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Choosing a College Major: A Prototype Decision Support System

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Abstract — *This article demonstrates the feasibility of a new computer technology, decision support systems (DSSs), to assist counselors with their clients in choosing a college major.*

INTRODUCTION

The selection of a major field of study which will eventually lead to a satisfying career can be viewed as one of the most important decisions for a college student. Computer applications in the career assessment process have attracted considerable professional interest (Sampson, 1990). Traditional assessment inventories, such as the Strong Interest Inventory (SII) (O'Shea, 1987) and the Self-Directed Search (SDS) (Reardon, 1987) are now available in computerized versions. The SII and SDS are but two examples of several career assessment inventories based on Holland's career choice theory (Holland, 1973, 1985a). The purpose of this article is to advance the successful use of the Holland system by incorporating it into newer, emerging computer technology.

A decision support system (DSS) is a computerized procedure for choosing among alternative courses of action with or without all the necessary information and often with uncertain information as well (Turban, 1990).

We will show how the Holland system can be incorporated into a DSS, thus opening the way for future research to determine the effectiveness of this device relative to existing assessment techniques.

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A CAREER CHOICE THEORETIC DSS

Studies have shown that counselors are not entirely consistent in the way they assess an individual's interests (Gati, 1987). Computer interpretation of interest inventories, for example, has been shown to offer advantages over counselors' judgments alone (Gati & Blumberg, 1991). This is easy to understand, since consistency is lost when personnel perform important tasks in materially different ways. Using computers as an adjunct to career counseling has been examined by other researchers (e.g., Brezezinski & Hiscox, 1984; Gati & Blumberg, 1991; Reardon, 1987; Sampson, 1990; Space, 1981). This article, however, takes a different perspective: utilizing a knowledge-based approach to develop a rule-based DSS that utilizes an expert's domain knowledge. A DSS is able to provide consistency in its reasoning, and thus such a system is a valuable asset to any process that demands a high degree of correctness and correlation.

The problem addressed by this article, that of identifying suitable major fields of study for a college student, needs to be addressed in a consistent manner for a given set of parameters that influence the decision making process. This problem is ideally suited to the application of the decision support approach, in that the domain is deterministic but the parameters are such that the deduction process is sensitive to an individual's needs. The advantages of this platform have been extensively documented in the DSS literature (Alter, 1980; Keen & Morton, 1976; Turban, 1990).

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, and therefore it is necessary to define the boundaries of our prototype system. This allows us to perform testing and quality assurance procedures on the system (Plant, 1990).

After consultation with psychologists and counselors, it was determined that a suitable domain for our DSS could be defined and bounded by the Holland personality types or themes (HPTs): *realistic, investigative, artistic, social, enterprising*, and *conventional*, commonly denoted by using only the first letter—R, I, A, S, E, and C (Holland, 1973, 1985). Most people have some characteristics of more than one of these types; very few people are pure types. However, one or two themes tend to be predominant in each individual, with the strongest theme termed the *primary* and the next strongest the *secondary*. Thus, people can be described by identifying their primary and secondary themes. The result is a two-letter code such as RI, AS, SE, and so on.

Some researchers propose using the three highest themes for representation (e.g., Gottfredson & Holland, 1989; Reardon, 1987). Others have found that the most effective predictors of occupational entry were the two highest scales in an interest inventory (Crowley, 1983; Harrington & O'Shea, 1982). We decided to use the two-letter code, but the need for refinement in this matter will be discussed later in the article.

SYSTEM DEVELOPMENT

The development of the DSS followed a methodology that attempted to promote rigor and accountability into the creation process (Plant, 1991). The methodology is illustrated in Figure 1.

