A Two-step Approach in Expert Evaluation of Correctional Information Technologies for Students with Autism Spectrum Disorders

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Abstract
Consolidation and processing of the experts` knowledge in the correction of communication and social skills of students with autism spectrum disorder seem to be both an actual task, and a challenge. Being well-aware of special needs of each and every student, psychologists and medics, as well as all the participants of education of ASD students, when making a decision about which information technology to use, apply their experience with exact ASD student. Expert evaluation technique enables support in such decision making, and its result can be used as input information to optimization task, solving which will allow taking into account different constraints.

Keywords [1]
Autism, autism spectrum disorder, ASD, analytic hierarchy process, AHP, expert evaluation, knapsack problem, branch and bound algorithm

1. Introduction

Personalized approach in treating the person with special needs is a key to successful his/her socialization. An educational process seems to be the most powerful tool in improving social and communication skills of a student. In this case, the outmost meaning an education has for students, who have autism spectrum disorders (ASD, for general, autism). The ASD persons have difficulties with communication, and it might be difficult to establish social connections. Education process, and inclusion, as its best form, can be of great support in correction and improving skills of such student, that will ensure his/her effective social life.

Supporting education of ASD students with information technologies seems to be logical (and necessary!) development direction of inclusive education in modern life. Now It-support is widely spreading, but unfortunately, it is unmanaged, mostly due to its complexity. Although some attempts of its structuring were taken [1], it is still far away from being an orderly process. Psychologists, medicians, teachers, and all the practicians, who are involved in IT support of ASD students education, are very valuable because of their experience with the exact student, and it is crucial to find an approach to collect their knowledge and use it to improve ASD student`s communication and social skills. Applying expert evaluation techniques will allow involving in IT support of ASD student education not only the abovementioned specialists but also parents, that will improve the results and make it more personalized and student-fitted. The main objective of the research is to improve a decision-making process for specialists who work with ASD student when then choosing the most appropriate information technology, used to correct communication and social skills of the student

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(Fig. 1). To reach this goal, a combination of some approaches is proposed, i.e. considering expert evaluation results as an optimization problem.

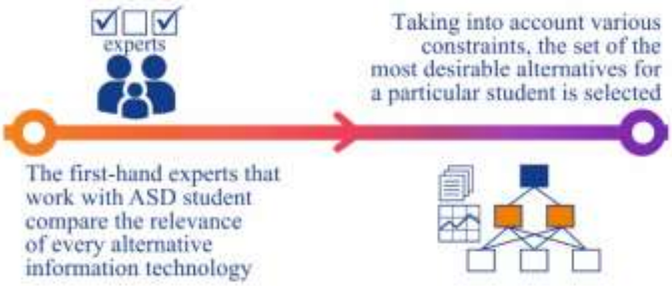

Figure 1. The concept of the research

2. Special needs of ASD students

The family of autism spectrum disorders is characterized by prominent biological markers, among which are stereotyped, repetitive movements of body parts, lowered interest in social activity, lowered gaze to faces, etc. [2]. An education process must not be a source of academic knowledge only, for ASD students it should become a mean of improvement and correction of communication and social skills and abilities. A balanced, thoughtful integration of information technologies into such a process will improve it significantly, for ASD students especially. The basis of such belief ground on the fact, that ASD student apperceive IT support and different gadgets like no other education technique [2-16].

Education of ASD students involves specialists in different directions [3]: psychologists, teachers, IT specialists, etc. By personalizing the process of ASD student's education, we improve it, and applying IT allows us to do it in a variety of different ways. For example, inclusive school can use some information technologies for ASD students' education. There might be some crucial questions, like which technology is the best for the exact student? How to choose between alternative technologies, if they differ, but slightly? How to combine the opinions of different specialists about those technologies? How to take into account that the desirable ITs` implementation is time and money consuming? Authors suggest an approach that allows answering answer such questions.

There are two main stages of the suggested approach of choosing the most relevant IT for ASD student: expert evaluation and its optimization. In this research, as an expert evaluation technique, we suggest an analytic hierarchy method (AHP). Its results, considered as a linear integer programming task, will be solved with branch and bound algorithm.

