A Prototype Decision Support System for Differential Diagnosis of Psychotic, Mood, and Organic Mental Disorders

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A Prototype Decision Support System for Differential Diagnosis of Psychotic, Mood, and Organic Mental Disorders

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The authors designed a decision support system to assist mental health professionals to perform differential diagnoses of psychotic, mood, and organic mental disorders in accordance with the American Psychiatric Association's revised third edition of the *Diagnostic and Statistical Manual of Mental Disorders*. A prototype system arrived at through a rigorous methodology illustrates a style of development that attempts to ensure system maintainability, correctness, and consistency of deduction and promotes high quality in software. *Key words*: mental disorders; decision support system; computer-assisted diagnosis; expert systems; artificial intelligence. **(Med Decis Making 1993;13:43–48)**

The ability of professionals to diagnose mental disorders is based upon years of training, research, and experience that enable them to differentiate between possible disorders and in turn prescribe appropriate treatments. The high-level criteria used in this diagnostic process follow a given path that allows for coarse diagnoses. The more experienced the clinician becomes, the more refined his or her diagnostic criteria become, allowing more fine-grained conclusions to be obtained.

High-level diagnostic paths have been defined for several classes of mental disorders by the American Psychiatric Association, in the revised third edition of its *Diagnostic and Statistical Manual of Mental Disorders* (DSM-III-R).[1] The aim of this reference book is to consolidate mental health terminology into an ultimate standard that is acceptable by all mental health professionals, such that there is a commonality of language and understanding.

We have developed a prototype decision support system (DSS) that follows the guidelines laid down in the decision trees of DSM-III-R for differential diagnosis of three separate but interconnected types of mental aberrations: 1) psychotic symptoms; 2) mood disturbances; and 3) organic mental disorders. *Psychotic symptoms* "include gross impairment in reality testing as evidenced by delusions, hallucinations, incoherence or marked loosening of associations, catatonic stupor or excitement, or grossly disorganized behavior."[1] *Mood disturbances* "are marked by a persistently depressed, elevated, expansive, or irritable mood."[1] *Organic mental disorders* "arise from a specific organic factor that is judged to be etiologically related to the disturbance or, in the case of Dementia and Delirium, all non-organic disorders that could account for symptoms have been eliminated."[1] Because several disorders may fit the individual diagnostic picture, a list of possible diagnoses is given, hence the term "differential diagnosis."

Our goal in developing the DSS was to illustrate the possibilities for knowledge-based technology in the areas addressed by mental health professionals. The aim was not to replace these professionals, but to indicate research directions that can be addressed by mental health workers.

The system presented is seen by the authors to be a prototype and is not intended for use as a final product.

A Differential-diagnosis DSS

Consistency is lost when people perform important tasks in materially different ways. A DSS is consistent in its reasoning, and thus can be a valuable asset to any process that demands a high degree of diagnostic correctness and correlation.

The instructions given by DSM-III-R for using the "Decision Trees for Differential Diagnosis" require the clinician to follow each tree manually and to "proceed down the tree until a leaf is found. If features from several different trees are present, each of the appropriate trees should be examined. . . ."

The DSS presented here removes the need to negotiate the multiple trees by "finger and eye" and to mentally keep track of the various diagnoses. Relevant questions are automatically selected, based on the responses of the clinician. If necessary, branching to another tree is automatic. Finally, all the possible diagnoses are listed for the clinician's perusal. If desired, the clinician could rerun the program with a slightly different set of conditions, allowing a "what-if" scenario.

