-3, OEE-3, AOE-4, EOE-4, OOE-3, AEA-1, AEE-1, AAA-3, AEA-3, AEE-3, EAE-3, EAE-4, EOE-1, EOE-2, OEA-2, OEE-2, OEA-4, OEE-4, OIE-1, OOE-1, OOA-4, OOE-4, IOA-3, IOE-3, OIE-3, IOA-4, IOE-4, IEA-1, IEA-2, IEA-3, IEA-4, IIA-1, IIA-2, IIA-3, IIA-4, IAE-1, OAA-1, OEA-1, AIE-2, IAE-2, OEA-3, AIE-4, AAA-2, AAE-2, EAA-1, EEE-1, EEA-2, EEE-2, EEA -3, EEE-3, EEA-4, EEE-4, IOA-1, IOE-1, IOA-2, IOE-2, OIA-2, OIE-2, OIA-4, OIE-4, OOA-2, OOE-2, OOA-3, IIE-1, IIE-2, IIE-3, IIE-4, AOE-3, IAA-3, OAE-3, IAA-4, OOA-1, OIA-1, OIA-3, AOE-1, AIA-2, EOA-3, AIA-4, AOA-4, EOA-4, OAA-4, OAE-4, EOA-1, EOA-2
Uncertain; undecided; ratio=0.5	6	AIA-1, AIO-1, AIA-3, AIO-3, AOA-3, AOO-3
Likely; rather true; 0.5<ratio<1.0	100	EOO-1, EOO-2, OIO-1, OOO-1, OIO-3, AIO-2, EOO-3, AIO-4, AOI-1, AOO-4, EOO-4, OAI-4, OAO-4, IAO-3, IAO-4, OAI-3, AOI-3, III-1, III-2, III-3, III-4, OOO-3, OOI-2, OOO-2, IOI-1, IOO-1, OII-2, OIO-2, IOI-2, IOO-2, OII-4, OIO-4, IAI-1, OAO-1, OEO-1, AII-2, OEO-3, IAI-2, AII-4, AAI-2, AAO-2, EEI-2, EEO-2, EEI-3, EEO-3, EEI-4, EEO-4, EEI-1, EEO-1, IIO-1, IIO-2, IIO-3, IIO-4, IEO-1, IEO-2, IEO-3, IEO-4, OII-1, OOI-1, IOI-3, IOO-3, OII-3, IOI-4, IOO-4, OOI-4, OOO-4, EOI-1, EOI-2, OEI-4, OEI-2, OEO-2, OEO-4, AEI-1, AEO-1, AAO-3, AEI-3, AEO-3, EAI-3, EAI-4, OOI-3, AOO-1, IAO-1, OAI-1, OEI-1, IAO-2, EOI-3, OEI-3, AOI-4, EOI-4, AOI-2, OAI-2, OAO-2, IEI-1, EII-1, EII-2, IEI-2, EII-3, IEI-3, EII-4, IEI-4
Certainly; true; ratio=1.0	25	AAA-1, AAI-1, AII-1, EAE-1, EAO-1, EIO-1, AEE-2, AEO-2, AOO-2, EAE-2, EAO-2, EIO-2, AAI-3, AII-3, EAO-3, EIO-3, IAI-3, OAO-3, AAI-4, AAO-4, AEE-4, AEO-4, EAO-4, EIO-4, IAI-4

APPENDIX B

VENN REPRESENTATIONS

Table B.1. Venn Representations

1 	2 	3 
4 	5 	6 
7 	8 	9 
10 	11 	12 
13 	14 	15 

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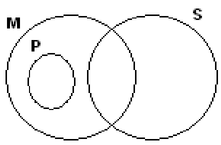
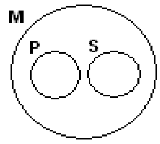
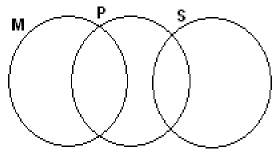
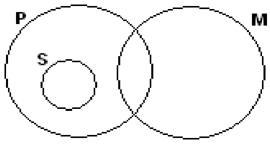
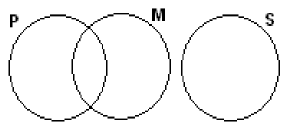
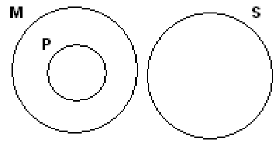
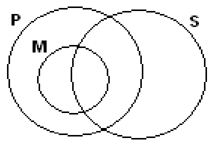
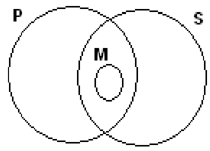
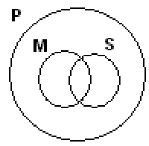
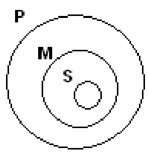
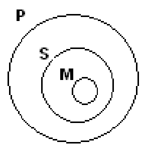
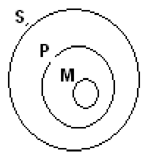
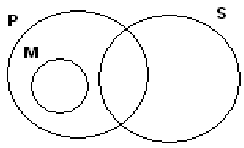
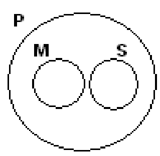
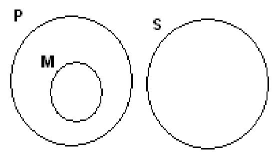
16 	17 	18 
19 	20 	21 
22 	23 	24 
25 	26 	27 
28 	29 	30 