3. Expert evaluation of information technologies for ASD

The distinguishing feature of the efficient education of students with ASD is its unconditional personalization. That is why it is important to collect and use the knowledge of experts that work with ASD students personally. The expert evaluation techniques are quite popular and are widely used in different spheres, including medicine and psychology, where experts' judgments often can be the only available information on the issue. According to recent scientific researches, using expert evaluation there were suggestions provide to improve the service level medical devices using Delphi method [17]; efficiency of insurance companies was evaluated using neutrosophic data analytical hierarchy process [18]; the implementation of strategic pathways of sustainable electricity system was analyzed, using Aggregation of Individual Priorities method [19]; service quality evaluation system was constructed using fuzzy analytical hierarchy process [20]; etc.

To accumulate personalized judgments of experts on the education of ASD students, the analytic hierarchy process was chosen as experts` opinion evaluation method. The main idea of how the method can be implemented in five consequent steps is presented at Fig. 2.

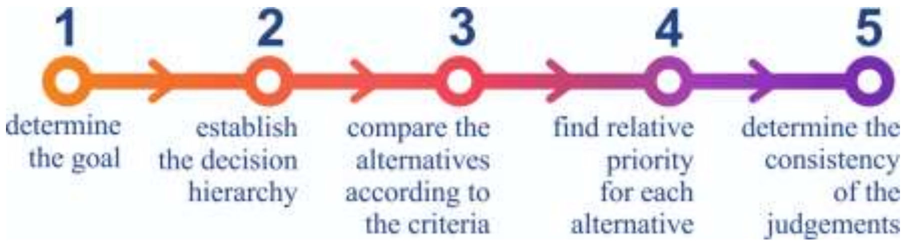

Figure 2: The concept of the AHP method

3.1 Step 1. Determine the goal

In a situation when ASD specialists should choose among many information technologies that will help in the correction of communication and social skills, the main goal is to rank such information technologies according to the experts` judgments.

3.2 Sep 2. Establish the decision hierarchy

All the information technologies that are to help in the correction of ASD students, should be assessed considering their needs, and take into account personal – psychological and medical – features of such students. The alternative information technologies should be compared according to some criteria, which are correlated with the main goal.

Let $C = \{C_i \mid i = 1,\ldots,n\}$ be a set of n personalized criteria, and $T = \{T_j \mid j = 1,\ldots,m\}$ is a set of m alternative information technologies that can be used in the correction of ASD students` communication and social skills.

In this study, as an example, we consider $n=4$ personalized criteria (Table 1) and $m=5$ alternative information technologies (Table 2, see [2-16]). The decision hierarchy is in fig. 3.

Table 1
Personalized criteria

Notation	Criterion
C_1	Communication skills improvement
C_2	Social skills improvement
C_3	Perception of relevant IT by the student
C_4	Easement of implementation into the school system of IT support of ASD students

Table 2
Alternative IT

Notation	Alternative IT
T_1	Glass and augmented reality
T_2	Laptop and virtual reality
T_3	PECS and augmented reality
T_4	Tablet and augmented reality
T_5	Virtual reality

