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Swathi Vasanthapuram

University of Nebraska-Lincoln, swathi44@gmail.com

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**ONTOLOGY FOR
PSYCHOPHYSIOLOGICAL DYSREGULATION OF ANGER/AGGRESSION**

by

Swathi Vasanthapuram

A THESIS

Presented to the Faculty of
The Graduate College at the University of Nebraska
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Under the Supervision of Professor Jitender S. Deogun

Lincoln, Nebraska

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**ONTOLOGY FOR
PSYCHOPHYSIOLOGICAL DYSREGULATION OF ANGER/AGGRESSION**

Swathi Vasanthapuram, M.S.

University of Nebraska, 2011

Adviser: Jitender S. Deogun

The advancement of Information Technology in the last four decades led to the use of computers in medicine. A new area called Health Informatics or Medical Informatics has emerged. This area comprises the application of information technology to the healthcare profession with the aim of creating tools that help healthcare personnel diagnose and treat patients more accurately and efficiently. IT not only provides tools for storing, integrating, and updating the patient information base but also for processing information efficiently. One of such tools is a Clinical Decision Support System. As there is enormous amount of data in the domain, there is the necessity of a formal way to represent, share and process this data. Ontologies are an integral part of clinical decision support systems because they help formalize and integrate domain knowledge.

In this project, we developed a software program that assists clinicians in making diagnostic decisions about a particular problem type called ‘psychophysiological dysregulation of anger/aggression’. In order to develop such a program we created a new ontology for the problem domain. The computer program asks a set of pertinent questions and the patient or clinician on behalf of the patient is required to answer it. All these

answers along with the results from various lab assessment tests are fed into the software program which then outputs a diagnosis by interacting with the ontology and also proposes the preferred treatment plan. While undergoing the treatment the patient is monitored at regular intervals by the clinician and this data is recorded as the treatment episode data.

We used Web Ontology Language (OWL) version 2 with Protégé 4.1.0 Beta as the editor to visualize the ontology, developed the code in Java using Eclipse Helios IDE to create the ontology and to deliver the result. We also used IBM DB2 database software to store and maintain records of the patient.

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TABLE OF CONTENTS

LIST OF FIGURES	iii
CHAPTER 1 INTRODUCTION.....	1
IT Trends.....	1
IT in Medicine.....	2
IT in Mental Health.....	5
Introduction of Ontologies in Medicine.....	7
CHAPTER 2 LITERATURE SURVEY.....	11
CHAPTER 3 INTRODUCTION TO PSYCHOPHYSIOLOGICAL DYSREGULATION.....	17
CHAPTER 4 SOFTWARE DESIGN.....	20
Objective.....	20
Motivation.....	20
OWL.....	21
Technologies and Tools used.....	22
CHAPTER 5 IMPLEMENTATION.....	24
Initial Steps.....	24
Ontology Development.....	26

Database Organization.....	40
Code Snippets.....	41
Output and Results.....	50
CHAPTER 6 TROUBLESHOOTING.....	54
CHAPTER 7 CONCLUSIONS AND FUTURE WORK.....	58
Conclusions	58
Future Work.....	59
REFERENCES.....	60

LIST OF FIGURES

Figure	Title	Page
Figure 1:	Ontology Example.....	9
Figure 2:	Data Flow in the Algorithm.....	24
Figure 3:	Primary Treatments.....	35
Figure 4:	Adjunctive Treatments.....	36
Figure 5:	Class structure.....	39
Figure 6:	DB2 Database.....	41
Figure 7:	Rules in Protégé.....	49

CHAPTER 1

INTRODUCTION

IT TRENDS

All of us know how important Information Technology (IT) is in today's world. IT is used anywhere and everywhere. IT has changed the way we live, learn, work and even communicate with each other [1]. Information Technology means a lot more than just processes, computers, software, hardware, information systems and programming languages.

According to the International Foundation for Information Technology (IF4IT), one of the definitions for Information Technology is [2]:

“The technology used for the study, understanding, planning, design, construction, testing, distribution, support and operations of software, computers and computer related systems that exist for the purpose of Data, Information and Knowledge processing.”

The end of 20th century saw one of the most prominent developments and growth in technology. Nowadays IT is extensively used in areas including telecommunications, mass media, education, aerospace, agriculture, transportation and medicine. IT has indeed improved the quality of our lives by revolutionizing the research and development in various fields of science and engineering. Our economy and society are increasingly

becoming dependent on IT directly or indirectly. Hence the 21st century is becoming a technology and media-suffused environment [3].

Continuing the trends from the twentieth century, the first decade of the twenty first century has seen an exceptional growth in technology like the mapping of the human genome, social media, nanotechnology, space-tourism, global communications and digital storage despite the most infamous ‘millennium Y2K bug’ [4]. And the coming few decades too would witness unparalleled advances in IT without being affected by a few glitches. This tremendous progress in IT has led to the coining of the term ‘Information Revolution’!

IT IN MEDICINE

The advancement of Information Technology in the last four decades led to the use of computers in medicine. In the very early years of the application of computers in the healthcare domain, researchers and professionals have prognosticated the use of these machines in assisting doctors in the diagnostic challenge.

The first professional organization for informatics was founded in 1949 in Germany by Gustav Wegner. The term “Medical Informatics” was first used in France in the 1960s. Since then numerous specialized university departments and training programs for medical informatics have been developed [5]. Health informatics or medical informatics can be defined in a broad sense as “the application of information technology to the healthcare profession with the aim of creating tools and procedures that can help doctors, nurses, and other healthcare personnel diagnose and treat patients more accurately and efficiently.”[6]

Medical Informatics made significant progress in the late 1960s with the development of MUMPS programming language at Massachusetts General Hospital. MUMPS allowed for the creation and integration of medical databases and continues to form the basis for many healthcare software systems.

Health Information Technology (HIT) plays a critical role in providing a more efficient and improved health care [7]. Like any other field, medicine too has its share of problems. These include high costs, medical errors, administrative inefficiencies, and lack of coordination among clinicians. Thus the seven important rules of thumb that form the basis of foundation for HIT are recognized as: avoid medical errors; improve use of resources; accelerate diffusion of knowledge; reduce variability in access to care; advance consumer role; strengthen privacy and data protection; and promote public health and preparedness. These rules led to the realization of the four major goals of the new vision for health care: inform clinical practice, interconnect clinicians, improve population health and personalize care. Despite the challenges posed by the full fledged use of IT in health care, these changes are inevitable and a well-planned, coordinated effort is required for a better health care industry.

In his book [8], Enrico Coiera says that in the early years the development of artificially intelligent computer systems was considered, though controversial, as having a lot of potential in medicine. Scientists hoped for such systems to become the ‘doctors in a box’ that would assist clinicians in diagnostic decision making. This led to the introduction of a new discipline called Artificial Intelligence in Medicine (AIM). These AIM systems were usually described as ‘clinical decision support systems’. Such decision systems, also known as expert systems, were used to perform various clinical tasks like

diagnostic assistance, handling alerts and reminders, prescription of medications, formulation of a treatment plan and critiquing an existing plan, image recognition and interpretation, and information retrieval.

An “expert system” is defined as a software that uses a knowledge base of human expertise for solving problems and clarifying uncertainties in the problem domains [9]. Initially many hurdles forestalled the introduction of such decision support systems like the cost, complexity of medical data and knowledge base, logistical problems, confinement and restriction of scientific research. However, efforts to realize such computer systems continued and resulted in the development of experimental prototypes. The first functional expert systems MYCIN and INTERNIST-1 were developed in the 1970s.

MYCIN was developed at Stanford University to assist physicians in the diagnosis of infectious diseases. The INTERNIST-I system developed at the University of Pittsburgh was used in internal medicine to diagnose extremely difficult cases with an accuracy equal to or even better than that of experienced physicians [10].

In the 1970s and ‘80s there was tremendous increase in the application of decision support systems and in the use of data mining and automated methods in medical informatics. Since mid 1990’s there has been exponential growth in network-based applications like client-server clinical information systems, commercialization of bioinformatics and rise of consumer health informatics. Some of the great inventions in medical informatics include CPRS (Computerized Patient Record System), EMR (Electronic Medical Records) and SNOMED (Systematized Nomenclature of Medicine).

Though initially the information systems in healthcare were used with a lot of skepticism, gradually things changed and people started accepting the idea of computer-based solutions being used by practitioners in healthcare. A couple of reasons for this subsequent evolution in attitudes are the emergence of world wide web (www) and other easy to use interfaces, increasing recognition and adoption of new technologies and vexation among the healthcare professionals regarding the colossal amount of information to be collected, shared, handled and processed [11].

IT IN MENTAL HEALTH

A century or more ago, physical diseases were known to be widespread and were usually left untreated due to lack of resources and research and development in medicine. However now mental diseases such as anxiety, depression and anger have become like that. Mental health problems range from severe psychiatric disorders (such as schizophrenia, bipolar disorder, post-traumatic stress disorder) to less severe psychological disorders (such as phobias and anxiety disorders, depression, eating disorders, learning disabilities) [12].

Research conducted by NIMH (National Institute of Mental Health)[13] shows that mental disorders are common throughout the United States, affecting tens of millions of people each year, and that only a fraction of those affected receive treatment. The treatment, assessment and diagnosis of mental disorders is in many ways different from the treatment and diagnosis of physical diseases. However, in spite of these differences, like any other field mental health too can benefit from Information Technology (IT).

The evolution of technology in mental health gave computerization a pivotal, essential role. For many decades researchers aimed at using IT in mental health. It was in the 1960s that computers were first used in this field. The first breakthrough of IT in this domain was the automated interpretation of psychological tests. Initially, simple computer based applications were used in scoring psychological tests but over the years, the delivery, monitoring and evaluation of cognitive-behavioral therapy and various psychological tests advanced by greater use of information technology.

Informatics researchers continue to examine the validity of the computerized tests in mental health. Though the computer treatment programs surpassed the initial phases of prototyping, developing, and testing in research studies, the industry still has not embraced a comprehensive use [14].

It is now well recognized that use of information technology does improve treatment of mental illnesses. Software systems like PC-based treatment systems, interactive voice response (IVR) treatment systems, and virtual-reality treatment systems are a few examples of systems that have been successfully used in psychotherapy [15]. There are four areas of psychology that greatly use computer technology: client-centered (simulation of therapist–patient dialogue), behavioral, psychoeducational and cognitive interventions (like problem-solving strategies), and cognitive-behavioral (a combination of methods typically employed in cognitive-behavioral therapy (CBT)). It is beneficial to merge computerized treatment programs with the other non-computerized treatment healthcare programs. Information technology services in mental health domain are administered in primary care, secondary care, specialist services, dedicated centers, community resource centers and via the Internet.