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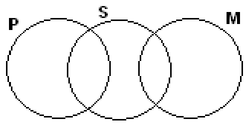
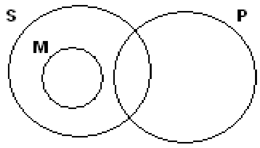
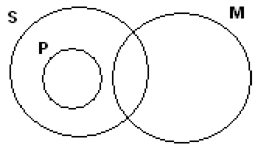
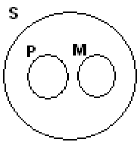
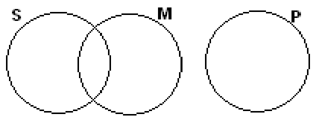
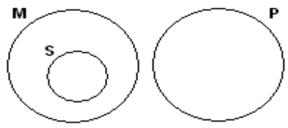
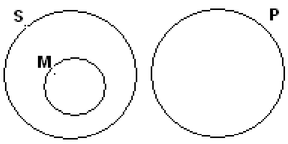
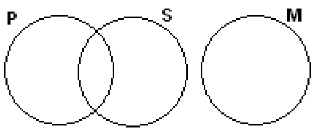
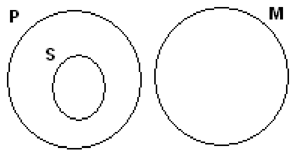
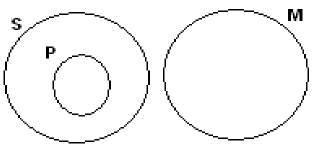
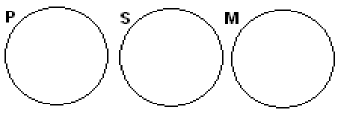
31  	32  	33 
34  	35  	36 
37  	38  	39 
40  	41  	

APPENDIX C

MOOD CASES OF FUZZY SYLLOGISMS

Certainly Not [25] Uncertain [6] Certainly [25]

Unlikely [100] Likely [100]

Number of valid and invalid cases for every mood in form of true set cases that are respresented by same venn diagram representation numbers in APPENDIX B.

Table C.1. Fuzzy Syllogisms

Certainly Not:

MOOD - FIGURE	INVALID	VALID	INVALID CASES	VALID CASES
EIA - 1	7	0	31,32,33,34,35,36,37	-
EIA - 2	7	0	31,32,33,34,35,36,37	-
EIA - 3	7	0	31,32,33,34,35,36,37	-
EIA - 4	7	0	31,32,33,34,35,36,37	-
AIE - 1	6	0	22,23,24,25,26,27	-
AIE - 3	6	0	22,23,24,25,26,27	-
IAE - 3	6	0	3,7,13,23,26,27	-
OAA - 3	6	0	3,7,13,32,34,37	-
IAE - 4	6	0	3,7,13,23,26,27	-
AOA - 2	5	0	8,11,13,16,21	-
AAE - 3	3	0	23,26,27	-
EAA - 3	3	0	32,34,37	-
EAA - 4	3	0	32,34,37	-
AAE - 1	1	0	25	-
AAO - 1	1	0	25	-
EAA - 1	1	0	36	-
EAI - 1	1	0	36	-
AEA - 2	1	0	21	-
AEI - 2	1	0	21	-
EAA - 2	1	0	36	-

(Cont.on next page)

Table C.1. (cont.)

MOOD - FIGURE	INVALID	VALID	INVALID CASES	VALID CASES
AAE - 4	1	0	13	-
AEA - 4	1	0	21	-
AEI - 4	1	0	21	-

Unlikely:

MOOD - FIGURE	INVALID	VALID	INVALID CASES	VALID CASES
OOA - 2	21	6	1,3,6,7,14,18,20,22,23,27,28, 30,31,32,33,34,35,37,38,40,41	4,19,24,26,29,39
OOE - 2	21	6	1,3,4,6,7,18,19,22,23,24,26,27 ,28,29,31,32,33,34,38,39,40	14,20,30,35,37,41
OOA - 3	21	5	1,2,6,8,9,11,12,14,15,16,17,18 ,20,21,31,33,35,36,38,40,41	4,5,10,19,39
OOA - 1	21	3	1,3,6,7,8,11,13,14,16,18,20,21 ,31,32,33,34,35,37,38,40,41	4,19,39
OIA - 1	21	3	1,2,3,6,7,8,9,11,12,13,14,15, 16,17,31,32,33,34,35,36,37	4,5,10
OIA - 3	21	3	1,2,3,6,7,8,9,11,12,13,14,15,1 6,17,31,32,33,34,35,36,37	4,5,10
IIE - 1	19	4	1,2,3,4,5,6,7,8,9,10,11,12,13,2 2,23,24,25,26,27	14,15,16,17
IIE - 2	19	4	1,2,3,4,5,6,7,8,9,10,11,12,13,2 2,23,24,25,26,27	14,15,16,17
IIE - 3	19	4	1,2,3,4,5,6,7,8,9,10,11,12,13,2 2,23,24,25,26,27	14,15,16,17
IIE - 4	19	4	1,2,3,4,5,6,7,8,9,10,11,12,13,2 2,23,24,25,26,27	14,15,16,17
OOE - 3	17	9	1,2,4,5,6,8,9,10,11,12,18,19,3 1,33,38,39,40	14,15,16,17,20,21,35,36,41
OIE - 1	17	7	1,2,3,4,5,6,7,8,9,10,11,12,13,3 1,32,33,34	14,15,16,17,35,36,37
OOE - 1	17	7	1,3,4,6,7,8,11,13,18,19,31,32, 33,34,38,39,40	14,16,20,21,35,37,41
OOA - 4	17	7	1,2,6,14,15,18,20,22,28,30,31, 33,35,36,38,40,41	4,5,19,24,25,29,39
OOE - 4	17	7	1,2,4,5,6,18,19,22,24,25,28,29 ,31,33,38,39,40	14,15,20,30,35,36,41
IOA - 3	17	7	1,2,6,8,9,11,12,14,15,16,17,18 ,20,21,22,28,30	4,5,10,19,24,25,29
IOE - 3	17	7	1,2,4,5,6,8,9,10,11,12,18,19, 22,24,25,28,29	14,15,16,17,20,21,30

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Table C.1. (cont.)