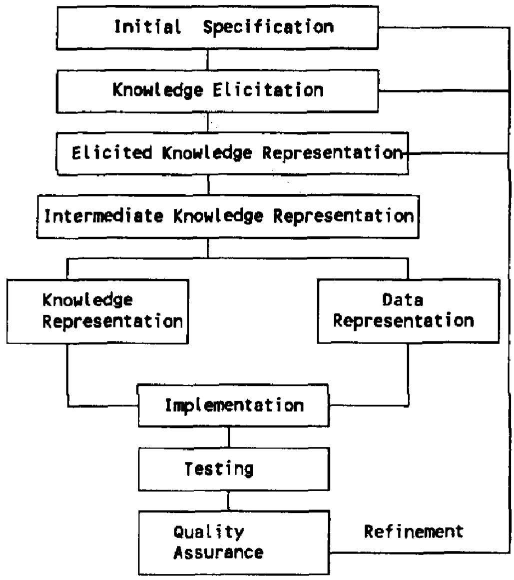

Figure 1. Development methodology.

The system developer commences with a specification of the system's requirements. Having specified the system, the developer then proceeds to select an elicitation technique (Burton, Shadbolt, Hedgecock, & Rugg, 1987) and extract the domain-specific knowledge from the domain expert or knowledge source. The elicited knowledge is usually in the form of text, such as a transcribed interview, and this is known as the *elicited knowledge representation*. The third stage is to analyze the elicited knowledge, a process known as *knowledge acquisition* (Welbank, 1983). The aim of knowledge acquisition is to refine the knowledge and identify inconsistencies, incompleteness, or areas that need clarifying. This process may utilize intermediate representations with which to add structure to the knowledge (e.g., decision tables or trees). The intermediate form allows the developer to select a representation, such as rules (Waterman, 1986), with which to implement the system. Finally, system testing and quality assurance measures can be performed. The stepwise development with multiple implementation independent stages allows for errors to be easily corrected and gaps in the knowledge to be filled with consistency.

We will now consider each of these stages in the development of the college major DSS.

Knowledge Elicitation

Knowledge elicitation is a process in which the domain knowledge is extracted from a domain expert or other sources by the knowledge engineer or system developer (Firlej & Hellens, 1991; Welbank, 1983).

The knowledge elicitation processes used in this study included both interview and literature referral. The primary source of knowledge upon which the system was based was a human expert: an experienced professional counselor and psychologist (the first author). Secondary sources were literature based (Holland, 1973, 1987; Rosen, Holmberg, & Holland, 1987).

The elicitation process that was followed defined the domain initially through the literature sources. In order to provide a greater depth to the reasoning process and a finer "grain size" of knowledge, the knowledge was further elicited from the human domain expert. This elicitation process was then repeated in an iterative manner to ensure an adequate coverage of the domain. This acted as though multiple experts were being utilized, an acknowledged technique for the attainment of knowledge that is complete, consistent, and correct, three fundamental requirements of any elicitation process (Mittal & Dym, 1985).

Knowledge Acquisition: Developing the Representations

The result of the knowledge elicitation phase is a series of decision tables. These are in two categories: the HPTs and the college majors classification.

Intermediate Representation: Decision Tables

The HPT matrix, given in Figure 2, can be obtained from HPTs and provides a taxonomy of personalities which include primary and secondary themes.

These two-letter codes, in addition to the six single-letter "pure" types combine to provide an adequate coverage of the major fields of study at the college level. However, it should be noted that even though the system has not been developed as yet to cover three-letter codes, this expansion can be achieved to cover more majors. The second phase of the acquisition process was to define the college majors that relate to these HPT types. In order to do this, the 87 major fields of study at the University of Miami (Coral Gables, FL) were examined. The acquisition process then involved coding these majors according to the HPT system. This was achieved primarily by consulting a standard reference guide to college majors (Rosen et al., 1987). Some of the majors at the University of Miami were worded slightly differently than in the reference text and judgements were made for these. The codings were then transformed into a decision table, which is presented in Figure 3.

Knowledge Representation: Rules

Knowledge representation schemes describe in terms of data structures the knowledge structures used by the expert over which his or her deductions occur. The

		Secondary					
		R	I	A	S	E	C
Primary	R	R	RI	RA	RS	RE	RC
	I	IR	I	IA	IS	IE	IC
	A	AR	AI	A	AS	AE	AC
	S	SR	SI	SA	S	SE	SC
	E	ER	EI	EA	ES	E	EC
	C	CR	CI	CA	CS	CE	C

Figure 2. Holland personality type (HPT) matrix.