Studies show that incorrectly diagnosed cases amount to 78% due to errors in applying DSM (diagnostic and statistical manual of mental disorders) and to 35% due to the clinicians' failure to ask the patient certain important questions [16]. One solution to avoid such human errors is to employ computer administered diagnostic interviews. Unlike clinicians, computers do not forget or fail to ask required questions and so help us obtain absolute and complete patient information by their interviews. Patients can answer the questions at their own pace at any computer terminal and scores are calculated and results are presented by the computer program to the patient or the clinician as soon as the interview is done, which in turn also helps the clinician save time. Hence the use of computer systems in psychotherapy is both cost and time effective. Another considerable advantage is that patients are more likely to give sensitive information to a computer rather than face-to-face to a person (a clinician) like sexual behavior, drug abuse, suicidal tendencies, etc.

One fact to be remembered is that a computer cannot replace a well-trained clinician but can assist and complement human interpretation.

INTRODUCTION OF ONTOLOGIES IN MEDICINE

In the late twentieth century, Artificial Intelligence (AI) adopted the term 'ontology' and began using it in the sense of a "specification of a conceptualization" in the context of knowledge and data sharing (Gruber) [17].

In medicine, representation and organization of medical terminologies is essential. It is easy for physicians to store and communicate medical knowledge with each other

because humans have the ability to implicitly process knowledge. But the ability to communicate complex medical concepts among the various Medical Information Systems becomes difficult. This can be achieved by constructing medical domain ontologies for representing medical terminology. The development of ontologies is definitely not an easy task as an in-depth analysis of the structure and the concepts of medical knowledge is necessary in order to represent the terminology [18]. Figure 1 shows an example of a sample ontology comprising of classes, subclasses, and relations between them.

Ontology is a formal representation of a set of concepts within a domain and the relationships between these concepts. Ontology can be viewed as an archive consisting of various types of objects (entities) that exist in a particular domain of interest. Ontologies are useful in the integration and alignment of heterogeneous knowledge sources in healthcare as well as other complex systems. The main focus of ontologies is representation and organization of medical terminologies. Ontologies make information systems more interoperable. Moreover, ontologies play an important role in transmitting, re-use and sharing of patient data and related domain knowledge.

Experts consider ontology to be the backbone of any meaningful and effective applications in health care. In recent years, there has been an increase of interest in ontology development within the biomedical research community because its benefits have been demonstrated in many applications. A number of programs, foundations and organizations have been set up for developing ontologies in an orderly fashion.

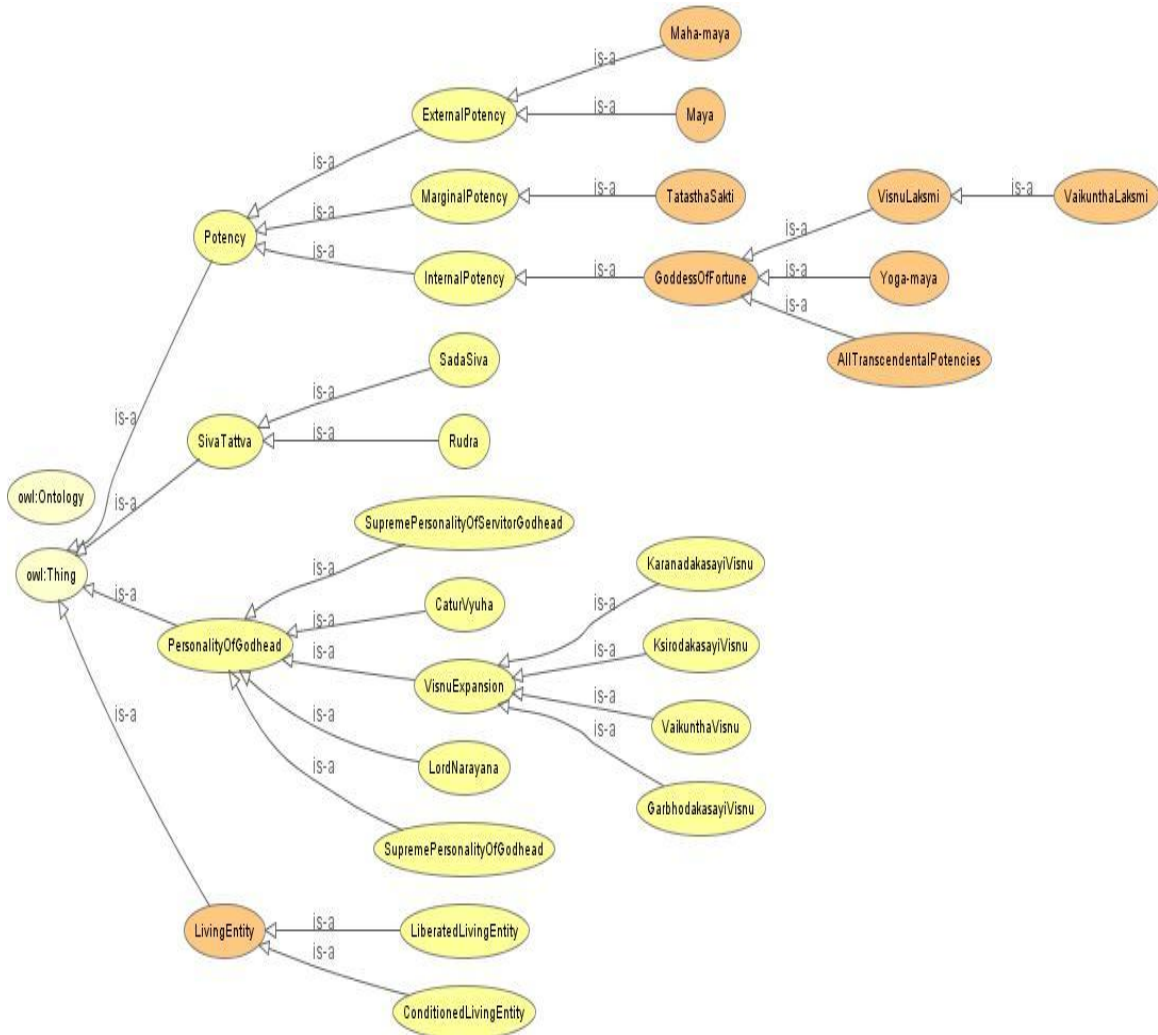


Figure 1

One such collaborative experiment involving developers of science-based ontologies is The Open Biological and Biomedical Ontologies (OBO) Foundry [19]. Its main goal is to build biological and biomedical ontologies that cover a broad area in the domain of life sciences. Some main ontologies realized as desired targets are Gene ontology, Protein ontology and Xenopus Anatomy Ontology.

OBO ontologies became a part of the National Center for Biomedical Ontology (NCBO) in 2006. NCBO [20] is a consortium of leading biologists, clinicians, and

ontologists whose vision is to develop, distribute and administer all biomedical knowledge and information using defined ontologies to make the data systems more interoperable and utilized to the full extent.

The Institute for Formal Ontology and Medical Information Science (IFOMIS) [21] is another research group founded in 2002 which has members from diverse fields like philosophy, computers, information science, logic and medical informatics. Its focus is on theoretically based research in formal and applied ontology.

For the last five to six years, W3 Semantic Web community has been focusing its attention towards health care and medicine. In November 2005 a new interest group called Semantic Web Health Care and Life Sciences (HCLS) was founded to develop and support the use of semantic web technologies to improve research and development in various domains of health care and life sciences. Other chief ontology centers worth mentioning are the National Center for Ontological Research (NCOR) and the European Center for Ontological Research (ECOR) [22].

More on ontologies and psychophysiological disorders is discussed in Chapter 2. In Chapter 3 we present the design of the proposed software system including objective, motivation and the tools used in this project. Chapter 4 is entirely dedicated to the implementation details and output. In Chapter 5 we briefly discuss the problems and errors encountered during the various phases of this implementation and how those issues were resolved. Conclusion and future work are discussed in the last chapter.

CHAPTER 2

LITERATURE SURVEY

As Medical and Clinical sciences are advancing rapidly with new discoveries, the use of Information Technology in these disciplines is becoming more and more essential. One of the primary motivations for adopting IT applications to clinical health is the belief that they improve the quality of patient care. IT provides tools for storing, integrating, updating and processing data in the patient information base.

Health care industry needs transformation in the context of efficiency, quality, cost and delivery of health care. Though experts emphasized the fact that information technology is key to improving health care, adapting the new technology to health care was difficult and its use is still limited. Studies showed that IT was greatly used in administrative and financial fields but not in clinical care delivery [23].

Though technology and media made their way into communication, transportation and finance in the early twentieth century itself, mental health was one field that constricted the use of IT. It was only in the late 1960s that behavioral scientists started experimenting with computerized programs in mental health care delivery. This led to the development of automated patient data systems which greatly reduced paper work at clinics and hospitals and automated clinical techniques that provided solutions to the various disorders in the mental health care domain [24]. Progress in application of IT in mental health led to the development of clinical decision support systems.

Clinical decision support system (CDSS) [25] is an interactive computer software system which is designed to assist physicians and other health care professionals in decision making tasks to determine the diagnosis. Design and development of such systems is really challenging. Despite many years of research and millions of dollars of expenditure on medical diagnostic systems, the decision support systems are not in widespread use as expected in the present time. This is mainly due to the complexity and richness of the medical knowledge base, workflow integration and difficulty in consolidating the enormous quantity of clinical research which is published on an ongoing basis. Ontologies are recognized as appropriate for knowledge encoding within these systems.

The advantages of using CDSS as a system to provide decision support are discussed in [11]. CDSS is considered valuable as a tool for information management and for providing recommendations based on the patient specific data. Building such a system is envisioned along various aspects such as the system's intended function, the mode by which advice is offered, the consultation style, the underlying decision-making process, and the factors related to human-computer interaction.

A major component of a CDSS is ontology; its creation, development and application. Ontologies moved from being just a research topic to being practically used in numerous fields like biomedical informatics, multi-agent systems, e-commerce, geographic information systems, semantic web services, natural language translation, etc. This section briefly discusses some of the existing Ontologies in medicine.

LinKBase[26],[27] is a biomedical ontology. It is a large, comprehensive and extendable knowledge base that supports Natural Language Processing and Understanding (NLP/NLU). It covers various aspects of medicine, including procedures, anatomy, pharmaceuticals and various disorders and anomalies. Basic Formal Ontology (BFO), a formal ontological framework developed by Barry Smith and his associates was used to structure the upper level of LinKBase. It contains millions of knowledge elements and is three times larger than Systematized Nomenclature of Medicine-Clinical Terms (SNOMED CT).

SNOMED CT is a collection of medical terminology containing clinical health care concepts such as diseases, procedures and pharmaceuticals. The SNOMED CT helps improve patient care by facilitating communications and interoperability in electronic health data exchange.

The **Disease Ontology**, a formal ontology of human diseases, was developed at Northwestern University. It maps human disease knowledge between datasets such as patient records and large scale genome, sequencing and microbiome projects. It was initially developed as part of the NUGene[28] project which aimed at the understanding of genetic mechanisms and to assist in the development of DNA-based technology for diagnosis and treatment of disease. It conforms to medical vocabularies such as ICD9/ICD10 (International Classification of Disease), SNOMED, MeSH (Medical Subject Headings), etc.