MOOD - FIGURE	INVALID	VALID	INVALID CASES	VALID CASES
OIE - 3	17	7	1,2,3,4,5,6,7,8,9,10,11,12,13,31,32,33,34	14,15,16,17,35,36,37
IOA - 4	17	7	1,2,6,8,9,11,12,14,15,16,17,18,20,21,22,28,30	4,5,10,19,24,25,29
IOE - 4	17	7	1,2,4,5,6,8,9,10,11,12,18,19,22,24,25,28,29	14,15,16,17,20,21,30
IIA - 1	17	6	1,2,3,6,7,8,9,11,12,13,14,15,16,17,22,23,27	4,5,10,24,25,26
IIA - 2	17	6	1,2,3,6,7,8,9,11,12,13,14,15,16,17,22,23,27	4,5,10,24,25,26
IIA - 3	17	6	1,2,3,6,7,8,9,11,12,13,14,15,16,17,22,23,27	4,5,10,24,25,26
IIA - 4	17	6	1,2,3,6,7,8,9,11,12,13,14,15,16,17,22,23,27	4,5,10,24,25,26
IOA - 1	17	5	1,3,6,7,8,11,13,14,16,18,20,21,22,23,27,28,30	4,19,24,26,29
IOE - 1	17	5	1,3,4,6,7,8,11,13,18,19,22,23,24,26,27,28,29	14,16,20,21,30
IOA - 2	17	5	1,3,6,7,8,11,13,14,16,18,20,21,22,23,27,28,30	4,19,24,26,29
IOE - 2	17	5	1,3,4,6,7,8,11,13,18,19,22,23,24,26,27,28,29	14,16,20,21,30
OIA - 2	17	5	1,2,3,6,7,14,15,22,23,27,31,32,33,34,35,36,37	4,5,24,25,26
OIE - 2	17	5	1,2,3,4,5,6,7,22,23,24,25,26,27,31,32,33,34	14,15,35,36,37
OIA - 4	17	5	1,2,3,6,7,14,15,22,23,27,31,32,33,34,35,36,37	4,5,24,25,26
OIE - 4	17	5	1,2,3,4,5,6,7,22,23,24,25,26,27,31,32,33,34	14,15,35,36,37
EOA - 1	9	1	31,32,33,34,35,37,38,40,41	39
EOA - 2	9	1	31,32,33,34,35,37,38,40,41	39
EOE - 1	7	3	31,32,33,34,38,39,40	35,37,41
EOE - 2	7	3	31,32,33,34,38,39,40	35,37,41
OEA - 2	7	3	18,20,28,30,38,40,41	19,29,39
OEE - 2	7	3	18,19,28,29,38,39,40	20,30,41
OEA - 4	7	3	18,20,28,30,38,40,41	19,29,39
OEE - 4	7	3	18,19,28,29,38,39,40	20,30,41
AOE - 1	7	1	22,23,24,26,27,28,29	21
AIA - 2	7	1	8,9,11,12,13,16,17	10

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Table C.1. (cont.)

AIA - 4	7	1	8,9,11,12,13,16,17	10
IIA - 2	17	6	1,2,3,6,7,8,9,11,12,13,14,15, 16,17,22,23,27	4,5,10,24,25,26
AOA - 4	7	1	8,9,11,12,16,17,21	10
EOA - 4	7	1	31,33,35,36,38,40,41	39
OAA - 4	7	1	3,7,23,27,32,34,37	26
IAE - 1	6	2	2,5,9,10,12,25	15,17
OAA - 1	6	2	2,9,12,15,17,36	5,1
OEA - 1	6	2	18,20,21,38,40,41	19,39
AIE - 2	6	2	8,9,10,11,12,13	16,17
IAE - 2	6	2	2,5,9,10,12,25	15,17
OEA - 3	6	2	18,20,21,38,40,41	19,39
AIE - 4	6	2	8,9,10,11,12,13	16,17
AOA - 1	5	3	21,22,23,27,28	24,26,29
IAA - 1	5	3	2,9,12,15,17	5,10,25
OAE - 1	5	3	2,5,9,10,12	15,17,36
OEE - 1	5	3	18,19,38,39,40	20,21,41
IAA - 2	5	3	2,9,12,15,17	5,10,25
EOE - 3	5	3	31,33,38,39,40	35,36,41
OEE - 3	5	3	18,19,38,39,40	20,21,41
AOE - 4	5	3	8,9,10,11,12	16,17,21
EOE - 4	5	3	31,33,38,39,40	35,36,41
IEA - 1	5	2	18,20,21,28,30	19,29
IEA - 2	5	2	18,20,21,28,30	19,29
IEA - 3	5	2	18,20,21,28,30	19,29
IEA - 4	5	2	18,20,21,28,30	19,29
AOE - 3	5	1	22,24,25,28,29	21
IAA - 3	5	1	3,7,13,23,27	26
OAE - 3	5	1	3,7,13,32,34	37
IAA - 4	5	1	3,7,13,23,27	26
EIE - 1	4	3	31,32,33,34	35,36,37
IEE - 1	4	3	18,19,28,29	20,21,30
EIE - 2	4	3	31,32,33,34	35,36,37
IEE - 2	4	3	18,19,28,29	20,21,30
EIE - 3	4	3	31,32,33,34	35,36,37
IEE - 3	4	3	18,19,28,29	20,21,30

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Table C.1. (cont.)