	R	I	A	S	E	C
R	Engineering Sci.	Medical Tech.	Music Eng. Tech.	Respiratory Ther.		
I	Engineering Chemistry Geology Biology Marine Science	Physics	Architecture	Psychology Psychobiology	Systems Anal. Architech. Eng.	Mathematics
A	Music Performance Dance Film Arts	Liberal Arts	Music	Foreign Languages Theater Arts English	Graphic Design	Broadcasting
S	Geography	Psychology Nursing	Philosophy Religion Music Therapy Education	Education	History Political Sci. S.American St. Criminal Just. Sociology	
E		Management Sci Industrial Eng	Music Industry Public Relations	Communications Business Admin.	Business Admin. Industrial Eng.	Comp. Info. Systems
C					Finance	Accounting

Figure 3. Decision table: Examples of Holland types and University of Miami majors.

question of how knowledge is represented within an expert system or DSS is of central concern. This is because the structure determines the type and ease of reasoning that can occur over a given knowledge base, ultimately determining the capability of the system.

A number of techniques are used to represent different knowledge types and the interrelationships of that knowledge (i.e., frames, semantic networks, production systems, and logic [Waterman, 1986]). We decided to utilize a production system architecture (Holsapple & Whinston, 1987) for our system, primarily because the structure of the career choice theoretic knowledge is suitable to being represented in a rule form and production systems are easy to implement, understand, and use. In addition, the modularity of production systems provides flexibility in the development and maintenance of the knowledge base. The use of a production system representation also allows for the decision tables to be easily transformed into rules, thus maintaining semantic consistency. An example rule is illustrated in Figure 4.

The system's decision rules are based primarily on the face validity of the items and their associated Holland themes, a procedure which has been proved to be valid

```
RULE 1
     IF    Type <> Realistic AND
           Type <> Investigative AND
           Type <> Artistic AND
           Type =  Social AND
           Type =  Enterprising AND
           Type <> Conventional
     THEN
                Major = Political Science

     BECAUSE
           "Political  Science  =  Enterprising  Type +
                                     Social Type".
```

Figure 4. Encoded Holland type rule.

in the Self-Directed Search (Gati & Blumberg, 1991; Holland, 1985b). However, going beyond the SDS, Figure 4 also 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 that DSSs exhibit. Once the two-letter code is determined, sample college majors associated with that code obtained from the *College Majors Finder* (Rosen et al., 1987) are presented to the user. 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.

Implementation

The system developer, 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 5 and implemented through use of an expert system shell, VP-Expert Version 2.1 (Hicks & Lee, 1988; Pigford & Baur, 1990).

The implementation of the system was performed with system maintenance and upgrading in mind, and so extensive use of partition of both the knowledge base and data base were made, thus increasing the modularity of the system. A simplified system logic is illustrated in Figure 6.

The system logic flow chart given in Figure 6 shows how different problem types chain the system to different parts of the modularized data or knowledge base. This was found to be an effective implementation strategy which facilitated modification.

SYSTEM OPERATION

The College Major Decision Support System was designed to be user friendly and to require as little interaction as possible, thus enabling a wide user group to take advantage of the system and to minimize the potential for input error. After the initial introductory screens of instruction (Figures 7 and 8), the user is asked to input data and information as the system deems necessary, as illustrated in Figure 9.

The present system consists of 15 such questions, as shown in Figure 9. The complete item inventory appears in Figure 10. These 15 items were selected from an initial item pool of approximately 70 items which were generated from an expert's knowledge and Holland's theme definitions, including interests, values, and personality traits associated with each theme. Some items were influenced by experience with the SII and the SDS. It is acknowledged that the DSS system

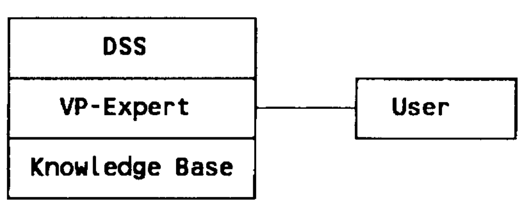

Figure 5. System design.