NCI (National Cancer Institute) Cancer Thesaurus provides definitions, synonyms, and other information on nearly 10,000 cancers and related diseases, 8,000

single agents and combination therapies, as well as a wide range of other topics related to cancer and biomedical research. The thesaurus has been converted to a formal ontology in OWL Lite (Web Ontology Language) to make it more useful and accessible to the public [29].

The **Master Ontology of Cancer** is another cancer ontology that was developed by Advancing Clinico-Genomic Trials on Cancer (ACGT). The ACGT Master Ontology (ACGT MO) has been implemented in OWL-DL which is the description-logic based subtype of the Web Ontology Language. It is a new terminology resource for data exchange in oncology, emphasizing the integration of both clinical and molecular data. ACGT MO integrates ontology based trial management application (ObTiMA) into the design process for guaranteeing automatic semantic integration without the need to perform a separate mapping process [30], [31].

The **Gene Ontology** (GO) is a major collaborative effort in bioinformatics to unify the representation of gene and gene product attributes across all species. In recent years, it became a standard tool in the bioinformatics arsenal. GO covers three domains: cellular component, molecular function and biological process of living units. The GO ontology is non static and public where members of the research and annotation communities can add, correct or alter the ontology after being appropriately reviewed by the ontology editors. GO is part of a larger classification effort namely the open biomedical ontologies (OBO) foundry which is a collective experiment involving

developers of science-based ontologies with the goal of creating a suite of orthogonal interoperable reference ontologies in the biomedical domain [27], [32].

CDSS developed using heart failure ontology is useful for the diagnosis of heart failure patients. **Heart Failure Domain (HEARTFAID)** project [33], [34] was developed by Marin Prcele, Alan Jovic, et al. The ontology was constructed using OWL syntax using the Protégé-OWL tool. HEARTFAID is a research and development project that aims at making all the processes related to diagnosis, prognosis and treatment of the Heart Failure within elderly population more effective and efficient.

Lipid Ontology is another useful work in scientific research. Lipids play a crucial role in the biology and cellular functions of many living organisms. Imbalance in lipid metabolism often causes diseases such as Alzheimer's syndrome, Mycobacterium infections and cancer. Hence a consistent and formal knowledge representation of lipid nomenclature is required to implement and deploy information systems that support the aggregation and interrogation of lipid resources. The ontology describes the LIPIDMAPS nomenclature classification explicitly using description logics (OWL-DL) [35], [27].

Vaccine Ontology (VO) was developed by Dr.Olive He and the VIOLIN (Vaccine Investigation and Online Information Network) development group working with Dr. Barry Smith at the University of Buffalo and Dr. Lindsay Cowell at Duke University. It later became part of the Infectious Disease Ontology (IDO). Vaccine research involves complex processes with various biological data that include gene and

protein expression, study of tissue and whole body responses. Hence a standard representation of vaccine knowledge, integration and analysis of vaccine types and resources data, and automated reasoning is mandatory. To accomplish this goal, VO was initiated and developed. It is represented in OWL and uses Protégé OWL as its editor. Basic Formal Ontology (BFO) is used as the top ontology and Relation Ontology (RO) is used to define term relationships [36], [37].

Foundational Model of Anatomy (FMA) ontology is integrated into the framework of the Anatomy Information System developed and maintained at the University of Washington. The ontology deals with the domain of human anatomy which is foundational for all the other biomedical sciences. Rosse et al [38] proposed that

$$\text{FMA} = (\text{AT}, \text{ASA}, \text{ATA}, \text{Mk})$$

This equation implies that FMA consists of four parts. The anatomy taxonomy (AT) classifies anatomical entities according to the attributes they share with one another. The anatomical structure abstraction (ASA) specifies the partitive and spatial relationships between those entities. The anatomical transformation abstraction (ATA) describes the morphological transformation of the entities during prenatal development and the postnatal life cycle. Finally, the meta-knowledge (Mk) specifies the principles and set of rules that define relationships in the other three components [39].

CHAPTER 3

INTRODUCTION TO PSYCHOPHYSIOLOGICAL DYSREGULATION

In this chapter, we briefly discuss a mental disease called psychophysiological dysregulation which is the main focus of this thesis.

Psychophysiological dysregulation [40], [41] is a condition where emotional or psychological factors predispose individuals to develop physical illness. The other names for this type of disorder are Psychosomatic and Somatoform (The word Psychosomatic was first introduced into medical literature by August Heinroth in 1818). In the year 1927, a British psychiatrist named Alexander Cannon showed how different emotions produced patterns of physiological changes.

In 1936, the American Psychosomatic Society (APS) was founded with a vision to link and articulate the research and development in psychology, physiology, internal medicine and other disciplines of medicine [42]. One of the initial projects undertaken by this group was the psychosomatic medical literature assembly. Psychosomatic illnesses deal with the body symptoms caused by emotional disturbances.

The American Psychiatric Association's Diagnostic and Statistical Manual of Mental Disorders (DSM IV) classifies psychophysiological illnesses as "Psychological Factors Affecting Physical Conditions" [43]. A number of studies have shown how the mind and body interact to bring out either good health or illness. For example, if one is nervous or anxious, one may feel nauseated, may have one's stomach upset or have diarrhea. These physical symptoms are not under the conscious control of the patient and may not be due to any serious physical disease in the past. Moreover, psychiatric disorders can affect any system or organ throughout the body, such as skin, eyes, digestive system, respiratory system, etc. Negative emotions may affect our hormones and lower our immunity to several diseases.

In [44] Dennis H. Novack discusses the rise, fall and rebirth of psychosomatic medicine as quoted by Theodore M. Brown. He says that many years ago, psychosomatic medicine was realized as a research field with a strong perception of clinical mission. In spite of various initiatives and projects ventured by scientists, there was not much success in creating awareness in people about such illnesses. A man having a heart attack after a fight with his boss; a woman's arthritis levels blowing up when she has a serious argument with her grown daughter; and a child suffering from asthma and hypertension at a very young age due to stress -- all these are the most common issues affecting more than half of our population currently that need to be addressed and these issues are to be resolved immediately. Such diseases were always under-recognized and ineffectively treated until very recently.

One of the very typical and risky psychosomatic connections is between aggression, stress and heart disease. An aggressive, impatient person has higher chances of getting a heart attack than a calm and easy-going person. Depression, anger, and social isolation often lead to heart diseases. Stress on the other hand, may cause breathing problems, digestive track disorders and many other physical ailments. These disorders are treated by dealing with either the psychological causes or physical symptoms or both. Since the psychological factor is always variable in such illnesses, it is challenging enough to treat them. The nature of treatment solely depends on the patient and the type and priority of the psychophysiological disorder he is suffering from. Physical symptoms can be treated, and emotional aspects can be addressed and dealt with. Stress management and relaxation techniques are definitely useful. Other treatments include psychological approaches like psychoanalysis, behavioral therapy; medications like antidepressants; or even hypnosis at times.

CHAPTER 4

SOFTWARE DESIGN

OBJECTIVE

The objective of this project is to develop an ontology and an algorithm for diagnosis of psychophysiological dysregulation of anger/aggression. There are many possible problem types under psychophysiological disorders but we deal with only one particular problem type i.e. aggression. In the process we maintain a database for all the patient records.

MOTIVATION

Ontologies are very essential for knowledge sharing in any domain especially in the mental healthcare. However, mental health domain still needs to develop increasingly more sophisticated ontologies. The main hurdle here is the nature of the mental illness itself. As opposed to physical illness, mental illness cannot be diagnosed easily because the cause of the illness or the specific treatment required cannot be identified accurately. This makes it difficult to identify the entities namely the classes, subclasses and their relations while developing the ontology in the first place. We made a sincere attempt to develop an ontology exclusively for a particular psychophysiological disorder.

OWL

This section discusses about the **Web Ontology Language (OWL)**. OWL is a language for creating, managing and sharing data using ontologies. It is endorsed by the World Wide Web Consortium (W3C). The normal syntax used in OWL is RDF/XML tags and schema.

Initially Resource Description Framework (RDF) was used for modeling of information for web resources in the Semantic Web. However, researchers identified the need for a more expressive language than the RDF. The U.S. Defense Advanced Research Project Agency (DARPA) introduced a richer language called DAML (DARPA Agent Markup Language). DAML [45] was later extended to DAML+OIL which combined the features of DAML and OIL (Ontology Inference Layer or Ontology Interchange Language) which was later succeeded by OWL. Many medical ontologies have been created using OWL. OWL has three sublanguages: OWL Full, OWL-DL (Description Logic) and OWL Lite.

Ontologies are created and designed in a simpler way by using editors. FluentEditor for OWL, JOE, OBO-Edit, Protégé, Swoop, WebODE are some of the editors used. Among these, **Protégé** is the most commonly used editor due to its relatively more advanced features, capabilities and ease of use. It is a free, open source editor developed at the Stanford University, written in Java that heavily uses Swing for the user interface. Ontologies can be accessed and edited from Java code using Protégé-OWL API and there are many developed plug-ins and applications in Protégé. Protégé

also supports databases that have JDBC drivers like Oracle, MySQL, MS Access, etc. There are several various versions of Protégé. We have used Protégé 4.1 Beta for developing the ontology presented in this thesis.

Ontologies may result in inconsistencies due to any discrepancies while developing them. To correct the inconsistencies, Semantic reasoners were designed. A Reasoner is a software that can infer logical consequences from a set of inference rules of an ontology language. Several open source reasoners are available, e.g. FACT++, RacerPro, HermiT and Jena.

TECHNOLOGIES AND TOOLS USED

We used **Java** programming language to develop an interactive software wherein the patient or the clinician enters required data into the decision support system. We also created the ontology from the Java program using OWL API (Application Programming Interface) which is an open source Java API. Java is one of the very advanced programming languages presently and even for the future. It is platform and machine-independent so it can be used on any machine and any operating system. Hence we selected this language for the development of our software.

Eclipse Helios is an Integrated Development Environment (IDE) or in simple terms, the editor used for programming Java code. It is user friendly and has an extensible plug-in system.

Protégé 4.1 Beta is the tool that we used to visualize the ontology. It is one of the most widely used editors for OWL. It is still being improvised to have more functionality compared to the previous version 3.4 that we used earlier.

DB2 developed by IBM is the relational database that we used to store the patient records. It contains all the data right from patient's basic info to the scores from various clinical assessment tests and also the treatment methods.

CHAPTER 5

IMPLEMENTATION

INITIAL STEPS

For the development of a diagnostic software our first step was to develop an algorithm and a flow chart that described briefly what the workflow would be.

SOCRATES [46], a prototype, was developed in 2004 to conceptualize a clinical decision support system. It was built to support clinical decision-making. The flowchart given below is a simpler version of the original organization given in SOCRATES. We used this simpler version in our project.