IEE - 4	4	3	18,19,28,29	20,21,30
AOE - 2	3	2	8,11,13	16,21
OAA - 2	3	2	2,15,36	5,25
IAE - 2	6	2	2,5,9,10,12,25	15,17
OAE - 2	3	2	2,5,25	15,36
AAA - 2	3	1	9,12,17	10
AAE - 2	3	1	9,10,12	17
EEA - 1	3	1	38,40,41	39
EEE - 1	3	1	38,39,40	41
EEA - 2	3	1	38,40,41	39
EEE - 2	3	1	38,39,40	41
EEA -3	3	1	38,40,41	39
EEE - 3	3	1	38,39,40	41
EEA - 4	3	1	38,40,41	39
EEE - 4	3	1	38,39,40	41
AEA - 1	2	1	21,28	29
AEE - 1	2	1	28,29	21
AAA - 3	2	1	23,27	26
AEA - 3	2	1	21,28	29
AEE - 3	2	1	28,29	21
EAE - 3	2	1	32,34	37
EAE - 4	2	1	32,34	37

Uncertain:

MOOD - FIGURE	INVALID	VALID	INVALID CASES	VALID CASES
AIA - 1	3	3	22,23,27	24,25,26
AIO - 1	3	3	24,25,26	22,23,27
AIA - 3	3	3	22,23,27	24,25,26
AIO - 3	3	3	24,25,26	22,23,27
AOA - 3	3	3	21,22,28	24,25,29
AOO - 3	3	3	24,25,29	21,22,28

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Table C.1. (cont.)

Likely:

MOOD - FIGURE	INVALID	VALID	INVALID CASES	VALID CASES
OIO - 1	3	21	4,5,10	1,2,3,6,7,8,9,11,12,13,14,15,16,17,31,32,33,34,35,36,37
OOO - 1	3	21	4,19,20	1,3,6,7,8,11,13,14,16,18,20,21,31,32,33,34,35,37,38,40,41
OIO - 3	3	21	4,5,10	1,2,3,6,7,8,9,11,12,13,14,15,16,17,31,32,33,34,35,36,37
OOO - 3	5	21	4,5,10,19,20	1,2,6,8,9,11,12,14,15,16,17,18,20,21,31,33,35,36,38,40,41
OOI - 2	6	21	14,20,22,30,35,37	1,3,4,6,7,18,19,22,23,24,26,27,28,29,31,32,33,34,38,39,40
OOO - 2	6	21	4,19,20,24,26,29	1,3,6,7,14,18,20,22,23,27,28,30,31,32,33,34,,35,37,38,40,41
III - 1	4	19	14,15,16,17	1,2,3,4,5,6,7,8,9,10,11,12,13,22,23,24,25,26,27
III - 2	4	19	14,15,16,17	1,2,3,4,5,6,7,8,9,10,11,12,13,22,23,24,25,26,27
III - 3	4	19	14,15,16,17	1,2,3,4,5,6,7,8,9,10,11,12,13,22,23,24,25,26,27
III - 4	4	19	14,15,16,17	1,2,3,4,5,6,7,8,9,10,11,12,13,22,23,24,25,26,27
IOI - 1	5	17	14,16,20,21,22	1,3,4,6,7,8,11,13,18,19,22,23,24,26,27,28,29
IOO - 1	5	17	4,19,20,24,26	1,3,6,7,8,11,13,14,16,18,20,21,22,23,27,28,30
OII - 2	5	17	14,15,22,35,36	1,2,3,4,5,6,7,22,23,24,25,26,27,31,32,33,34
OIO - 2	5	17	4,5,24,25,26	1,2,3,6,7,14,15,22,23,27,31,32,33,34,35,36,37
IOI - 2	5	17	14,16,20,21,22	1,3,4,6,7,8,11,13,18,19,22,23,24,26,27,28,29
IOO - 2	5	17	4,19,20,24,26	1,3,6,7,8,11,13,14,16,18,20,21,22,23,27,28,30
IIO - 1	6	17	4,5,10,24,25,26	1,2,3,6,7,8,9,11,12,13,14,15,16,17,22,23,27
IIO - 2	6	17	4,5,10,24,25,26	1,2,3,6,7,8,9,11,12,13,14,15,16,17,22,23,27

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Table C.1. (cont.)

OOI - 2	6	21	14,20,22,30,35,37	1,3,4,6,7,18,19,22,23,24,26,27,28,29,31,32,33,34,38,39,40
IIO - 3	6	17	4,5,10,24,25,26	1,2,3,6,7,8,9,11,12,13,14,15,16,17,22,23,27
IIO - 4	6	17	4,5,10,24,25,26	1,2,3,6,7,8,9,11,12,13,14,15,16,17,22,23,27
OII - 1	7	17	14,15,16,17,35,36,37	1,2,3,4,5,6,7,8,9,10,11,12,13,31,32,33,34
OOI - 1	7	17	14,16,20,21,35,37,41	1,3,4,6,7,8,11,13,18,19,31,32,33,34,38,39,40
IOI - 3	7	17	14,15,16,17,20,21,22	1,2,4,5,6,8,9,10,11,12,18,19,22,24,25,28,29
IOO - 3	7	17	4,5,10,19,20,24,25	1,2,6,8,9,11,12,14,15,16,17,18,20,21,22,28,30
OII - 3	7	17	14,15,16,17,35,36,37	1,2,3,4,5,6,7,8,9,10,11,12,13,31,32,33,34
IOI - 4	7	17	14,15,16,17,20,21,22	1,2,4,5,6,8,9,10,11,12,18,19,22,24,25,28,29
IOO - 4	7	17	4,5,10,19,20,24,25	1,2,6,8,9,11,12,14,15,16,17,18,20,21,22,28,30
OOI - 4	7	17	14,15,20,22,30,35,36	1,2,4,5,6,18,19,22,24,25,28,29,31,33,38,39,40
OOO - 4	7	17	4,5,19,20,24,25,29	1,2,6,14,15,18,20,22,28,30,31,33,35,36,38,40,41
OOI - 3	9	17	14,15,16,17,20,21,35,36,41	1,2,4,5,6,8,9,10,11,12,18,19,31,33,38,39,40
EOO - 1	1	9	39	31,32,33,34,35,37,38,40,41
EOO - 2	1	9	39	31,32,33,34,35,37,38,40,41
AIO - 2	1	7	10	8,9,11,12,13,16,17
EOO - 3	1	7	39	31,33,35,36,38,40,41
AIO - 4	1	7	10	8,9,11,12,13,16,17
AOI - 1	1	7	21	22,23,24,26,27,28,29
AOO - 4	1	7	10	8,9,11,12,16,17,21
EOO - 4	1	7	39	31,33,35,36,38,40,41
OAI - 4	1	7	37	3,7,23,26,27,32,34
OAO - 4	1	7	26	3,7,23,27,32,34,37
EOI - 1	3	7	35,37,41	31,32,33,34,38,39,40
EOI - 2	3	7	35,37,41	31,32,33,34,38,39,40
OEI - 4	3	7	20,30,41	18,19,28,29,38,39,40
OEI - 2	3	7	20,30,41	18,19,28,29,38,39,40

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Table C.1. (cont.)