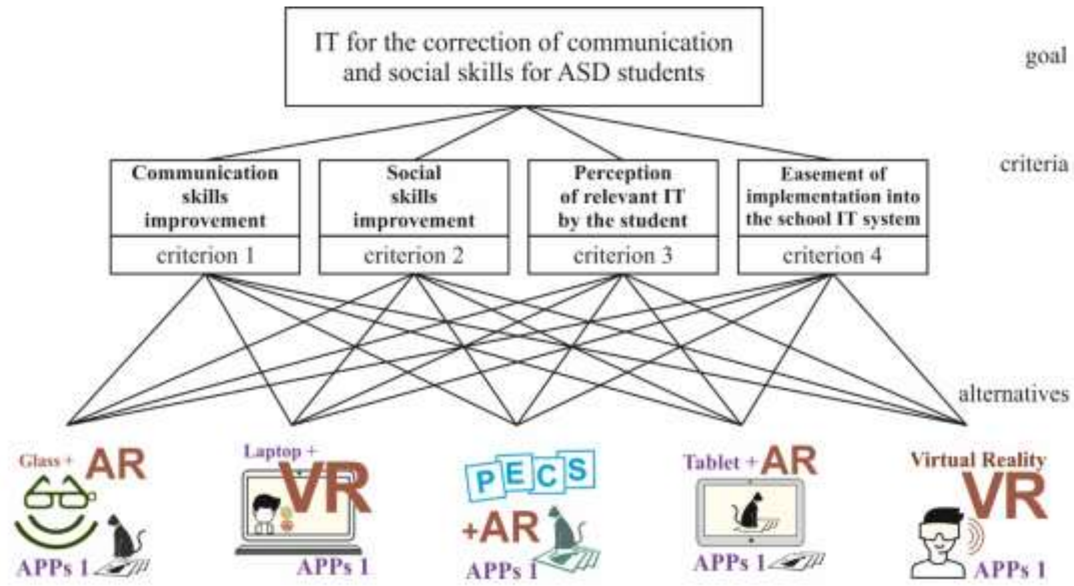

Figure 3: Decision hierarchy

3.3 Step 3. Compare the alternatives according to the criteria

There is 4 main type of experts who are close enough to the ASD student to be able to rate alternative technologies considering personalized criteria. Such experts are school specialists, i.e. psychologist, medic, teacher and his/her assistant, and non-school specialist, who cooperate with ASD student – the parents. To assess the alternatives, such specialists should compare every two alternatives considering each criterion. Fig. 4 shows how the linguistic description of the importance can be quantified.

Figure 4: AHP rating concept

On the basis of experts` opinion, the judgment matrix *A*, as an $m \times m$ matrix of pair-wise comparisons is formed, $A = (a_{ij}), a_{ij} > 0, a_{ji} = 1/a_{ij}, a_{ii} = 1$, where $i = 1,...,m$, $j = 1,...,m$, *m* is a number of alternatives, and a_{ij} is a ration of the importance of one alternative over another (for example, fig. 5 shows the judgment matrix of one of the experts on the criterion *Communication skills improvement*). On each of *n* criterion, an expert should make $\frac{m(m-1)}{2}$ comparisons.

$$
\begin{array}{c}
\quad\; T_1 \quad T_2 \quad T_3 \quad T_4 \quad T_5 \\
A = \begin{bmatrix} 1 & 1/5 & 1/5 & 3 & 1 \\ 5 & 1 & 1/2 & 5 & 6 \\ 5 & 2 & 1 & 6 & 2 \\ 1/3 & 1/5 & 1/6 & 1 & 1/2 \\ 1 & 1/6 & 1/2 & 2 & 1 \end{bmatrix}
\end{array}
$$

Figure 5: The pair-wise comparison matrix for *Communication skills improvement* criterion.

3.4 Step 4. Find relative priority for each alternative.

Experts` judgements result in n matrixes. For every matrix, each column of the matrix is normalized, the sum of each line is divided in m, and the achieved vector w is a priority vector (fig. 6). Accept of this method of finding the priority vector, there are some others [21-23], which differs in precision.

$$
\begin{array}{ccccccc}
T_1 & T_2 & T_3 & T_4 & T_5 & & w
\end{array}
$$
$$
\begin{bmatrix} 1 & 1/5 & 1/5 & 3 & 1 \\ 5 & 1 & 1/2 & 5 & 6 \\ 5 & 2 & 1 & 6 & 2 \\ 1/3 & 1/5 & 1/6 & 1 & 1/2 \\ 1 & 1/6 & 1/2 & 2 & 1 \end{bmatrix} \begin{bmatrix} 0.099 \\ 0.353 \\ 0.386 \\ 0.052 \\ 0.110 \end{bmatrix}
$$
$$\lambda = 5.432, CI = 0.108, CR = 0.096$$

$$
\begin{array}{ccccccc}
T_1 & T_2 & T_3 & T_4 & T_5 & & w
\end{array}
$$
$$
\begin{bmatrix} 1 & 2 & 4 & 7 & 4 \\ 1/2 & 1 & 2 & 8 & 7 \\ 1/4 & 1/2 & 1 & 5 & 1 \\ 1/7 & 1/8 & 1/5 & 1 & 1/2 \\ 1/4 & 1/7 & 1 & 2 & 1 \end{bmatrix} \begin{bmatrix} 0.417 \\ 0.322 \\ 0.133 \\ 0.041 \\ 0.088 \end{bmatrix}
$$
$$\lambda = 5.317, CI = 0.079, CR = 0.07$$

$$
\begin{array}{ccccccc}
T_1 & T_2 & T_3 & T_4 & T_5 & & w
\end{array}
$$
$$
\begin{bmatrix} 1 & 2 & 1/2 & 1/2 & 1 \\ 1/2 & 1 & 1/2 & 1/7 & 2 \\ 2 & 2 & 1 & 1/2 & 2 \\ 2 & 7 & 2 & 1 & 9 \\ 1 & 1/2 & 1/2 & 1/9 & 1 \end{bmatrix} \begin{bmatrix} 0.143 \\ 0.093 \\ 0.209 \\ 0.471 \\ 0.084 \end{bmatrix}
$$
$$\lambda = 5.355, CI = 0.089, CR = 0.079$$