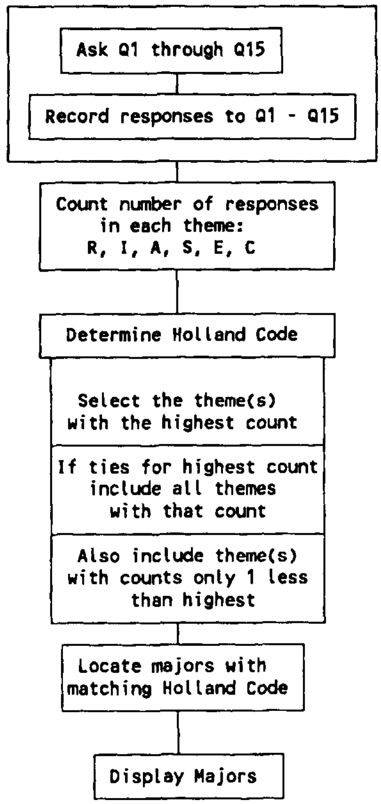

Figure 6. System logic flowchart.

Figure 7. Introductory Screen I.

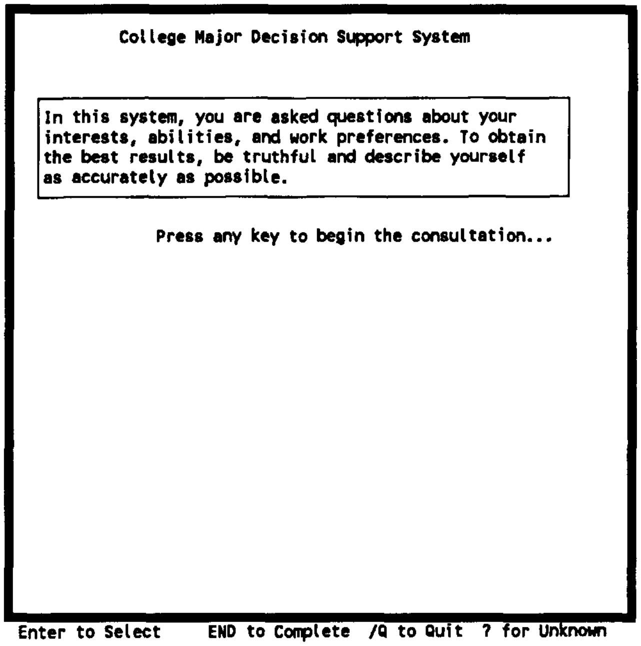

Figure 8. Introductory Screen II.

would be more psychometrically sound utilizing a larger number of items. However, 15 items was the maximum allowable in the VP-Expert Version 2.1. Higher capacity expert system shells will inevitably be available. Figures 11 and 12 show the results of two sample career assessments, manifesting different outcomes of using the system.

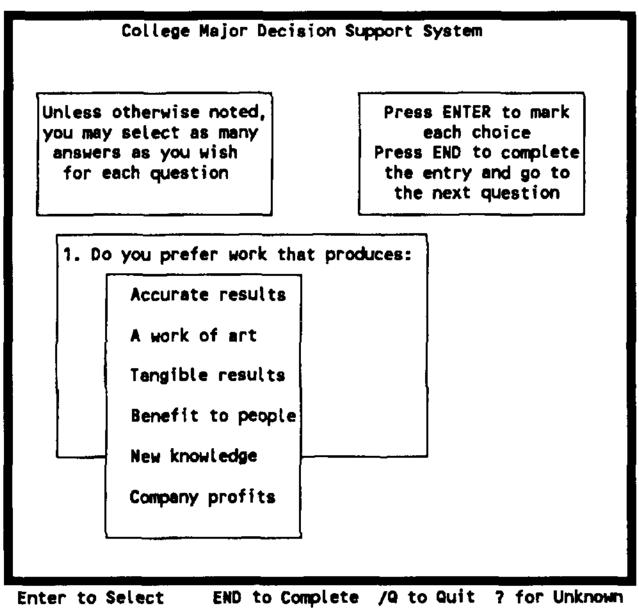

Figure 9. Focused query screen.