IOI - 4	7	17	14,15,16,17,20,21,22	1,2,4,5,6,8,9,10,11,12,18,19,22,24,25,28,29
OEO - 4	3	7	19,20,29	18,20,28,30,38,40,41
IAI - 1	2	6	15,17	2,5,9,10,12,25
OAO - 1	2	6	5,1	2,9,12,15,17,36
OEO - 1	2	6	19,2	18,20,21,38,40,41
AII - 2	2	6	16,17	8,9,10,11,12,13
OEO - 3	2	6	19,2	18,20,21,38,40,41
IAI - 2	2	6	15,17	2,5,9,10,12,25
AII - 4	2	6	16,17	8,9,10,11,12,13
IAO - 3	1	5	26	3,7,13,23,27
IAO - 4	1	5	26	3,7,13,23,27
OAI - 3	1	5	37	3,7,13,32,34
AOI - 3	1	5	21	22,24,25,28,29
IEO - 1	2	5	20,19	18,20,21,28,30
IEO - 2	2	5	20,19	18,20,21,28,30
IEO - 3	2	5	20,19	18,20,21,28,30
IEO - 4	2	5	20,19	18,20,21,28,30
AOO - 1	3	5	24,26,29	21,22,23,27,28
IAO - 1	3	5	5,10,25	2,9,12,15,17
OAI - 1	3	5	15,17,36	2,5,9,10,12
OEI - 1	3	5	20,21,41	18,19,38,39,40
IAO - 2	3	5	5,10,25	2,9,12,15,17
EOI - 3	3	5	35,36,41	31,33,38,39,40
OEI - 3	3	5	20,21,41	18,19,38,39,40
AOI - 4	3	5	16,17,21	8,9,10,11,12
EOI - 4	3	5	35,36,41	31,33,38,39,40
IEI - 1	3	4	20,21,30	18,19,28,29
EII - 1	3	4	35,36,37	31,32,33,34
EII - 2	3	4	35,36,37	31,32,33,34
IEI - 2	3	4	20,21,30	18,19,28,29
EII - 3	3	4	35,36,37	31,32,33,34
IEI - 3	3	4	20,21,30	18,19,28,29
EII - 4	3	4	35,36,37	31,32,33,34
IEI - 4	3	4	20,21,30	18,19,28,29
AAI - 2	1	3	17	9,10,12

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Table C.1. (cont.)

EEO - 2	1	3	39	38,40,41
IEO - 1	2	5	20,19	18,20,21,28,30
EEI - 3	1	3	41	38,39,40
EEO - 3	1	3	39	38,40,41
EEI - 4	1	3	41	38,39,40
EEO - 4	1	3	39	38,40,41
EEI - 1	1	3	41	38,39,40
EEO - 1	1	3	39	38,40,41
AOI - 2	2	3	16,21	8,11,13
OAI - 2	2	3	15,36	2,5,25
OAO - 2	2	3	5,25	2,15,36
AEI - 1	1	2	21	28,29
AEO - 1	1	2	29	21,28
AAO - 3	1	2	26	23,27
AEI - 3	1	2	21	28,29
AEO - 3	1	2	29	21,28
EAI - 3	1	2	37	32,34
EAI - 4	1	2	37	32,34

Certainly:

MOOD - FIGURE	INVA LID	VALID	INVALID CASES	VALID CASES
EIO - 1	0	7	-	31,32,33,34,35,36,37
EIO - 2	0	7	-	31,32,33,34,35,36,37
EIO - 3	0	7	-	31,32,33,34,35,36,37
EIO - 4	0	7	-	31,32,33,34,35,36,37
AII - 1	0	6	-	22,23,24,25,26,27
AII - 3	0	6	-	22,23,24,25,26,27
IAI - 3	0	6	-	3,7,13,23,26,27
OAO - 3	0	6	-	3,7,13,32,34,37
IAI - 4	0	6	-	3,7,13,23,26,27
AOO - 2	0	5	-	8,11,13,16,21
AAI - 3	0	3	-	23,26,27
EAO - 3	0	3	-	32,34,37
EAO - 4	0	3	-	32,34,37
AAA - 1	0	1	-	25

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Table C.1. (cont.)

MOOD - FIGURE	INVA LID	VALID	INVALID CASES	VALID CASES
AAI - 1	0	1	-	25
EAE - 1	0	1	-	36
EAO - 1	0	1	-	36
AEE - 2	0	1	-	21
AEO - 2	0	1	-	21
EAE - 2	0	1	-	36
EAO - 2	0	1	-	36
AAI - 4	0	1	-	13
AAO - 4	0	1	-	13
AEE - 4	0	1	-	21
AEO - 4	0	1	-	21

APPENDIX D

CONVERSATION ON PREMISES

APPENDIX D shows the changes in valid/invalid states of moods wit respect to 41 possible set situations after conclusion and premiss conversations.