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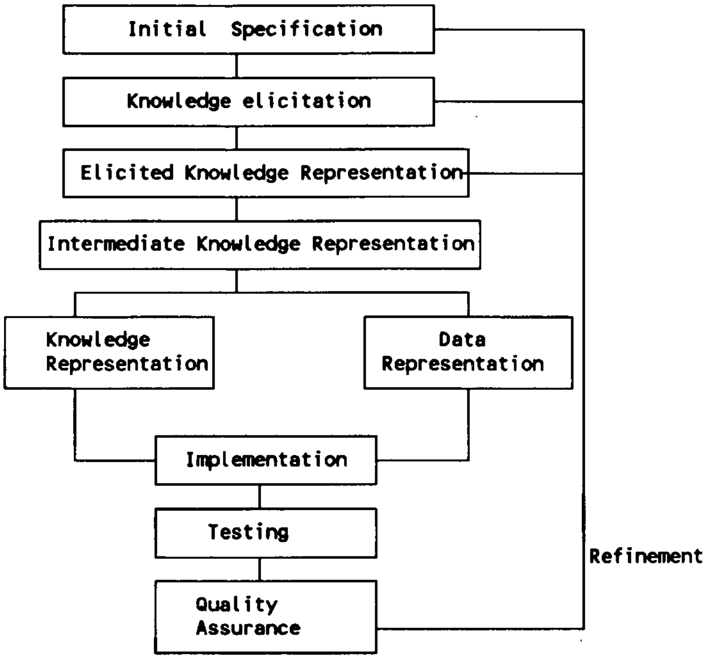

FIGURE 1. Development methodology.

SYSTEM SPECIFICATION

The domain can be seen, from our previous discussion, to be suitable for a knowledge-based solution. However, it can also be seen as extensive in scope, so it is necessary for us to define the boundaries of our prototype system. This allows us to perform validation and verification procedures on the system.[2]

After consultation with clinicians and mental health professionals, it was determined that a suitable domain for our DSS could be defined and bounded by the "Decision Trees for Differential Diagnosis" in DSM-III-R.[1] These decision trees contain a concise body of information from which a diagnosis can be made in the three categories of mental disorders mentioned above: psychotic, mood, and organic. The paths through these trees form an acknowledged route to diagnosis from an initial assessment of a patient's symptoms.

Methods

SYSTEM DEVELOPMENT

The development of the DSS followed a method that attempted to impart rigor and accountability to the creation process.[3] The stepwise method, simplified in figure 1, utilizes multiple implementation-independent stages and allows for errors to be easily corrected and gaps in the knowledge to be filled with consistency. Below we describe the stages in the development of the differential-diagnosis DSS.

Knowledge Elicitation. The knowledge-elicitation processes used were referral to the literature and interviews.[4,5] The three primary sources of knowledge upon which the system was based were the DSM-III-R and an assistant professor and a third-year resident in the Department of Psychiatry, School of Medicine, University of Miami. The domain was defined through the literature source and then, to provide a greater depth to the reasoning process and a finer grain size of knowledge, the two domain experts were consulted. The use of multiple experts is an acknowledged technique for the attainment of knowledge that is complete, consistent, and correct, three fundamental requirements of any elicitation process.[6]

Knowledge Acquisition: Developing the Representations. The result of the knowledge-elicitation phase was a series of high-level decision trees for the differential diagnosis of mental disorders, based primarily on those presented in DSM-III-R, with others from our human experts.

The DSM-III-R decision trees were developed by clinical specialists for other specialists with similar training. However, in order to create the DSS, it was necessary to decompose these trees and examine them from an information-system perspective, including an assessment of their completeness, consistency, and correctness (although this was not doubted). Completeness and consistency were examined because a clinician using these trees might also use to derive a diagnosis a background of common sense and a predeveloped knowledge base, aspects of knowledge that would be missing if the trees were naively encoded into a computer system. A suitable vehicle for examining completeness and consistency is a decision table.

Intermediate Representation: Decision Tables. The DSM-III-R decision trees[1] were converted into me-

	1	9	11	13	14
Persistent Mood	Y	Y	Y	Y	Y
Organic Factor	Y	N	N	N	N
One or More Periods	-	Y	Y	N	N
At Least One Mood Syndrome	-	Y	N	-	-
Two Weeks	-	-	-	Y	N
See Organic Tree	X				
Goto Mood Tree 01				X	
Goto Mood Tree 02					X
Goto Mood Tree 03		X			
Goto Mood Tree 04			X		

FIGURE 2. High-level decision process.

	1	2	3	4	5	6	7	8
Exclusive Depressive Synd	Y	Y	Y	Y	N	N	N	N
Major Syndrome	Y	Y	N	N	Y	Y	N	N
Two Years of Dysthymia	Y	N	Y	N	Y	N	Y	N
No Mood Disorder								
Major Depressive Episode								
Depressive Disorder NOS								
Dysthymia & Major Depression								
Major Depression								

FIGURE 3. All possible combinations: Mood Tree 01.