$$
\begin{array}{ccccccc}
T_1 & T_2 & T_3 & T_4 & T_5 & & w
\end{array}
$$
$$
\begin{bmatrix} 1 & 1 & 1 & 2 & 1 \\ 1 & 1 & 1 & 4 & 1 \\ 1 & 1 & 1 & 1 & 2 \\ 1/2 & 1/4 & 1 & 1 & 1 \\ 1 & 1 & 1/2 & 1 & 1 \end{bmatrix} \begin{bmatrix} 0.214 \\ 0.258 \\ 0.225 \\ 0.134 \\ 0.169 \end{bmatrix}
$$
$$\lambda = 5.292, CI = 0.073, CR = 0.065$$

Figure 6: AHP calculations

The priority vectors form the Table 3.

Table 3
Comparison of the characteristics of five alternative information technologies

	C_1	C_2	C_3	C_4	Relative priority
T_1	0,099	0,417	0,143	0,214	0,218
T_2	0,353	0,322	0,093	0,258	0,256
T_3	0,386	0,133	0,209	0,225	0,238
T_4	0,052	0,041	0,471	0,134	0,175
T_5	0,110	0,088	0,084	0,169	0,113

The relative priority vector contains an overall evaluation of the alternatives, and in this research, we calculate relative priority as average for every alternative.

3.5 Step 5. Determine the consistency of the judgements.

To determine the consistence of experts` opinions, the main eigenvalue λ is used. To find it, the elements of each column of matrix A should be summed, and the λ can be achieved by multiplying the found vector of sums with *w*. The judgements are more consistent, the closer λ is to the rank of matrix *A*. To find the consistency index *CI*, λ should be reduced by *m* and divided into (*m*-1), $CI = \frac{\lambda - m}{m-1}$ (fig. 6).

To calculate the consistency ratio *CR*, the random consistency index *RI* (Table 4, [25]) is used, according to the rank of matrix *A*, $CR = \frac{CI}{RI}$ (fig. 6). The consistency ratio of less than 0.1 is considered as the fact, that the matrix meets the consistency standards [25].

Table 4
Random consistency index (M is the rank of the matrix A)

M	1	2	3	4	5	6	7	8	9
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45

According to the relative priority vector (Table 4), the most relevant information technology is T_2. No doubt, that the implementation of each information technology will have some limitation, such as financial and time limits. Then it is possible, that some other, and not the suggested by AHP method technology will fit better these limitations. As a suggestion, we can consider such a situation as a knapsack problem.

4. Optimization of the set of relevant ITs as a Knapsack Problem, and branch and bound algorithm to solve it

The Knapsack Problem (KP) is a well-known combinatorial optimization problem, introduced in 1950, and since then it overgrowth with various methods of its solving, and various spheres of its implementation [25]. Recently, researchers formulated KP or its variations to implement it in the Internet of Things [26]; in the optimization process of information protection tools placement [27]; in balancing incremental revenue with financial constraints [28]; to improve the diversity of the information exposed to social-media users, that are connected [29]; to prevent maritime cargo disruption as during 2020 pandemic lockdowns [30]; etc. [31-35].

The mathematical programming formulation of the Knapsack Problem is:

$$F(x)=\sum_{j=1}^{m} z_j x_j \rightarrow Max \tag{1}$$

$$\sum_{j=1}^{m} a_{ij} x_j \leq b_i,\ i=1,..,k \tag{2}$$

$$x_j \in \{0,1\},\ j=1,...,m \tag{3}$$

Being solved, the KP (1)-(3) gives an answer to a question, which items are packed in a knapsack (x_j=1), and which are not (x_j=0). Let us formulate the KP (1)-(3) in terms of choosing the set of relevant information technologies among available with all constraints satisfied.

Let

m=5 is the number of alternative information technologies for communication and social skills correction (T_1-T_5, Table 2);

k=2 is the number of resources, the first is connected to the cost of implementation of the technology into IT system of the school, the second one is the time for such implementation;

b_i is the ith resource capacity, b_1=12 money conditional units, b_2=9 time conditional units;

z_j is the usefulness of the jth IT (its profit), in fact, these elements are obtained from the relative priority vector w (Table 4), where zi=1 for the least relevant alternative, and all the alternatives are evaluated similary according to AHP results. In this case, z_1=3, z_2=5, z_3=4, z_4=2 z_5=1.

a_{ij} is the amount of units of ith resource for each item j. These data are collected from technical documentation on each information technology, and $(a_{ij})=\begin{pmatrix} 5 & 7 & 2 & 8 & 4 \\ 3 & 4 & 5 & 2 & 5 \end{pmatrix}$.