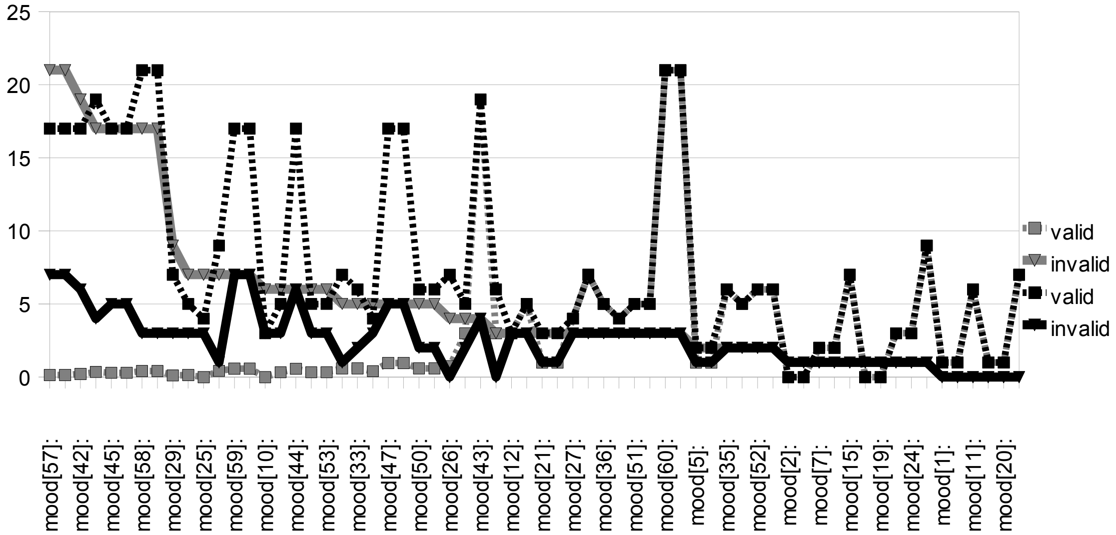

***Figure 1* – Conclusion Change: E TO O , A TO I**
Gray: Before Conversation Black: After Conversion

Valids for Figure 1:	
Mood[1]:	AAA
mood[3]:	AAI
Mood[11]:	AII
mood[18]:	EAE
Mood[20]:	EAO
Mood[28]:	EIO
Mood[26]:	*EIE
Mood[9]:	*AIA

Figure D.1. Conversation on Conclusion for *Figure 1*

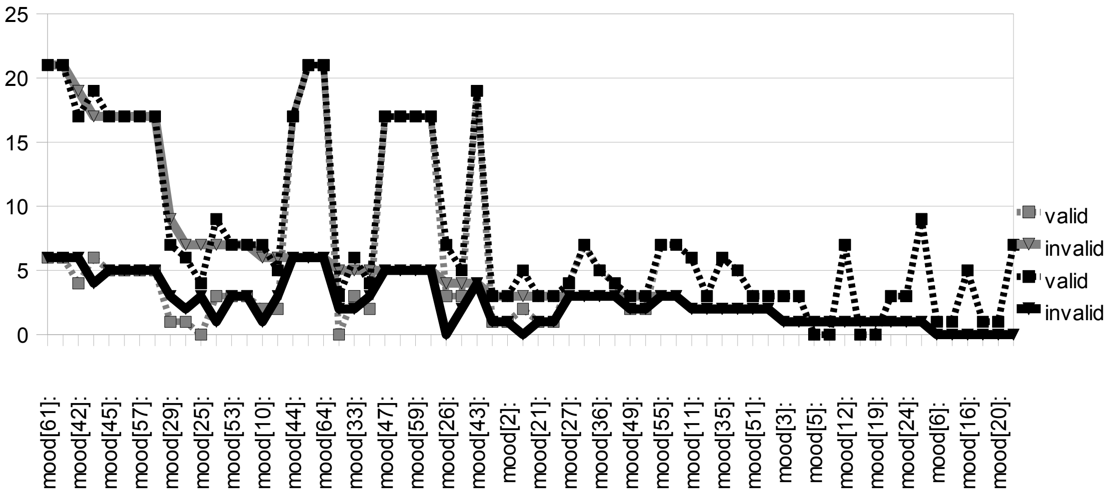

***Figure 2* – Conclusion Change: E TO O , A TO I**
Gray: Before Conversation Black: After Conversion

Valids for Figure 2:	
Mood[6]:	AEE
Mood[8]:	AEO
Mood[16]:	AOO
Mood[18]:	EAE
Mood[20]:	EAO
Mood[28]:	EIO
Mood[14]:	*AOE
Mood[26]:	*EIE

Figure D.2. Conversation on Conclusion for *Figure 2*

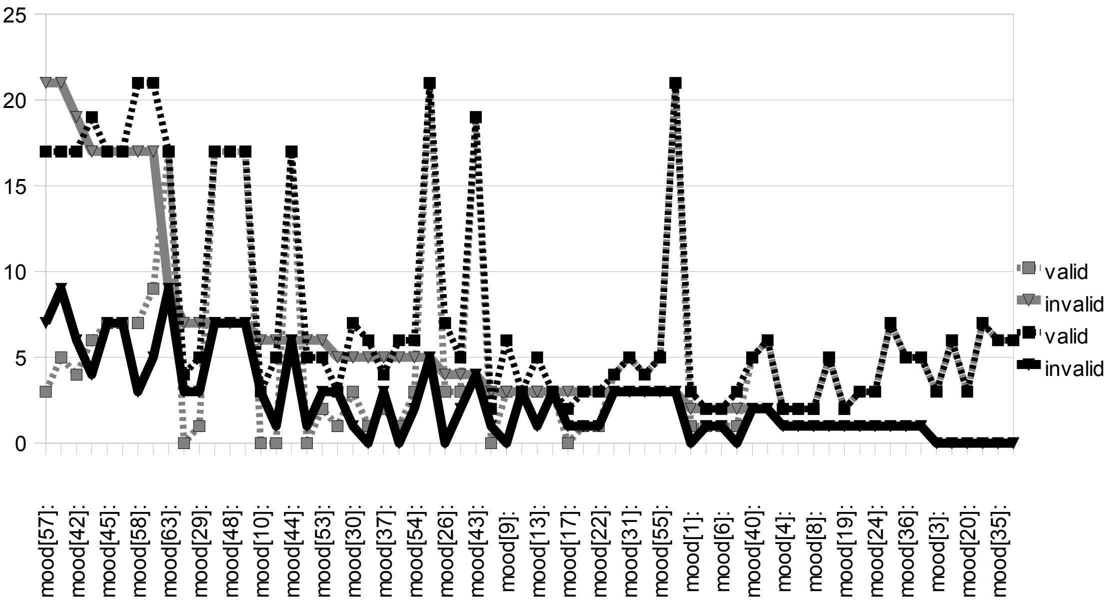

Figure 3 **– Conclusion Change: E TO O , A TO I**
Gray: Before Conversation Black: After Conversion

