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AN ADAPTIVE UNCERTAINTY REASONING - BASED MODEL FOR COMPUTERIZED TESTING

Radoslav Pavlov, Ruslan Mitkov, Philip Filev

ABSTRACT

After introducing computerized adaptive testing and its so far known approaches, the paper will describe an entirely new adaptive uncertainty reasoning based model for computerized testing. The structure of a testing system, based on it, will be presented and the advantages of the new approach will be discussed.

ADAPTIVE TESTING

Adaptive testing, proposed as an idea about 50 years ago, but fully implemented only with the availability of the computers, is an important and promising testing mode, which treats examinees of different knowledge level in a different way. Tests of ordinary difficulty result in decrease of interest among the good students and overcharge among the poor ones. Unlike traditional testing, adaptive testing does not present the same standard test to all the students. In computerized adaptive testing (CAT), the program "adapts itself" towards the knowledge level of the student: each next text item to be chosen depends of the current success of the testee. Adaptive testing serves at the same time to determine the knowledge level (and if necessary the score or the mark) of the student.

ADAPTIVE TESTING- APPROACHES SO FAR

Some simple strategies have been developed for drill and practice as well as for examination (Pavlov R., Eskenasi A., Mitkov R.,1985), (Mitkov R., 1986). These strategies aim either at testing the student to reach a certain "treshold number", or at establishing whether a poor result in certain area is casual or at taking into account expected boredom or fatigue of the students. No preliminary theory has been made use of, only experimental models of the student. Nevertheless these simple strategies have yielded comparatively good results. Besides, they are economic and easy to implement. However, these simple strategies are used only for training and cannot serve for estimation of the student's knowledge level.

Historically, a dynamic impact of the development of CAT strategies gave the "latent trait theory" (Birnbaum,1968), later called "item response theory" (IRT) (Lord, 1980). Adaptive testing on the basis of IRT represents a procedure, which selects the items to be offered taking into account how successful the previous answers have been. Mitkov (1987) reported on a modification of Lord's approach for CAT.

The methods of Owen (1975), Urry (1977), Lord (180), and Mitkov (1987) are quite accurate for the estimation of the testee's knowledge level. Unfortunately they are based on probabilistic models whose slow numerical solution (especially when working with the most widespread school personal computers) and respective time delay for the item selection is not always justifiable.

OUR NEW ADAPTIVE TESTING APPROACH

Our new approach for determining one's knowledge level (note) is an artificial intelligence approach based on uncertainty reasoning strategy. What is the motivation for the chose of this approach?

- large testing systems, which have in their item bank hundreds of items, are supposed to estimate the knowledge level of the testee on the basis of <u>incomplete information</u> : it is practically impossible that all the items should be administered to the testee;
- the initial item characteristics (difficulty level, discrimination power) are determined by the teacher and being originally subjective they should be regarded as <u>uncertain facts</u> ;
- the system should be able to explain <u>why</u> it has reached its conclusion.

As already mentioned, our adaptive testing approach makes use of an uncertainty reasoning strategy. The main idea is, that the testing process can be regarded as an affirmation (or rejection) of the hypothesis on the testee's knowledge level. As a quantitative approximation of the hypothesis serves the <u>c</u>ertainty <u>f</u>actor (CF). The response to each item causes recalculation of the CF (increase or decrease) until

CF > CFtreshold for affirmation or
CF < CFmin for rejection the hypothesis.

Each test item is a triple object-attribute-value generally represented as :

<attribute> of <object> is <value> with certainty CF.

The triple can by interpreted as a rule, which says:

IF the answer to the test item q with difficulty d is correct
THEN it is presumed that hypothesis for student's knowledge level affirmed with CF.

The testing process is clearly divided into two steps:

(1). proposal of a hypothesis on the basis of:

- information retrieved from the library on the examination history in the same domain or subdomain;

- preliminary (3-5) test items with high discrimination power.

(2). hypothesis verification.

As mentioned above. the solution to each item causes recalculation of the hypothesis (which in our case generally states: the student's knowledge level in the domain D is L and is estimated with the note N) by means of Buchanan and Shortliffe's (1984) formula:

$$
CFNEW(q1,q2)=\begin{cases}
CF(h,q1)+CF(h,q2)-CF(h,q1)*CF(h,q2) \\
\qquad \Leftrightarrow q\ CF(h,q1)>0,\ CF(h,q1)>0 \\[1em]
[CF(h,q1)+CF(h,q2)]/[1-\min(|CF(h,q1)|,|CF(h,q2)|)] \\
\qquad \Leftrightarrow CF(h,q1)>0,\ CF(h,q1)<0 \\
\qquad CF(h,q1)<0,\ CF(h,q1)>0 \\[1em]
-\ CF(-q1,-q2) \\
\qquad \Leftrightarrow CF(h,q1)<0,\ CF(h,q1)<0
\end{cases}
$$

where CF(q1,q2) is the certainty factor, contributed by the solution of the test item q1 and q2.

The certainty factor on each item is a linear function of the item's difficulty level and consequently changes dynamically as the difficulty level changes.