	1	2	3	4	5	6	7	8
Exclusive Depressive Synd	Y	Y	Y	Y	N	N	N	N
Major Syndrome	-	-	-	-	Y	Y	N	N
Two Years of Dysthymia	-	-	-	-	-	-	Y	N
No Mood Disorder								
Major Depressive Episode								
Depressive Disorder NOS								
Dysthymia & Major Depression								
Major Depression								

FIGURE 4. Redundant states marked by—: Mood Tree 01.

chanically perfect decision tables.[7] All of the decision tables were of the limited-entry type. It is immediately apparent by looking at the three major decision trees (Psychotic Symptoms, Mood Disturbances, and Organic Mental Disorders) that each condition has only two states, Yes and No. The binary logic of the decision tree leads to the conclusion that the "divide and conquer" or "functional decomposition" method could be applied to each of the major decision trees, thus preventing a major combinatorial explosion. As a representative example, let us consider the Mood Disturbances Decision Tree; the first five conditions of question 1 act as filters without indicating a diagnosis. The conditions are:

1. Persistent mood
2. Organic factor
3. One or more periods
4. At least one mood symptom
5. Two weeks of depressive syndrome

A "No" response to any condition in question 1 terminates processing, since the assumption is made that if there is no symptom, there is no disorder. If the response to condition 2 is "Yes," then the search terminates at this table and switches to the Organic Tree. A "Yes" to condition 3 is followed by condition 4. Any response here causes continuation to either the Mood03 or the Mood04 tree. If condition 3 is answered by a "No," then condition 5 follows, and any response here causes continuation to either the Mood01 or the Mood02 tree.

We can determine how much this pruning of the tree saves in terms of combinations. If the entire Mood Disturbances Decision Tree in the DSM-III-R had been used as a single entity, there would have been 16 possible conditions, each with two states, yielding a total of 2^{16} or 65,536 possible combinations. By decomposing the tree as a whole down into five decision trees, and ultimately five decision tables, the maximum number of combinations becomes 60. The final number of combinations after the removal of redundant rules is 20, a difference of 65,516.

	1	5	7	8
Exclusive Depressive Synd	Y	N	N	N
Major Syndrome	-	Y	N	N
Two Years of Dysthymia	-	-	Y	N
No Mood Disorder	X			
Major Depressive Episode			X	X
Depressive Disorder NOS		X		
Dysthymia & Major Depression			X	
Major Depression				X

FIGURE 5. Final reduced table: Mood Tree 01.

Figure 2 shows the reduced high-level decision table. The column numbers (1, 9, 11, 13, 14) refer to the original condition stub components. We can see from the action stub how the system decomposes the problem and directs evaluation to the specialized subtrees Mood Tree 01 through Mood Tree 04.

Figures 3–5 shows how the subtree Mood Tree 01 was reduced. The action stub is not shown in figures 4 and 5 because the focus of the reduction at these phases is in the condition stub.

Knowledge Representation: Rules. The knowledge representation we decided to utilize was a production-system architecture for our system.[8] Our choice was influenced by the following rationales: the structure of the differential defect-diagnostic knowledge is suitable for representation in rule form; production systems are easy to implement, understand, and use; and the modularity of a production system provides flexibility in the development and maintenance of the knowledge base. The use of a production-system representation also allows the decision tables to be easily transformed into rules, thus maintaining semantic consistency.

An example of a rule from the decision table in figure 5 is of the form:

RULE 1

IF Exclusive_Depressive_Syndrome = No AND
Major_Syndrome_Not_Superimposed = Yes AND
Two_Years_of_Cyclothymia = No
THEN
Mood = Depressive Disorder

Other rules are of the form:

RULE 21

IF Delusions = Yes AND
Hallucinations = Yes AND
Mood = No AND
Anxiety = No AND
Mental Disorder = No AND
Etiology = Yes AND
Syndrome = No AND
Cessation = Yes
THEN
Organic2 = Organic_Delusional Syndrome
Organic2 = Organic_Hallucinosis
Organic2 = Psychoactive_Subst_Induced_Withdrawal
BECAUSE
"The presence of delusions, hallucinations and etiology in combination are a strong indicator to confirming an organic diagnosis such as delusional syndrome, hallucinosis or psychoactive substance–induced withdrawal."