Valids for Figure 3:	
Mood[3]:	AAI
Mood[11]:	AII
Mood[20]:	EAO
Mood[28]:	EIO
Mood[35]:	IAI
Mood[52]:	OAO
Mood[1]:	*AAA
Mood[9]:	*AIA
Mood[18]:	*EAE
Mood[26]:	*EIE
Mood[33]:	*IAA
Mood[50]:	*OAE

Figure D.3. Conversation on Conclusion for *Figure 3*

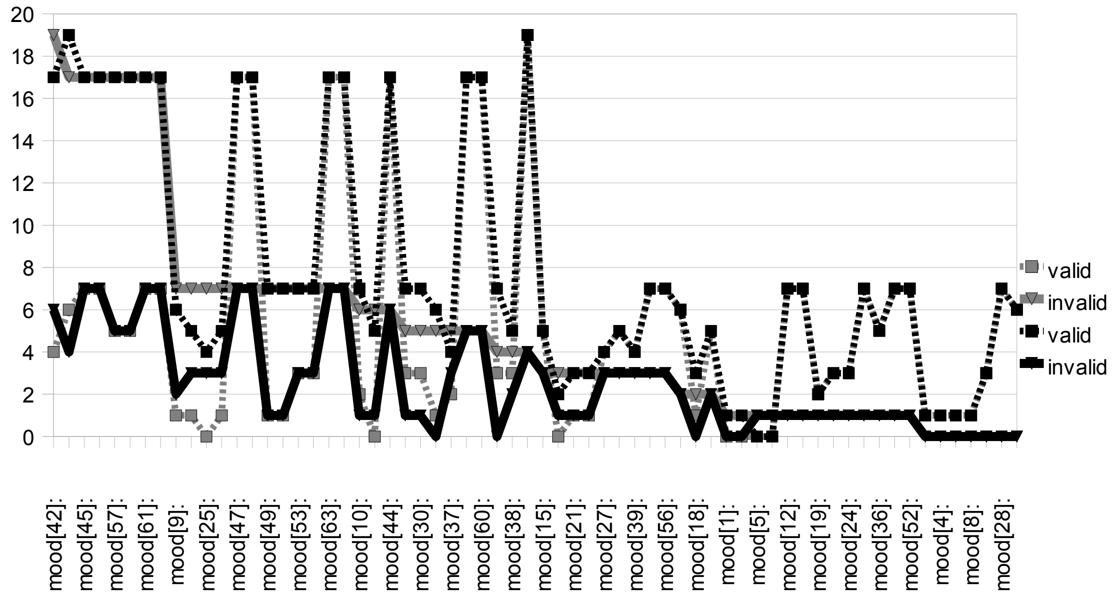

Figure 4 **– Conclusion Change: E TO O , A TO I**
Gray: Before Conversation Black: After Conversion

Valids for Figure 4:	
Mood[3]:	AAI
Mood[4]:	AAO
Mood[6]:	AEE
Mood[8]:	AEO
Mood[20]:	EAO
Mood[28]:	EIO
Mood[35]:	IAI
Mood[1]:	*AAA
Mood[2]:	*AAE
Mood[18]:	*EAE
Mood[26]:	*EIE
Mood[33]:	*IAA