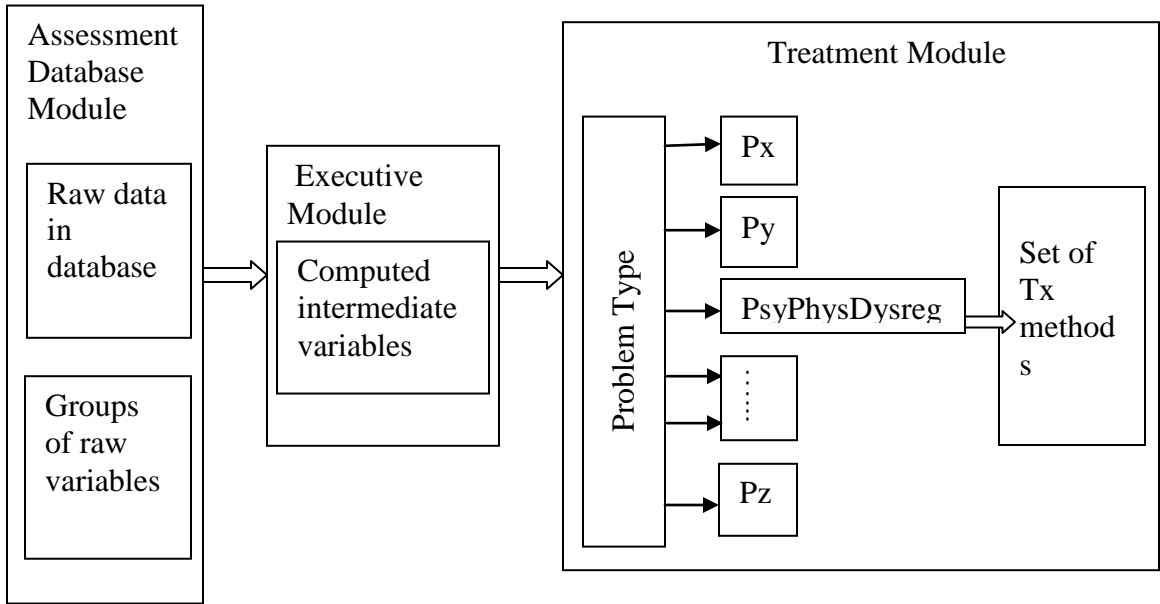


Figure 2

Assessment Module: basically consists of patient information like name, age, medical history of the patient like whether he has active psychosis or tendency of non-suicidal self-harm as indicated by results from standard clinical assessment tests like BPRS, NAB-S, etc. These values are stored in the database in the patient records. While making any decision, the clinician accesses the database and inspects these values to proceed to the necessary procedures.

Executive Module: consists of the newly computed intermediate variables for algorithms. Depending on the variables in the database, we compute the probabilities of few variables required and for this purpose we declared and used temporary variables. The module helps in interpreting the patient data, interacting with the clinician team and communicating the treatment team decisions. This is an important module which actually computes the final result that determines the problem type of the patient.

Treatment Module: consists of a sub-module called ‘Problem type’ that maintains a list of possible problem types. From the variables of the executive module, we determine the problem the patient is suffering from. There are a variety of problem types possible but we focus on one problem in our project; psychophysiological dysregulation of anger (PsyPhysDysreg). Once the problem type is known, the necessary steps for the treatment as developed by the sub-module of the Treatment module, ‘Set of Treatment Methods’, can be executed. Another sub-module of the treatment module is ‘TAC Module’ which is the acronym for Therapy/Activity/Class. It consists of a database to track the implementation of the treatment therapy and also the client’s response to it. This module

collects and records data about patient's therapy like TAC id, scheduled hours for therapy, hours attended or cancellations initiated by the patient, behavior profile like attention, participation, modality progress scale of the patient are recorded.

Once we have developed the flowchart and the appropriate algorithm, the next step to develop the ontology is followed.

ONTOLOGY DEVELOPMENT

The first step in developing the ontology was to identify the possible classes, sub-classes, relationship between them, object properties, datatype properties and instances of the classes. Given below is a brief description of the entities that we have identified for the proposed ontology.

- A. **Patient:** This class is the initial class that contains patient info. The clinician or the patient himself is required to fill these details in the computerized questionnaire. It has a subclass **Basic_Details** which stores the basic information of the patient like his name, age and sex which are represented as the datatype properties. It is this subclass for which we create individuals or members like Darwin, David, etc. This data is stored in a relational database (we used DB2) so that formal patient records are available for future use.

B. Historical_archive: This class contains the medical history of the patient.

Based on the details provided by the patient, the different probabilities are calculated that help the system determine the type of the problem. There are four subclasses in it.

1. **P_of_aggr-indep_of_active psychosis:** The purpose of this subclass is to determine the probability of aggression independent of active psychosis i.e. the observed aggression is not linked only to the psychotic symptoms. This value increases if the patient has History of aggression, History of aggression while on maintenance antipsychotics (medication used to manage psychosis) or while on maintenance mood stabilizers (medication used to treat psychosis) but does not have History of aggression specific to acute psychosis. The four subclasses of this subclasses are: hx_of_aggr, hx_of_aggr-acute_psychosis, hx_of_aggr-antipsychotic and hx_of_aggr-mood_stabilizer.
2. **P_of_r/o-social_skill_deficit:** This subclass allows the system to rule out developmental social inadequacy in the patient. The probability computed in this subclass increases if the patient does not have History of severe global personal inadequacy and aggression specific to institutional context. This subclass has two associated subclasses. These subclasses are: hx_of_aggr-institutional_context and hx_of_global_personal_inadequacy.

3. **P_of_r/o-unacceptable_behavior:** This subclass allows the system to rule out non-aggressive antisocial behavior. The associated probability increases if the patient does not have History of non-aggressive SUB (socially unacceptable behavior), History of non-aggressive SUB while on maintenance antipsychotic medication and also while on maintenance mood stabilizers but does have History of non-aggressive SUB specific to acute psychosis. This subclass has four sub-classes: hx_of_nonaggrsub, hx_of_nonaggrsub-acute_psychosis, hx_of_nonaggrsub-antipsychotic and hx_of_nonaggrsub-mood_stabilizer.
4. **P_of_r/o-psychophys_dysreg:** This subclass allows the system to rule out psychophysiological dysregulation for multiple systems. The probability increases if there is no History of non-aggressive SUB, no History of non-suicidal self-harm, no History of poly-substance abuse but does have History of sexual promiscuity/heterosexual preoccupation. The four respective subclasses of this subclass are: hx_of_non_aggr_sub, hx_of_nonsuicidal_self-harm, hx_of_polysub_abuse and hx_of_sexual_promiscuity.

C. **Std_Clinical_Assessment:** This is the next main class in the class hierarchy.

It involves the battery of tests conducted on the patient to determine his problem type based on the values or scores obtained in these psychological tests. It has the following four subclasses:

1. **Mental_status_exam:** The first of the four subclasses is Mental status exam (MSE). MSE is psychiatric equivalent of a physical or medical examination. MSE indicates how the patient is doing right now i.e. what is the present state of patient's mental health. The type of MSE most useful for this part of the decision-making is an assessment of ongoing symptoms and other key indicators. It has one subclass.

a) **BPRS_items:** The Brief Psychiatric Rating Scale (BPRS) is a rating scale which a clinician or researcher uses to measure psychiatric symptoms such as depression, anxiety, hallucinations and unusual behavior. Each symptom is rated 1-7, and depending on the version, a total of 18-24 symptoms are scored [47]. There are three specific BPRS items: BPRS-x, BPRS-y and BPRS-z. These items measure the three psychotic symptoms (hallucinations, delusions and confusion) respectively that contribute to the computed probability that the person is presently psychotic.

2. **Neuropsych_assessment_battery:** The second subclass of Std_Clinical_Assessment is Neuropsychological Assessment Battery (NAB). NAB is a set of psychological tests designed explicitly to assess impaired brain function. The tests are administered by a specially trained technician or professional. It has the following one subclass:

a) **NAB-S:** NAB-Screening determines if the 'neurocognition is grossly intact'. It takes an hour usually to do the initial "screening" tests, and

several more to complete an entire NAB. In general the Tests and procedures employed in a neuropsychological examination vary as a function of:

- Purpose of examination.
- Neurological intactness of the examinee.
- Thoroughness of the examination.

In our project we collect three sample scores in these tests namely NAB-x, NAB-y, NAB-z.

3. **Social_cognition&skills_battery:** Social cognition is the study of how people process social information, especially the encoding, storage, retrieval, and application of information to social situations [48]. Social skills are a behavioral manifestation of social cognition. Hence there is a battery of tests to determine these two aspects. It has the following two subclasses.
 - a) **AIPSS:** The Assessment of Interpersonal Problem Solving Skills (AIPSS) is a role play test of the examinee's cognitive and behavioral skills to solve interpersonal problems. Hence we use a fictional measure of inter-personal problem solving to increment the probability that observed aggression is the result of impaired self-control versus lack of social skills. This test monitors the patient's problem solving skills. It has a score between 1 and 100.
 - b) **Hinting_task:** This test involves a set of questions of fictional conversations which is an indicator of the theory of the patient's

mind. We take one value for this purpose that ranges from 0-20. Higher the score, the better problem solving ability the patient has, that is, 0 indicates that problem solving ability is poor in the patient while 20 indicates it is high.

4. **Risk_assessment_battery:** This subclass represents another battery of tests done to see if the patient is a risk or a possible threat to himself or the society. It has one subclass.

a) **Sociopathy_screen-Hare:** Sociopathy_screen-Hare is a specialized type of social history combined with structured interview named the “Hare” after the researcher who developed it. This subclass determines whether the patient is above the statistical threshold for sociopathy, which would reduce the probability that the aggression results from psychophysiological dysregulation. We take three sample scores here HARE-x, y and z each ranging from 1-100. Any score above 80 indicates that sociopathy is a symptom of the patient.