This shows how explanations can be attached to rules, allowing the system to inform the user of the system's reasoning strategies. This is an advantage of production systems. The rule structure also allows the use of "what-if" experimentation on the part of the user and allows the user to change the parameters of a problem and examine the consequences. Rule 21 is an example of a rule that provides multiple instantiations of possible diagnoses from which the clinician may choose a differential diagnosis.

SYSTEM IMPLEMENTATION

The knowledge engineer, having acquired the domain knowledge and data and having represented that information in forms that would facilitate retrieval of knowledge-based decisions could then implement the system. This was accomplished through a system with the architecture presented in figure 6 and implemented through use of an expert system shell, VP-Expert Version 2.1[9,10] (see figure 6).

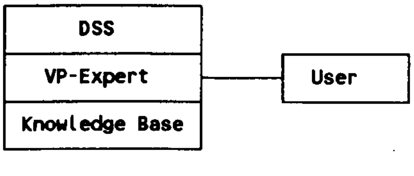

FIGURE 6. System design.

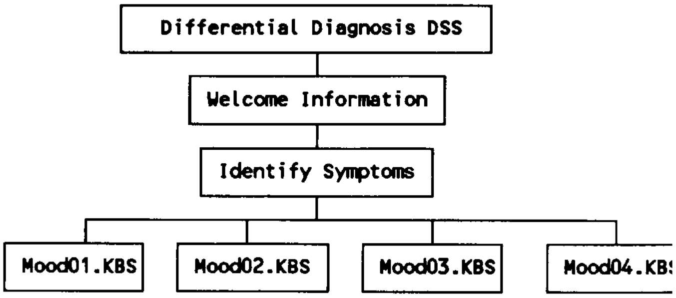

FIGURE 7. System logic flow chart.

The implementation of the system was performed with system maintenance and upgrading in mind, so extensive use was made of a partitioning of both the knowledge base and the database, thus increasing the modularity of the system.

A simplified system logic flow chart is illustrated in figure 7. This chart shows how different problem types chain the system to different parts of the modularized database or knowledge base. This was found to be an effective implementation strategy that facilitated modification.

SYSTEM OPERATION

The differential-diagnosis DSS was designed to be user-friendly and to require as little interaction as possible, thus enabling a wide user group to take advantage of it and minimizing the potential for input error. After the initial introductory screens of instruction (e.g., figure 8), the user is asked to input data and information as the system deems necessary, as illustrated in figure 9. Figure 10 shows how the system attempts to determine the symptom type with an increasing degree of focus. This is continued in figure 11, which shows a compressed consultation with the system. At the end of this process, the system delivers a diagnostic analysis of the form shown in figure 12.

TESTING AND QUALITY ASSURANCE

The promotion of quality in our system was a prime concern from its conception, and even though it was intended to be a prototype, this did not give license for poor design and implementation. The use of this approach increased the three major factors affecting knowledge-based systems' quality, which can be called C^3: consistency, completeness, and correctness. The modular approach to development in conjunction with stringent initial specification requirements made the prototype extremely robust within its domain parameters.

The process of validation and verification in relation to knowledge-based systems has been demonstrated to represent a significant stumbling block.[4,11] However, the techniques used in the development of our system are such that a high level of correctness is reached.

```
WELCOME
TO THE
Differential Diagnosis Consultant

Press any key to begin consultation
```

Enter to Select END to Complete /Q to Quit ? for Unknown

FIGURE 8. Introductory screen.

```
Does the patient exhibit gross impairment in reality testing
as evidenced by delusions, hallucinations, incoherence or
marked loosening of associations, catatonic stupor or
excitement, ambivalence, a flat affect, severe disorientation
of person, place or time, or grossly disorganized behavior?
> YES <          NO
```