Then the KP of this research is:

$$F(x)=3x_1+5x_2+4x_3+2x_4+x_5 \rightarrow Max \tag{4}$$

$$\begin{aligned} &5x_1+7x_2+2x_3+8x_4+4x_5 \leq 12 \\ &3x_1+4x_2+5x_3+2x_4+5x_5 \leq 9 \end{aligned} \tag{5}$$

$$x_j \in \{0,1\},\ j=1,...,5 \tag{6}$$

To solve this task, we use the branch and bounds algorithm (Fig. 7). The resulting value will be interpreted as a suggestion to use (the value of the variable = 1) or not to use (the value of the variable = 0) the appropriate IT.

The KP solution is $x_1=0, x_2=1, x_3=1, x_4=0, x_5=0$. In terms of the ask of choosing the set of the most relevant information technologies among available with time and money constraints satisfied, it is advisable to implement the second and first of the proposed ITs, and it will take 9 money conditional units with 9 time conditional units.

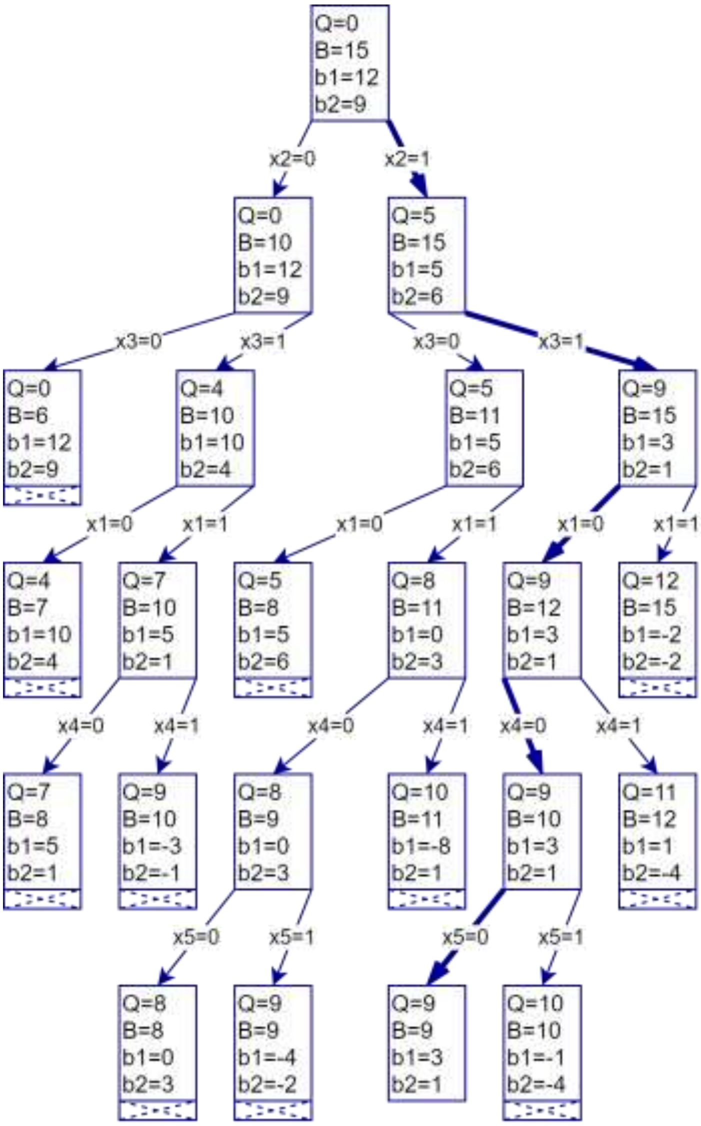

Figure 7: Application of the branch and bounds algorithm to solve (4)-(6) task

5. Conclusion

The concept of the process of choosing information technology, suitable for teaching students with autism, consists of two steps, the expert evaluation technique, where authors suggested the analytic hierarchy process. The second step was an optimization of the set of relevant ITs as a knapsack problem, and branch and bound algorithm to solve it. All the methods implemented in the study were proven to be effective, and combining them gives an additional tool in decision making for psychologists, teachers, medicians, etc. who work with children with an autism spectrum disorder.

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