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1. Do you prefer work that produces:
CHOICES:Tangible results (R); New knowledge (I); A work of art (A); Benefit to
people (S); Company profits (E); Accurate results (C).

2. Which type of work environment do you prefer (CHOOSE ONE):
CHOICES:Structured (R,C); Unstructured (I,A).

3. What type of problems do you prefer to work with:
CHOICES:Scientific (I); People (S); Financial (E,C); Mechanical (R); Abstract
(A).

4. How do you prefer to solve problems:
CHOICES:Discuss ideas (I); Take action (R); Discuss feelings (S); Consult
rules (R,C).

5. Which do you prefer (CHOOSE ONE):
CHOICES:Working alone (R,I,A); Working in groups (S,E);

6. Which describes you best:
CHOICES:Friendly (S); Orderly (C); Practical (R); Expressive (A); Ambitious
(E); Reserved (I).

7. Do you prefer to (CHOOSE ONE):
CHOICES:Play it safe (C); Take risks (E).

8. Which describes you best:
CHOICES:Competitive (E); Physical (R); Sensitive (A,S); Conservative (C);
Intellectual (I);

9. Which describes you best:
CHOICES:Intuitive (A), Adventuresome (R); Analytical (I); Dependable (S);
Traditional (C);

10. What would you prefer to use in your work:
CHOICES:Music or art (A); Persuasion (E); Theories (I); Compassion (S);
Reference manuals (C); Tools and machines (R);

11. Which would be easy for you to do:
CHOICES:Win an argument (E); Discover something (I); Help someone (S);
Organize something (C); Fix something (R); Create something (A).

12. Which is your strongest ability:
CHOICES:Scientific (I); Teaching (S); Efficiency (C); Mechanical (R); Artistic
(A); Sales (E).

13. What do you usually base your decisions on:
CHOICES:Practicalities (R,C); Logic (I); Intuition (A); Feelings (S); Career
goals (E).

14. Which comes most naturally to you:
CHOICES:Understanding others (S); Investing skills (C); Physical skills (R);
Musical ability (A); Managerial skills (E); Mathematics (I).