Enter to Select END to Complete /Q to Quit ? for Unknown

FIGURE 9. Diagnostic query screen.

```
Does the patient exhibit gross impairment in reality testing
as evidenced by delusions, hallucinations, incoherence or
marked loosening of associations, catatonic stupor or
excitement, ambivalence, a flat affect, severe disorientation
of person, place or time, or grossly disorganized behavior?
> YES <          NO

Which hallucination does the patient exhibit?
>Auditory <    Gustatory       Tactile
 Uncal         Visual

Has the duration of psychotic symptoms been less than one
month?
 YES             > NO <

Were the psychotic symptoms active for MORE than one
week?
> YES <          NO
```

Enter to Select END to Complete /Q to Quit ? for Unknown

FIGURE 10. Focused diagnostic query screen one.

```
Is a major depressive or manic syndrome concurrent with
the active-phase symptoms?

> YES <          NO

Total duration of all mood syndromes is brief relative to
the total duration of the psychotic disturbance?

> YES <          NO

Social or occupational functioning markedly impaired?

> YES <          NO

More than six-month duration of continuous signs of
illness (primatial, active, and residual phases)?

> YES <          NO
```

Enter to Select END to Complete /Q to Quit ? for Unknown

FIGURE 11. Focused diagnostic query screen two.

This can be justified by exhaustively showing that the system's performance matches the requirements of the decision tables, a testing mechanism that is not normally feasible to demonstrate. The subsequent successor to this system will require alternative testing techniques such as critical data testing, random data tests, or functional testing.[12]

Summary and Conclusions

The aim of this study was to investigate the area of decision support systems in relation to the differential diagnosis of psychotic, mood, and organic mental disturbances. We have illustrated that the technology is capable of assisting the mental health professional and that a decision support system such as that we have described could be of use in many ways, for example:

```
Differential Diagnosis is :  Schizophrenia

Press any key to conclude consultation.....
```

Enter to Select END to Complete /Q to Quit ? for Unknown

FIGURE 12. Differential diagnosis.

1. as a DSS for physicians who have little or no psychiatric training, in order to allow for appropriate consultation
2. as a DSS for physicians who do have psychiatric training
3. as a training aid for psychiatric residents and medical students who are learning about psychiatry
4. as a review aid for psychiatrists, who as a rule see only relatively "high-functioning neurotics."

Decision support systems could be stand-alone or be part of integrated support environments incorporating decision support systems, notebooks, patient records, reference material, and patient charts in a unified way, to assist the clinician to reduce the administrative overhead that accompanies a large-scale practice. Further, decision support systems of this type can aid general practitioners in more succinctly referring patients to specialists such as neurologists and psychopharmacologists. The broader implication for such support systems, however, points to an increasing role in the area of family and patient education and information retrieval. The ability of the physician to spend extended periods of time counseling family units is becoming an area of concern in terms of time, cost, and resource utilization. An alternative approach is to increase the range of the decision support system to have sophisticated explanation-based capabilities at many levels. The system, having assisted in determining the physician's diagnosis, could be used by the patient and the family to examine the broader consequences of the diagnosis, including such issues as long-term implications, the medication and its side effects, related health care problems, family-unit stress, and patient management. These areas are already covered to a limited extent in many leaflets, and to deeper levels in texts; however, a decision support system incorporating hypertext or multimedia capabilities would be able to provide a higher degree of correlation between the diagnosis and the information relevant to that diagnosis—thus increasing the quality of the mental health care service provided.

Our system is intended not as a replacement for a clinician but rather as an indication of a maturing technology suitable to mental health care. The prototype indeed showed that considerable work in the DSS subfields of certainty factor analysis, explanations, representations, elicitation, and analysis is needed prior to full exploitation of this technology by the practicing clinician. In addition, the incorporation of the research in decision analysis by workers such as Bursztajn,[13] in conjunction with the research into the decision support system, indicates that significant progress can be made in the area of medical decision advisory systems. It has been noted that systematic decision making that promotes consistency and completeness and that can act as a vehicle for information retrieval and support would be of significant benefit to the physician, the patient, and the medical community.[14] It was therefore one of our aims to illustrate that by use of a rigorous approach to systems development we could move toward ensuring completeness, correctness, and consistency of diagnosis. We strongly advocate the use of such an approach in the future development of decision support systems for diagnostic support in mental health care.

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