D. **Problem_Type:** This is another main class which lists out the exact problem the patient is suffering from. There are a number of possible problem types in psychophysiological dysregulation. We elaborate and discuss one of these problem types: anger or aggression. It has the following six subclasses:

1. **Defined_in_terms_of:** A specific problem type is defined in terms of key characteristics, presumptive cause, treatment indications, nature of

expected treatment response and moderating factors or dimensions. These are represented as five different subclasses as follows:

- a) **Key_characteristics:** The key characteristics of psychophysiological dysregulation of anger/aggression include aggression and related antisocial behavior stemming from an inability to control or manage autonomic and emotional arousal, and abnormally high autonomic and emotional sensitivity to interpersonal and environmental situations that evoke anger, not attributable to CNS dysregulation, social skills deficits or environmental circumstances.
- b) **Presumptive_cause:** dysregulation of interacting cognitive and autonomic arousal systems.
- c) **Tx_indications:** The subclass Tx_indications includes some combination of
 - ongoing aggression or related antisocial behavior
 - observable behavioral and physiological arousal
 - history of beneficial response to treatment targeting cognitive control of arousal, anger and aggression
- d) **Expected_tx_response:** The nature of the expected treatment response is the elimination of aggression and related antisocial behavior.
- e) **Moderating_factors:** The two factors or dimensions for this problem type that moderate the response to treatment are:

- i. social competence dimension: presence or history of social/interpersonal skill deficits
 - ii. cognitive dimension: presence or history of cognitive or neurocognitive impairment
2. **Problem_description:** This is the second subclass of Problem_Type which presents the narrative description of problem, e.g. “Aggressive behavior and physical intimidation associated with anger, frustration or interpersonal conflict, frequency is 1-2 instances per week, targeting vulnerable peers, family or service providers, with history of significant physical injury to victim.”
3. **Priority_level:** The Priority_level subclass reflects whether treatment will proceed immediately. It shows the expected outcome. It ranges from 1-4; 1 being the highest and 4 being the least priority.
4. **Long_term_goal:** This subclass gives a narrative description of problem resolution, e.g. “Uses appropriate problem-solving without aggression or related antisocial behavior.”
5. **Short_term_goal:** Similar to the above subclass, this subclass gives a narrative description of intermediate goals, e.g. “Abstains from aggression for 1 month”.
6. **Key_indicators:** designated variables in the database selected for tracking response to treatments/interventions.

E. **Intervention:** The fifth main class in the class hierarchy is Intervention ontology for psychophysiological dysregulation of anger/aggression. This class describes a set of designated treatments and other modalities selected to treat this problem. It has one subclass:

1. **Formulary:** This subclass represents Formulary/Treatment array for psychophysiological dysregulation of anger. The most basic definition for Formulary is a list of medicines. It usually specifies which medicines are approved to be prescribed under a particular contract for a specific treatment. But here, in the development of the ontology, we use Formulary in the sense of various treatments or therapies advised to the patient depending on his problem type. There are two kinds of treatments—primary and adjunctive which are the two subclasses here.

a) **Primary_tx:** Primary treatments (directly targeting the dysregulation and related behavior) include the following:

- Dialectical cognitive-behavioral therapy
 - group component
 - dyadic component
- Physical relaxation/stress management therapy
- Counterconditioning therapy
- Anger management therapy

b) **Adjunctive_tx:** Adjunctive treatments (targeting barriers to primary treatment) include the following:

- Behavior management / contingency management program (for cognitive and motivational barriers)
- Social skills training (for interpersonal motivational barriers)
- Psychopharmacotherapy to temporarily moderate extreme physiological arousal components (for neurophysiological barriers)

Below are two screenshots that show the members of Primary and Adjunctive treatments in the ontology in Protégé editor.

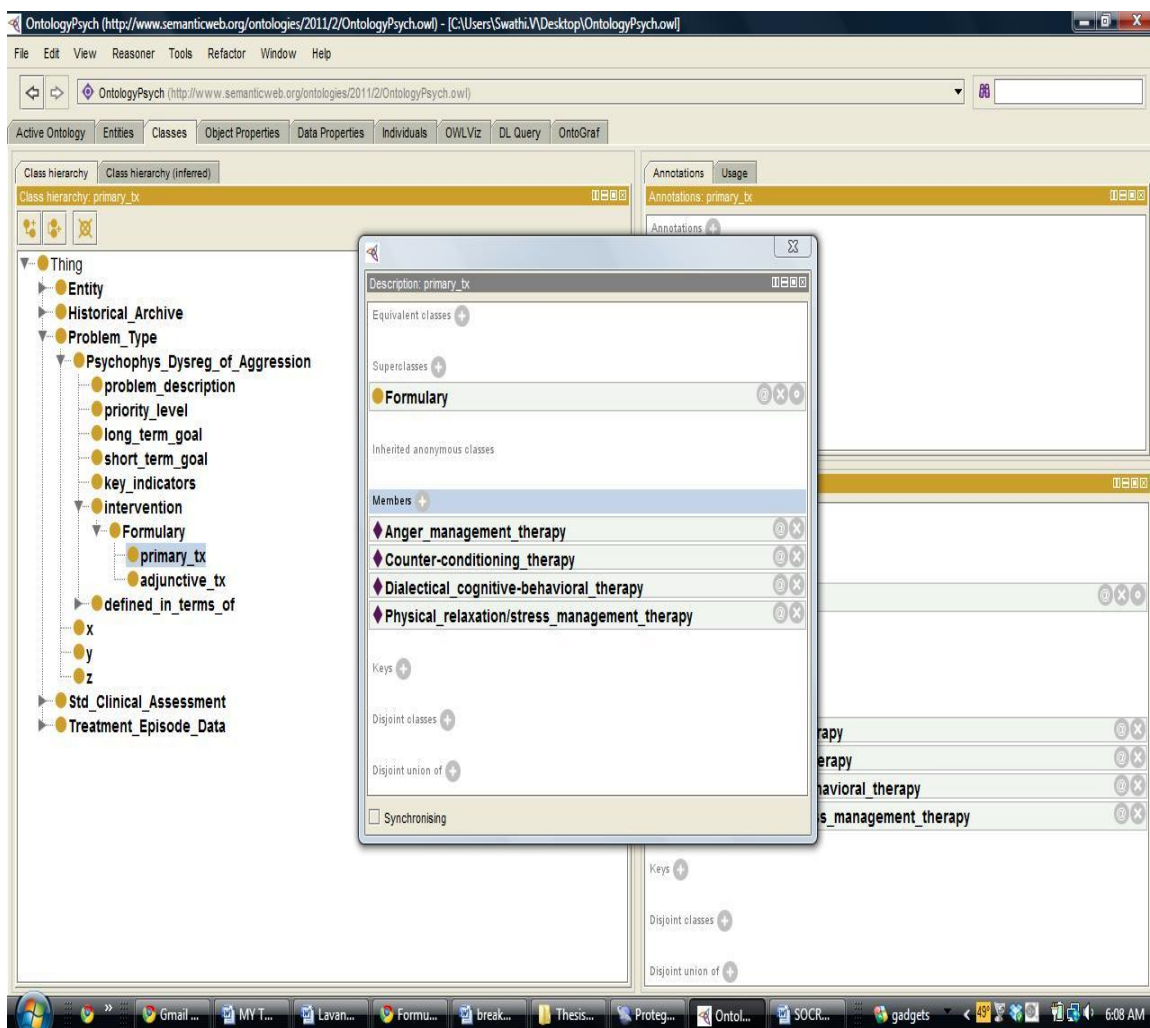


Figure 3

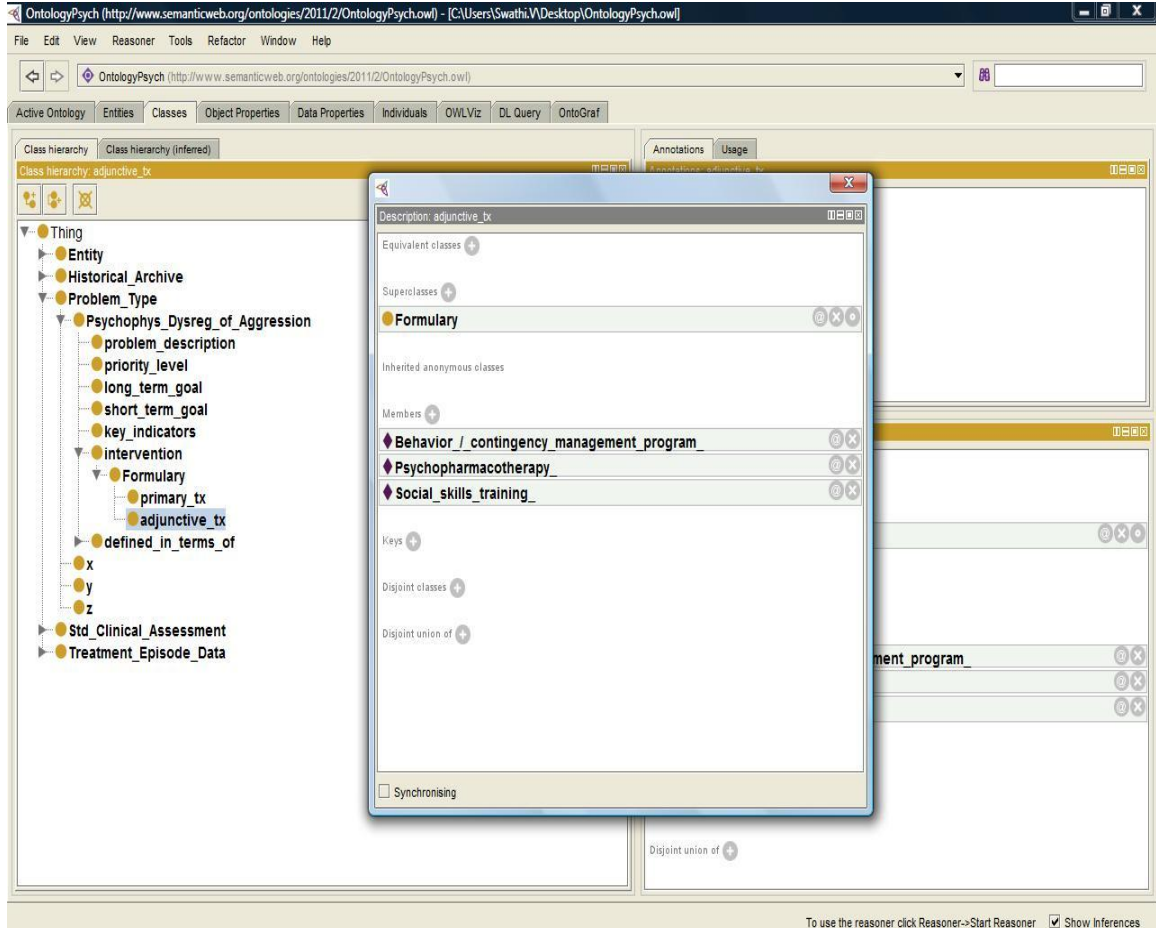


Figure 4

F. Problem_Priority: This is the sixth main class of the ontology. A proper treatment plan is defined if the priority level of the problem is known. This value is entered by the clinician after examining the patient and evaluating and assessing the data from various tests. It has a value between 1 and 4; 1 being the highest priority and 4 being the lowest priority. This class has two subclasses as given below.