Figure D.4. Conversation on Conclusion for *Figure 4*

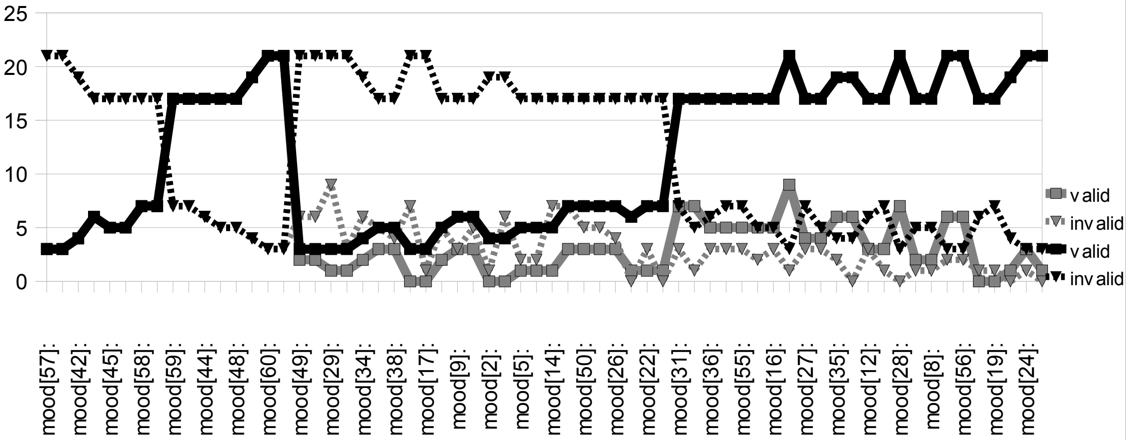

***Figure 1* – First and Second Premises Change: E TO O, A TO I**
Gray: Before Conversation Black: After Conversion

Figure D.5. Conversation on Premises for *Figure 1*

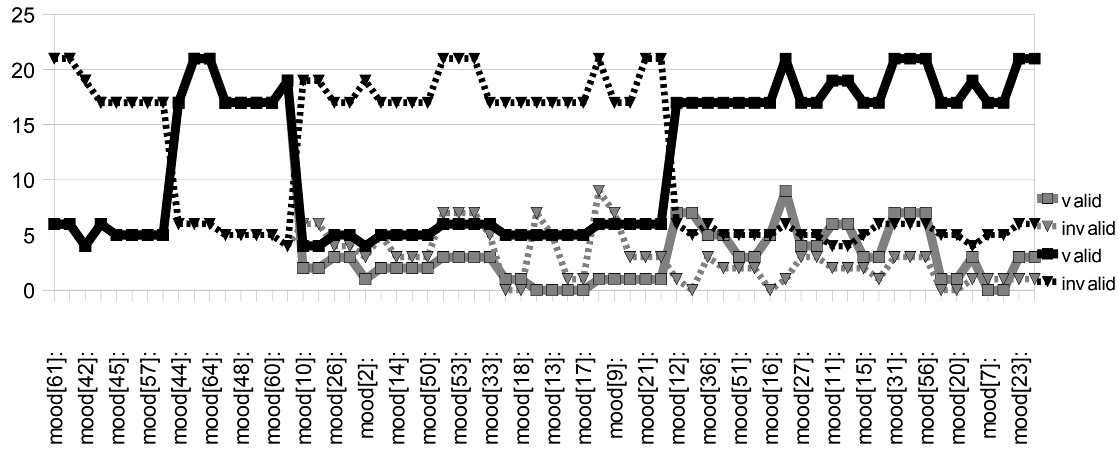

***Figure 2* – First and Second Premises Change: E TO O, A TO I**
Gray: Before Conversation Black: After Conversion

Figure D.6. Conversation on Premises for *Figure 2*

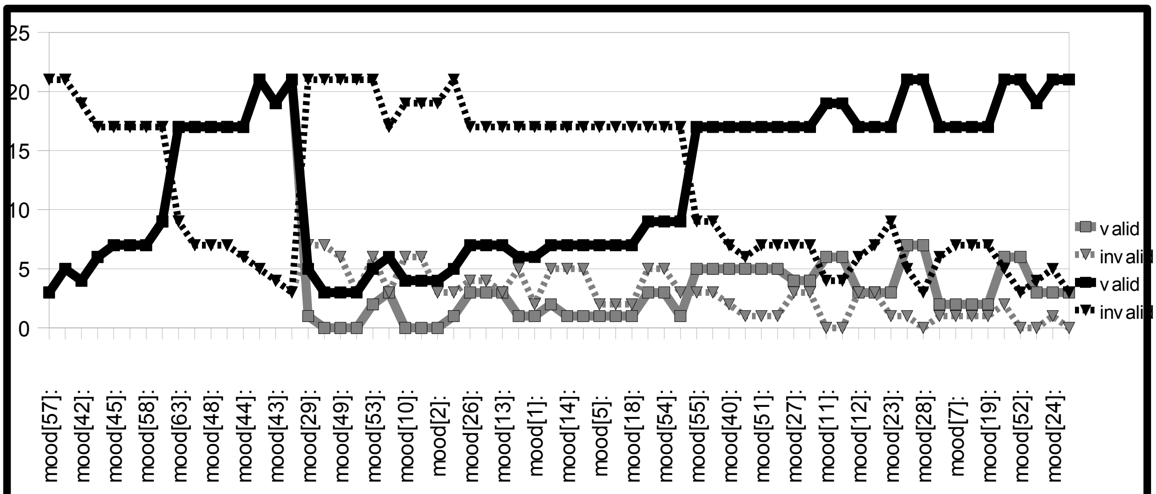

***Figure 3* – First and Second Premises Change: E TO O, A TO I**
Gray: Before Conversation Black: After Conversion

Figure D.7. Conversation on Premises for *Figure 3*

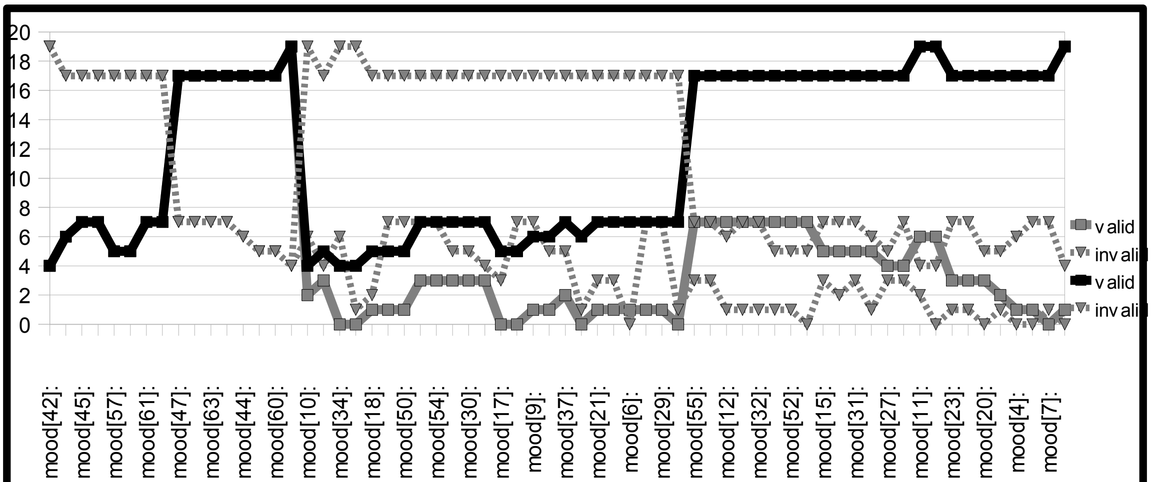

***Figure 4* – First and Second Premises Change: E TO O, A TO I**
Gray: Before Conversation Black: After Conversion

Figure D.8. Conversation on Premises for *Figure 4*