15. How would you prefer to be involved with a new product:
CHOICES:Using it (C); Making it (R); Designing it (A); Marketing it (E);
Research & Development (I); Writing about it (S).
```

Figure 10. DSS items. Unless otherwise noted, the client may select as many answers as desired for each item. Holland scoring is noted for each choice.

TESTING AND QUALITY ASSURANCE

The process of testing and quality assurance in relation to knowledge-based systems has been demonstrated to be a significant problem (Plant, 1990; O'Leary, 1988; Rushby, 1988). However, the techniques used in the development of our system are such that a high level of correctness is reached. 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

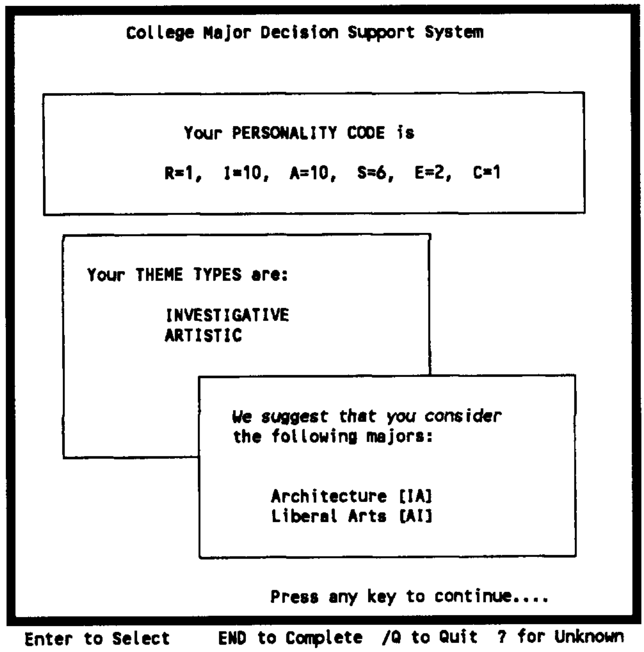

Figure 11. Sample Outcome Screen I.

demonstrate. The successor to this system will require alternative testing techniques such as critical data testing, random data tests, or functional testing (Rushby, 1988).

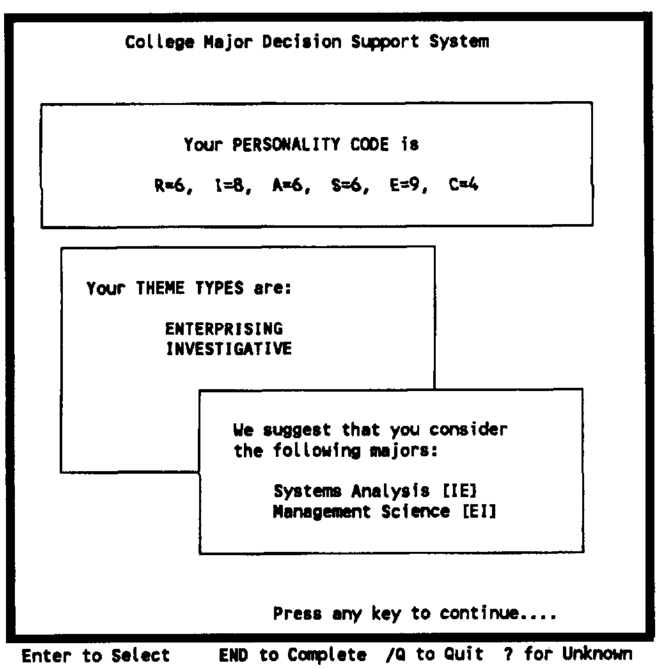

Figure 12. Sample Outcome Screen II.

SUMMARY AND CONCLUSIONS

The aim of this study was to produce a prototype DSS which is capable of assisting clients who are undecided about their educational or career goals. The system can be used in several ways:

1. Determining the Holland categorization of a client's personality type.
2. Determining feasible college majors based upon the client's personality type.
3. Utilizing the system's explanation capabilities to assist in the presentation of the selection and associated selection criteria.
4. A training aid to graduate students preparing to enter the counseling profession.

The system has a significant amount of potential in these areas. Nevertheless, there are several opportunities for improving this prototype system. First, more domain knowledge could be utilized by increasing the number of data entry opportunities from the present number of 15. As previously noted, this will come with advanced computer software. Second, an immediate way in which to improve the system's scope and sensitivity is to move to a three-theme Holland code. This would allow an increase in the ability of the system to select a finer grain size of solution. The explanation capability of the system could also be increased in order to act as a computer-aided instruction tool for both client and counselor. This explanation capability could be supplemented with references to outside sources, such as videos and literature regarding potential career paths.

The system that we have presented is not intended to replace existing assessment methods, but is instead an indication of a maturing decision support technology suitable for career counseling. Indeed, the prototype showed that considerable work in the DSS subfields of explanations, representations, elicitation, and analysis is needed prior to full exploitation of this technology by the practicing counselor. In addition, the incorporation of the research in decision analysis in conjunction with the research into the decision support system indicates that significant progress can be made in the area of psychological decision advisory systems. It has been noted that systematic decision making, which promotes consistency and completeness and which can act as a vehicle for information retrieval and support, would be of significant benefit to the counselor, client, and the counseling profession. 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 assessment. We therefore strongly advocate the use of such an approach in the future development of DSSs for assessment systems in career counseling.

Future goals of this work are large scale demonstrations of this system incorporating more counseling knowledge and integration with expert diagnostic knowledge.

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