1. **Greater_than_Equals_3:** If the value of problem priority is greater than or equal to 3 i.e. 3 or 4, then the treatment can be done if the patient wishes to; there's no hurry.
2. **Less_than_3:** If the priority is less than 3 i.e. 1 or 2, then immediate action is definitely required since it indicates the highest priority. There are two subclasses in this: Tx_selection and Tx_monitoring.
 - a. **Tx_selection:** Here we decide what kind of treatment therapy is to be followed by the patient. It has three subclasses.
 - i. **Requiring_immediate_management:** If the frequency or intensity of aggression or related antisocial behavior demands an immediate preventive management, then algorithm for psychopharmacotherapy for anger/aggression and algorithm for FAB (frontal assessment battery)/BMP (behavioral management program) for aggression are suggested.
 - ii. **Pref_for_anger_mgmt_over_dcbt:** If the preferences & abilities of the patient favor skill training over dialectical CBT, then anger management therapy should be started. If it is not preferred, then dialectical cognitive behavioral therapy should be started.
 - iii. **Pref_for_countercondi_over_grprelax:** If the patient has preferences & abilities that favor counterconditioning therapy over group relaxation/stress management, then

counterconditioning therapy should be initiated, otherwise relaxation/stress management should be initiated.

- b. **Tx_monitoring:** This is the second subclass of Less_than_3 priority class. The patient is monitored at regular intervals by the clinician to see his improvement while undergoing the treatment. The monitoring goes on until the priority level of the problem has reduced to 4.
- i. **Last_24_hours:** If there has been an instance of aggression or related antisocial behavior during last 24 hours, then the algorithm for psychopharmacotherapy for anger/aggression should be followed along with the algorithm for FAB/BMP for aggression.
 - ii. **Past_day:** If the patient's adherence to treatment schedule has not been complete, then algorithms for FAB/BMP for rehabilitation nonadherence should be followed.
 - iii. **Past_week:** If for each modality listed on Treatment Plan under psychophysiological dysregulation of anger the adherence is more than 75% then follow rehabilitation nonadherence.
 - iv. **Past_month:** If the instances of aggression have been lower than the last month, then FAB/BMP and psychopharmacotherapy for aggression can be suggested.

- v. **3-month_interval:** If for each modality listed on Treatment Plan under psychophysiological dysregulation of anger TAC does not show expected progress then respective treatment review algorithm.

Below is the screenshot of the entire class structure as viewed in Protégé.

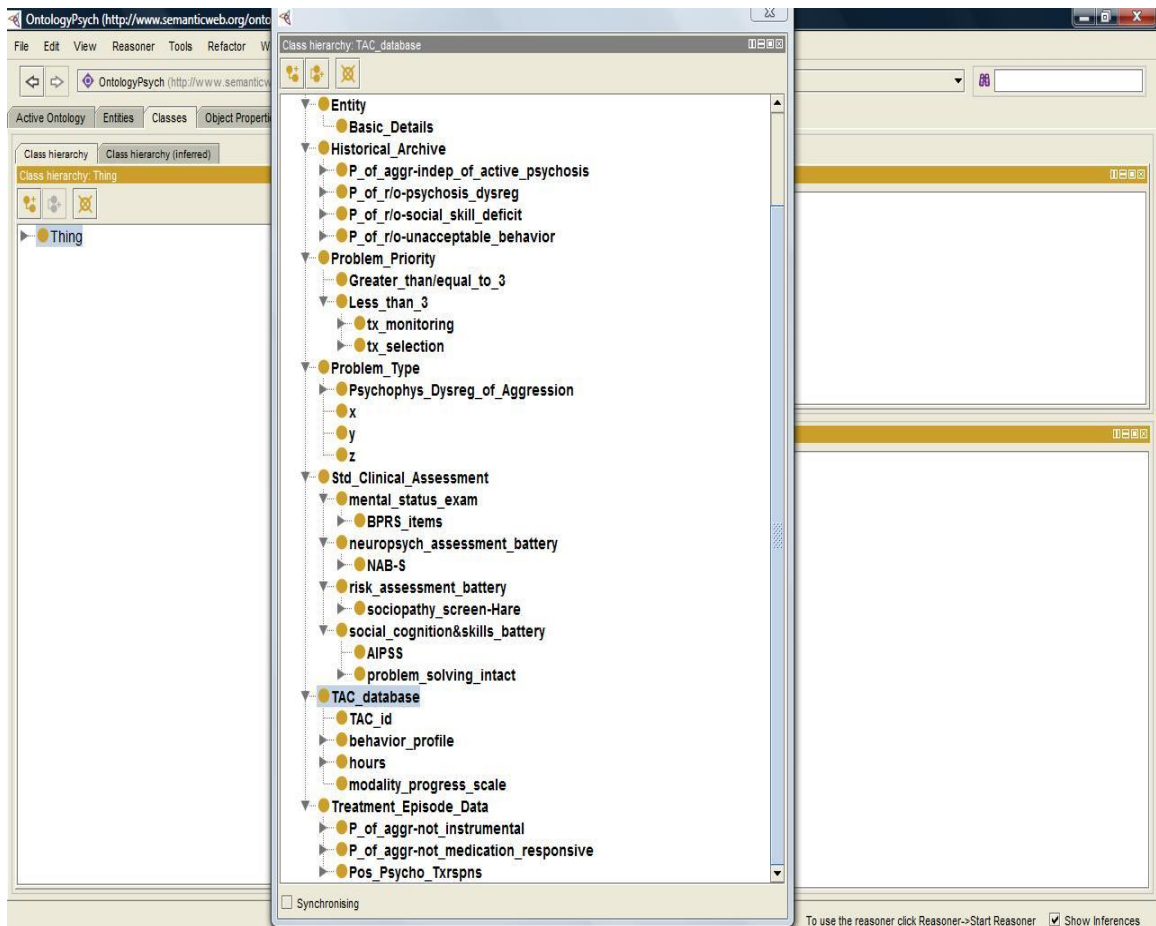


Figure 5

DATABASE ORGANIZATION

In this section, we briefly describe the organization of the database and the kind of data stored in it. The relational database DB2 contains the patient information as records. The clinician enters data as per the questions asked by the computer program; all this data is saved in the database as the respective column values. Thus there are columns like name, age, sex, todays_date, h_aggr_acute_psychosis, h_nonaggr_mood_stabilizer, bprs_x, nab_y, ps_z, problem_type, priority, aggr_req_immed_mgmt, etc for each value entered.

There is a module named TAC (Therapy/Activity/Class) in the database. This module stores the data of the patient while he is undergoing any kind of treatment. Each patient has a unique Tac id. The clinician conducts periodic reviews and records the number of hours actually scheduled for a particular therapy for the particular patient along with how many hours did the patient attend, cancel or got it excused for some reason among the scheduled hours are also recorded. The clinician enters the values which determine the patient's behavior profile on a scale from 1 to 4 what is the score obtained by the patient during the treatment therapy for his attention, participation, spontaneity, etc. And finally the clinician enters the score for his overall progress which is a value between 1 and 10.

The column values in the database are: TAC id#, Scheduled hours, Cancelled hours, Excused hours, Attended hours, Behavior Profile and Modality progress scale [1..10].

Behavior profile has six other values in it. They are: Attention [1..4], Participation [1..4], Spontaneity [1..4], Withdrawn [1..4], Bizarre [1..4] and Disruptive [1..4].

Below is the screenshot of the database containing various patient records.

SWATHI-PC - DB2 - ANGER - SWATHI.PATIENT_RECORDS

Edits to these results are performed as positioned UPDATES and DELETES. Use the Tools Settings notebook to change the form of editing.

ID	NAME	AGE	SEX	TODAY'S_DATE	H_A...	H_AG...	H_AG...	H_AG...	H_GL...	H_AGG...
1	sid		30 male	Apr 9, 2011	1	0	1	1	0	
1	sid		30 male	Apr 9, 2011	1	0	1	1	0	
2	karnaa				0					
1	sid		30 male	Apr 9, 2011	1	0	1	1	0	
1	sid		30 male	Apr 9, 2011	1	0	1	1	0	
1	sid		30 male	Apr 9, 2011	1	0	1	1	0	
1	ajay						1	1	0	
1	hello						1	1	0	
1	null						1	1	0	
1	madhu	27	female	Sep 9, 2011	1	0	1	1	0	
1	indu latha	26	female	Sep 4, 2011	1	0	1	1	0	
1	vasant	25	female	Mar 30, 2011	1	0	1	1	0	
1	bala	23	male							
1	balaji	23	male	Sep 8, 2011	1	0	1	1	0	
1	deepu	22	female	Sep 10, 2011	1	0	1	1	0	
1	karan	23	male	Apr 4, 2011	1	0	1	1	0	
1	rasu	26	female	Aug 8, 2011	1	0	1	1	0	
1	depand	23	female	Sep 9, 2011	0	0	0	0	0	
2	ashu	28	male	Sep 9, 2011	1	0	1	1	0	
1	sallu	40	male	Jan 1, 2011	0	0	0	0	0	
1	srk	40	male	Feb 2, 2011	0	0	0	0	0	
1	aish	39	female	Jan 2, 2011	1	0	1	1	0	
1	hii	10	m	Aug 29, 2011	1	0	1	1	0	
1	JOSHI	28	female	Dec 12, 2011	0	0	0	0	0	
1	nwtsup	72	male	Dec 12, 2011	0	0	0	0	0	
2	joey	45	male	Dec 12, 2011	1	0	1	1	0	
1	dhoni	34	male	Apr 9, 2011						
1	Dhoni	34	male	Apr 9, 2011	1	0	0	0	0	
2	srt	38	male	Nov 11, 2011	1	0	1	1	0	
1	hmm	2	m	Nov 11, 2011	0	0				
1	ish	56	fem	Feb 12, 2011	0	0	0	0	0	
1	ababa	11	f	Jan 10, 2011	0	0	0	0	0	

Shows sample rows of table. You can change the any of the displayed cell selecting a cell and typing value. You might need to scroll bars to see all of the columns. If a column contains one of the following data types, its not displayed: GRAPHIC, VARCHAR, LONG VARCHAR, BLOB, and DECIMAL. For types, a limited number of characters are displayed. If a column distinct type based on or preceding data types, its not displayed.

Commit Roll Back Filter Fetch More Rows

Automatically commit updates

34 row(s) in memory

Close Help

Figure 6

CODE SNIPPETS

We developed Java code to create the ontology and also to store the patient records in database DB2.