Suppose the student's note is preestimated to be N and he is administered an item with CF and suppose he answers correctly to the test item q1 with CF1 (=0.5) and to the test item q2 with CF2 (=0.45). Then

CFNEW(q1,q2)=0.5+0.45-0.5*0.45=0.725 (Fig.1)

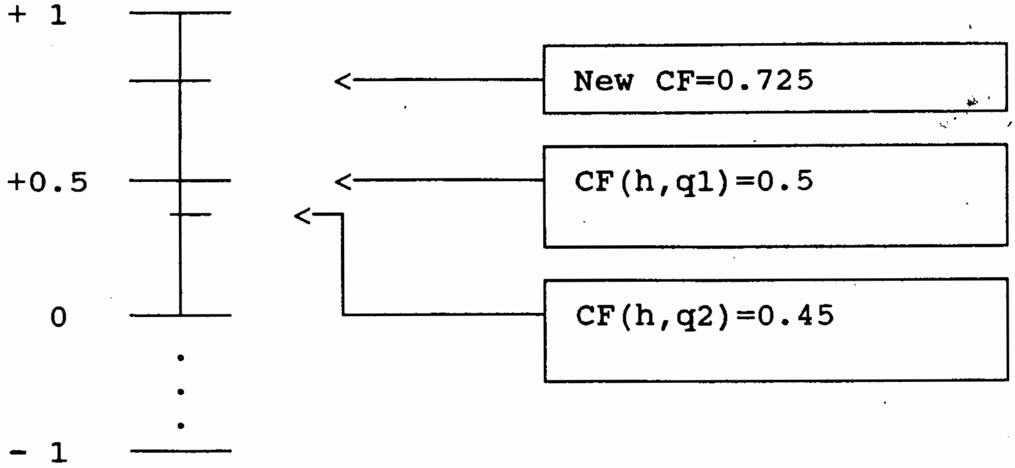
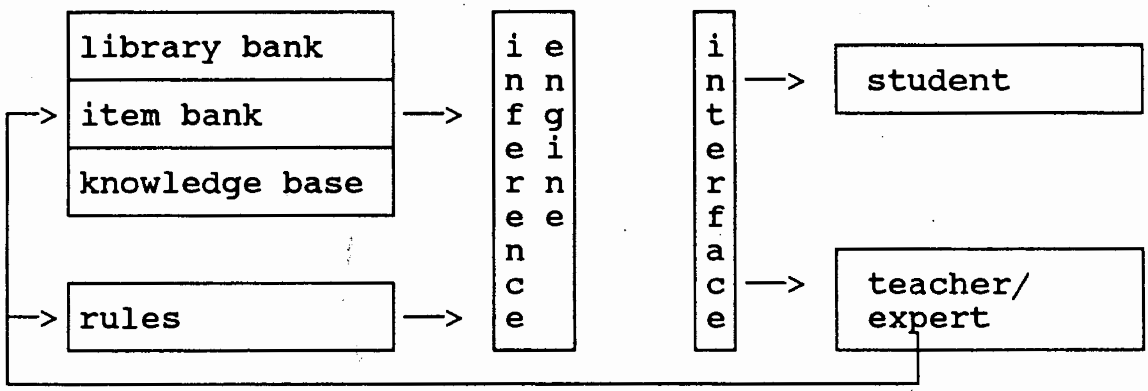


Fig.1. A graphic view of combined CF

THE COMPONENTS OF THE TESTING SYSTEM

The testing system consists the following components: item bank, knowledge base, library bank, inference engine, interface component (Fig.2).



The <u>item bank</u> consists of the test items, which are ordered hierarchically in test domains : the "upper" test domains contain the "lower" ones. Additional relations between the domains (or the test items) are described by rules. A good example of the typical hierarchy is the test domain of mathematics, represented as:

1. mathematics
1.1. elementary mathematics
1.1.1 arithmetics
. . .
1.2. higher mathematics
. . .
1.2.10. probability calculus
1.2.10.1. random events
1.2.10.2. random variables

The items in the bank are characterized by difficulty level and discrimination power parameters, which are empirically estimated. Each generation and each response of a item is recorded in the library. These data serve to update difficulty level and discrimination power after each test. For example, if the discrimination power parameter falls under 0.19 the expert (teacher) is signalled to revise the item. The library contains also information on the examination history of each student and the teacher is able to check his past scores. These recorded scores are used also to predetermine the expected note (step 1). Knowledge on relations between the items, difficulty level and discrimination power values and acceptability criteria of test items, as well as knowledge how to propose, to affirm or to reject a hypothesis, is available in the knowledge base.

UNCERTAINTY REASONING-BASED AND IRT-BASED ADAPTIVE TESTING

As IRT based, so uncertainty reasoning based adaptive testing has many advantages in comparison with traditional computerized testing: one evident advantage is, that the way to plausible estimation of the knowledge level of the testee is considerably shortened. Our approach is also stable to "hesitations": a single or even two incorrect answers do not influence decisively upon a few correct ones. Our approach seems to be somehow compatible with the IRT methods, because the success on a test item generally leads to a selection of a more difficult one and vice versa. Its main advantage we regard in the elimination of the numerical solutions of complex differential equations, which delays the generation of next test items.

The uncertainty reasoning-based approach is about to be experimented as a computer program. The practical results will show differences between it and IRT methods.

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