The code related to connectivity to the database is as follows:

- ‘import’ statements are used to specify the classes from other packages that we want to reference. Here we require the connection, drivers, resultset from the java.sql package.

```
import java.sql.Connection;
import java.sql.DriverManager;
import java.sql.SQLException;
import java.sql.Statement;
import java.sql.ResultSet;
import java.util.Iterator;
import java.io.*;
```

- To get connected to the database and then create a Statement to query the database, the following code is used:

```
Connection connection = null;
String driver = "com.ibm.db2.jcc.DB2Driver";
String url =
"jdbc:db2://localhost:50000/Anger:user=user;password=pwdpwd";

    Class.forName(driver);
    connection = DriverManager.getConnection(url);
    if(connection != null){
        System.out.println("connected");
    }else{
        System.out.println("Failed");
    }

    Statement stmt = connection.createStatement();
    //insert values into the database
    stmt.executeUpdate(" insert into patient_records (id, name)
values ('1','Harry' )" );
    //To get values from the database:
    ResultSet result = stmt1.executeQuery("SELECT * FROM
patient_records WHERE name='Harry' ");
```

In DB2, to create a table with a certain column values of a particular data type (integer, string, varchar, date) we write the following sample lines:

```
create table patient_records
(
id int,

name varchar(255),
age int,
```

```

sex varchar(10),
todays_date date,

h_aggr integer,
h_aggr_acute_psychosis int,
h_aggr_antipsychotic int,
h_aggr_mood_stabilizer int,

h_global_personal_inadequacy int,
h_aggr_insti int,

problem_type varchar(255),

priority int,
new_date date,
aggr_req_immed_mgmt int,
pref_for_anger_mgmt int,
pref_for_counter_cond int,
aggr_past24hrs int,
adhere_tx_pastweek int,
aggr_thismonth int

};

```

The Java code to create the ontology is discussed briefly below. Protégé (core, standalone, core-trunk) and Jena plug-ins were installed for this purpose.

- The ‘import’ statements required to create the ontology are:

```

import edu.stanford.smi.protege.exception.OntologyLoadException;
import edu.stanford.smi.protegex.owl.ProtegeOWL;
import edu.stanford.smi.protegex.owl.model.OWLDatatypeProperty;
import edu.stanford.smi.protegex.owl.model.OWLModel;
import edu.stanford.smi.protegex.owl.model.OWLNamedClass;
import edu.stanford.smi.protegex.owl.model.RDFIndividual;
import edu.stanford.smi.protegex.owl.model.RDFSClass;

```

- Statements used to create ontology, create a class and a subclass :

```

OWLModel owlModel = ProtegeOWL.createJenaOWLModel();

// create the entire class structure of the ontology
OWLNamedClass patientC = owlModel.createOWLNamedClass("Patient");

// Create subclass (easy version)

```

```
OWLNamedClass basdetC =
owlModel.createOWLNamedSubclass("Basic_Details", patientC);
```

- Once the entire class structure is created, it can be viewed using the function

`printClassTree()`

```
private static void printClassTree(RDFSCClass cls, String indentation)
{
    System.out.println(indentation + cls.getName());
    for (Iterator it = cls.getSubclasses(false).iterator();
it.hasNext();)
    {
        RDFSCClass subclass = (RDFSCClass) it.next();
        printClassTree(subclass, indentation + "    ");
    }
}
```

- The sample output of the above function is

```
Patient
  Historical_Archive
    P_of_aggr-indep_of_acute_psychosis
      hx_of_aggr
      hx_of_aggr-acute_psychosis
      hx_of_aggr-antipsychotic
      hx_of_aggr-mood_stabilizer
    P_of_r/o-psychosis_dysreg
      hx_of_non_aggr_sub
      hx_of_nonsuicidal_self-harm
      hx_of_polysub_abuse
      hx_of_sexual_promiscuity
    P_of_r/o-social_skill_deficit
      hx_of_aggr-institutional_context
      hx_of_global_personal_inadequacy
    P_of_r/o-unacceptable_behavior
      hx_of_nonaggrsub
      hx_of_nonaggrsub-_mood_stabilizer
      hx_of_nonaggrsub-acute_psychosis
      hx_of_nonaggrsub-antipsychotic
  Std_Clinical_Assessment
    mental_status_exam
      BPRS_items
        BPRS-x
        BPRS-y
        BPRS-z
    neuropsych_assessment_battery
      NAB-S
      NAB-x
```

```

        NAB-y
        NAB-z
    risk_assessment_battery
        sociopathy_screen-Hare
            HARE-x
            HARE-y
            HARE-z
    social_cognition&skills_battery
        AIPSS
        problem_solving_intact
            PS-x
            PS-y
            PS-z

```

- Each class or subclass can have any number of datatype properties. To create and map those properties, the code is as follows:

```

OWLDatatypeProperty namePrp =
owlModel.createOWLDatatypeProperty("pname");
    namePrp.setRange(owlModel.getXSDstring());
    namePrp.setDomain(basdetC);

    OWLDatatypeProperty agePrp =
owlModel.createOWLDatatypeProperty("page");
    agePrp.setRange(owlModel.getXSDint());
    agePrp.setDomain(basdetC);

```

- The constraints on these properties are specified too. For example, let us impose a restriction on the number of ‘gender’ options (i.e. 2 –male and female).

```

OWLNamedClass basdetC = owlModel.createOWLNamedClass("Basic_Details");
OWLObjectProperty property =
owlModel.createOWLObjectProperty("gender");
    OWLRestriction pRestriction =
owlModel.createOWLMaxCardinality(property, 2);

```

- We create individuals or members for any class as desired. For example, there is a patient ‘Fred’ listed as an individual under the class ‘Basic_Details’. We set the value of one of its properties and specify it to be an integer.

```

RDFIndividual darwin = basdetC.createRDFIndividual('Fred');
    darwin.setPropertyValue(p1Prp,p_aggr_indep_activepsych );

```

```
Integer intValue1 = (Integer)
darwin.getPropertyValue(p1Prp);
```

Rules: Special Feature of Ontology

In this section, we describe the ‘rules’ functionality of the ontology developed.

One strong difference between a general database and an ontology is that the latter provides powerful deductive reasoning in the form of ‘rules’. ‘Rules’ is a special functionality of ontologies which differentiates the ontologies from relational databases. Rules help to check the consistency and accuracy of the logic of the ontology i.e. its classes, structure and relationship between the entities. Semantic Web Rule Language (SWRL) is an expressive OWL-based rule language that allows users to write rules. Each rule consists of two parts: an antecedent (body) and consequent (head).

Example:

```
hasParent(David,Lisa) ^ hasSister(Lisa,Rachel) -> hasAunt(David,Rachel)
```

OWL 1.0 did not allow users to define rules like the example above (hasAunt defined in terms of hasParent and hasSister). This concept of rules was added to OWL 2.0. Protégé 3.4 has a user-friendly built-in capability called a SWRL tab but this feature is not yet available in Protégé 4. However, version 4 supports working with rules by a particular view in the user interface called “Rules” view.

Below we show some example rules that we used in our ontology.

- Patient(?p), hist_of_aggr(?p, "yes"), hist_of_aggr-maintenance_antipsychotic(?p, "yes"), hist_of_aggr-maintenance_moodstabilizer(?p, "yes"), hist_of_aggr-specific_to_acutepsychosis(?p, "no") -> p1(?p, "increases")

Meaning: If Patient has any history of aggression, aggression while on maintenance antipsychotics or mood stabilizers and does not have aggression specific to acute psychosis, then the probability of the patient having aggression independent of active psychosis increases.

- Patient(?p), hist_of_global_personal_adequacy(?p, "no"), hist_of_aggr-specific_to_institutional_context(?p, "no") -> p3(?p, "increases")

Meaning: If Patient does not have history of severe global personal inadequacy or aggression is specific to institutional context, then the probability of r/o social skill deficit increases.

- Patient(?p), hist_of_nonaggrsub(?p, "no"), hist_of_nonaggrsub-specific_to_acutepsychosis(?p, "yes"), hist_of_nonaggrsub-maintenance_antipsychotic(?p, "no"), hist_of_nonaggrsub--maintenance_moodstabilizer(?p, "no") -> p4(?p, "increases")

Meaning: If Patient has non-aggressive SUB specific to acute psychosis and does not have non-aggressive SUB while on maintenance antipsychotics or mood stabilizers, then probability of r/o socially unacceptable behavior increases.

- Patient(?p), hist_of_nonagrsub(?p, "no"), hist_of_suicidal(?p, "no"), hist_of_polysub_abuse(?p, "no"), hist_of_sexual_promiscuity(?p, "no") -> p2(?p, "increases")

Meaning: If Patient does not have any history of non-suicidal self-harm, poly-substance abuse and sexual promiscuity/heterosexual preoccupation, then probability of r/o psychophys. dysreg. /multiple systems increases.

- Patient(?p), currently_active_psychosis(?p, "no"), neurocogn_grossly_intact(?p, "yes"), social_probsolving_intact(?p, "yes"), sociopathy_above_threshold(?p, "no") -> problem_present(?p, "yes")

Meaning: If Patient does not have currently active psychosis or Sociopathy above threshold but has Neurocognition and Social problem solving grossly intact, then we can say that the probability of having the problem increases.

Below is a screenshot showing one of the above mentioned rules.

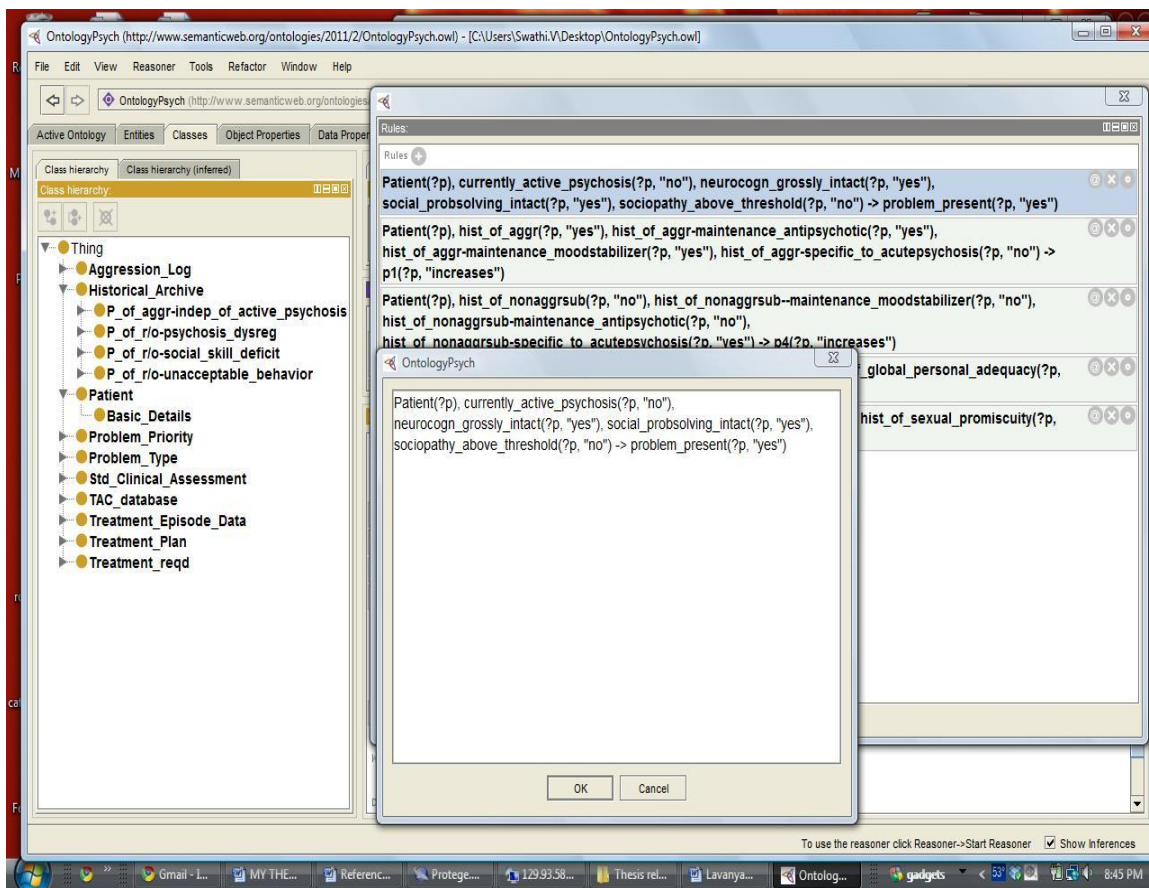


Figure 7

OUTPUT AND RESULTS

When the patient or the clinician enters patient info and the symptoms, the output is the problem type and the treatment plan. During the treatment phase, treatment episode data is collected.

Sample output is given below:

Please answer the following questions in just YES or NO
Press '0' to exit

PART 1: BASIC DETAILS

Enter NAME : Andrew

Enter AGE : 38

Enter SEX : male

Enter TODAY'S DATE in this format yyyy-mm-dd : 2011-04-11

PART 2: HISTORICAL ARCHIVE

1. Is there any history of aggression? : yes
2. Is history of aggression specific to acute psychosis ? : no
3. Is there any history of aggression while on maintenance antipsychotic ? : yes
4. Is there any history of aggression while on maintenance mood stabilizer ? : yes
5. Is there any history of severe global personal inadequacy ? : no
6. Is there any history of aggression specific to institutional context ? : no
7. Is there any history of non-aggressive SUB ? : no
8. Is there any history of non-aggressive SUB specific to acute psychosis ? : yes
9. Is there any history of non-aggressive SUB while on maintenance antipsychotic ? : no
10. Is there any history of non-aggressive SUB while on maintenance mood stabilizer ? : no
11. Is there any history of non-aggressive SUB ? : no
12. Is there any history of non-suicidal self-harm ? : no
13. Is there any history of poly-substance abuse ? : no
14. Is there any history of sexual promiscuity/heterosexual preoccupation ? : no

PART 3 : STANDARD CLINICAL ASSESSMENT

15. Enter score of BPRS item 1 : 3.2

16. Enter score of BPRS item 2 : 4

17. Enter score of BPRS item 3 : 4.3

18. Enter score of NAB-S item 1 : 34

19. Enter score of NAB-S item 2 : 30
 20. Enter score of NAB-S item 3 : 20.6
 21. Enter AIPSS value : 50
 22. Enter score of Hinting Task : 16
 23. Enter score of Sociopathy Screen- HARE item 1 : 37
 24. Enter score of Sociopathy Screen- HARE item 2 : 45
 25. Enter score of Sociopathy Screen- HARE item 3 : 28

Questionnaire Done!

OUTPUT----->

Name of the patient: Andrew

PROBLEM TYPE: Psychophysiological Dysregulation of ANGER/AGGRESSION
 present

LIST OF POSSIBLE TREATMENT PLANS:

PRIMARY Treatments:

1. Dialectical cognitive-behavioral therapy
2. Physical relaxation/stress management therapy
3. Counterconditioning therapy
4. Anger management therapy

ADJUNCTIVE Treatments:

5. Social skills training
6. Psychopharmacotherapy to temporarily moderate extreme physiological arousal components

Do you want to enter info of another patient? Press yes/no only

no

THANK YOU!

TREATMENT EPISODE DATA:

Enter Name: Andrew

A) Enter problem priority [1..4] : 1 (highest)

B) Enter TODAY'S DATE in this format yyyy-mm-dd : 2011-05-15

C) Ongoing aggression requiring immediate management?: yes

TREATMENT:

- go to algorithm for psychopharm. for anger/aggression
- go to algorithm for FAB/BMP for aggression

D) Patient preference for anger mgmt over dcbt?: yes

TREATMENT:

- begin anger management therapy

E) Patient preference for counterconditioning over group relax: yes

TREATMENT:

- begin counterconditioning therapy

F) Aggression during past 24 hours? yes

TREATMENT:

- psychopharm. for anger/aggression
- FAB/BMP for aggression

G) Adherent to treatment past week >75%? **yes**
 TREATMENT:
 - Rehab. Nonadherence

H) Aggression down this month? **no**
 TREATMENT:
 - FAB/BMP and psychopharm. for aggression

TAC MODULE :

I) TAC Id : **01524**
 J) Scheduled hours : **40**
 K) Cancelled hours : **4**
 L) Excused hours : **3**
 M) Attended hours : **33**
 N) Attention [1..4] : **3**
 O) Participation [1..4] : **4**
 P) Spontaneity [1..4] : **3**
 Q) Withdrawn [1..4] : **1**
 R) Bizarre [1..4] : **1**
 S) Disruptive [1..4] : **1**
 T) Progress Scale [1..10] : **9**

Output Explanation:

‘Andrew’ is the patient and the clinician initially enters the data required to complete the questionnaire provided which asks information about the patient’s basic details, medical history and standard clinical assessment tests results. Then he is diagnosed and a set of treatment methods are proposed.

While the patient is undergoing treatment, the clinician enters the treatment episode data. Once the problem priority is determined, the clinician monitors the patient

and his improvement at regular intervals of treatment like during the past day, past week, past month and also past 3 months. The TAC module values are also noted. The clinician takes note of how the patient fares and stores this data in the database. With regular check-ups the patient's betterment and improvement can be known. The treatment therapies can be stopped once the priority level of the problem is either 3 or 4 (i.e. lowest priority)

CHAPTER 6

TROUBLESHOOTING

This chapter discusses some of the problems encountered by us during the implementation of this project. Short description about how we were able to find a solution to these problems and how we finally resolved the issues is also given below.

➤ Migration from Protégé 3.4 to Protégé 4.1:

A new version 4.0 of Protégé was released in 2009. But it did not provide the functionalities that the users were looking for and there were many releases after that and finally the latest version 4.1 Beta was released on March 11, 2011.

Explanation: Work related to this ontology was previously done in Protégé 3.4.

But as the latest version 4.1 was released, we developed the ontology in this newer version. Protégé 4.1 is not backward compatible with the previous versions of 4.* and also 3.* and work is still going on in improving this software and fixing the bugs reported. This made us face a lot of problems as the plug-ins, tabs, methods that were used in 3.4 were no longer present or compatible with 4.1. So dealing with an entirely new set of features was a difficult task to begin with.

But due to some improved and advanced features present in 4.1, we decided to use the latest version to be on par with the new expanded software.

Some of the improved capabilities in 4.1 are:

- fully conformant with OWL2.0
 - automatic updates for the new features, software required and also bug fixes.
 - platform independent installer program redesign.
- Errors like
- the import edu “import edu.stanford.smi.protege.owl.ProtegeOWL;” cannot be resolved,
 - OWLNamedClass, OWLDatatypeProperty cannot be resolve

Solution: The errors were caused because the required jar files to run OWL and protégé in Java were not present. Hence, these jars were to be placed in the correct folder of the Java Project for these errors to be rectified.

- RDFResource cannot be resolved at the following statement:
 RDFResource newInstance = basdetC.createInstance("Fred");

Solution: RDFResource requires

edu.stanford.smi.protege.owl.model.RDFResource or org.semanticweb.owlapi.io packages. But we did not use those in our code. Hence instead of adding more packages and then using RDFResource, the alternative was to use RDFIndividual class and createRDFIndividual() method to create an individual.

RDFIndividual darwin = basdetC.createRDFIndividual("Fred");

- Errors while trying to query the database using dynamic data
 Example: The patient enters his name and we need to store this data in the database i.e. whatever name the patient enters, we have to pass that variable ‘dynamically’ to the database.

Solution: There are various syntaxes for passing data dynamically to any database like using single quotes, just the variable name without any quotes or using objects that represent precompiled SQL statement (PreparedStatement). But this issue was easily solved by encoding the dynamic data to be passed in the following manner: “'+name+'”

Example:

```
"update patient_records set age='"+age+"' where name='"+name+"' "
```

- In one of the rules we wrote there was the following error:
 Patient(?p), hist_of_aggr-specific_to_institutional_context(?p, "no"),
 hist_of_global_personal_adequacy(?p, "no") -> p3("increases")
 Error: Encountered “increases” at line 1, column 127. Expected one of: individual name or \$var\$

Solution: The problem here was that the property ‘p3’ should have the class ‘Patient’ in its domain intersection because depending on the values entered by the patient, the values of various properties are calculated and finally these are used to output the diagnosis of that individual. Once ‘Patient’ class is added in its domain, the individual name should be present in the rule specified. Hence the correction would be “ p3(?p,”increases”) at the end of the rule.

- While developing the ontology, there was an inconsistency with one of the subclasses. Basic_Details was added as a subclass of Patient and Historical_Archive.
 Error: Basic_Details was highlighted in red meaning that there is some inconsistency in the ontology structure.

Solution: this error occurred because Patient and Historical_Archive are declared as two disjoint classes. There cannot be the same sub-class in two such disjoint classes as there cannot be any intersection between those classes. Hence Historical_Archive was removed as the superclass of Basic_Details to have a consistent ontology.

CHAPTER 7

CONCLUSIONS AND FUTURE WORK

CONCLUSIONS

The objective of the thesis is to develop a new ontology for a mental illness called ‘psychophysiological dysregulation of anger/aggression’ and we accomplished that to a great extent.

We developed an interactive program where the clinician enters the data about the patient like his basic details, various results from the lab assessment tests and patient’s medical history relevant to the problem. With this info provided, the program gives the output i.e. the problem type and a proposed treatment plan. To make the decision about this diagnosis we developed the ontology from the Java program.

After the treatment plan is proposed, the clinician can monitor the patient and his improvement while undergoing the treatment during the past 24 hours, past week, past month and 3 month intervals. To easily access records of a patient whenever necessary and at any point of time, we used a relational database called IBM DB2 which stores all info about the patient.

To visualize the ontology, we used one of the widely used ontology editors called Protégé 4.1 Beta which is the latest version available. We created the entire class structure here, checked for inconsistencies using standard reasoners like Fact++, HermiT and finally removed the inconsistencies. We wrote rules and checked for their validity.

FUTURE WORK

We used sample data for the patient records. So the next step could be to use real time actual data of the patient to come up with an accurate diagnosis.

As a lot of research is going on in mental health domain, any new discoveries related to this particular problem type and the ontology can be implemented in order to expand the existing ontology.

Protégé 4.1 is still in its developmental stage and new, improved features are being added every now and then. So in future, whoever works on this project, can make use of the latest available features and improve the ontology. Rules are not yet fully sophisticated and functional in this version; therefore, improvements can be made in rule base also.

The look and feel of the interactive program used by the clinician to enter and store data of the patient can be improved by developing an advanced web-based GUI.

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