A problem of long distances in the educational environment

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Abstract. A process of the specialist’s professional development involve two aspects of the decision-making support: choosing a field of study (by an applicant) and choosing an applicant for a job position and training (by a company). The correctness of solving this task depends greatly on developing methods allowing to identify potential of an applicant. The goal of this research is developing a formalized approach to create the metrics in the educational environment, which would allow comparing applicants to each other in terms of compliance with the requirements of a certain job. The methods: the research uses system analysis approaches; models of characteristics changing during the training; scaling of heterogeneous values; integrating particular estimations (getting integral estimation) based on expert opinions. The results: the analysis allowed identify a set of dependencies related both to a study subject and job requirements, distinctive features and resource characteristics of learning technologies. Several models and an approach to assessing a prospective applicant were suggested taking into account a multi-dimensional resource, which is required to train a certain applicant up to the required level. The practical relevance: the suggested approach allows to make formalized setting and further addressing a set of evaluation and optimization tasks related both to the best choice of future job (for an applicant), and a choice of most promising applicants and learning techniques (for a company).

1. Introduction

Nowadays, every person can choose his or her learning vector by himself/herself. This applies not only to education, but also to any area he or she would like to progress in. However, if a sports coach can easily reveal that a child is not gifted and informs the parents thereof, it is much worse when a gifted student chooses his or her further learning path deliberately, but incorrectly. Such student either cannot understand a scope of efforts he or she would need to take to complete the education, or does not have a clear notion of future job. In this particular case, incorrectly means a student (even with good academic achievements in his or her studies) would not be able to do his or her job effectively enough in the future in the chosen professional area because of certain personal traits. It should be noted that such incorrect choice is paid by the State, and the experience can be traumatic for the person, if he or she would not succeed in the chosen career.

When an organization recruits applicants or sends people to professional coaching, any incorrectness and coaching process are paid by this organization. For this reason, the organization is above all interested in choosing applicants, who meet its requirements to the maximum. It must be said...
that though the recruited applicants often meet the present-day requirements, they are not always sufficiently promising employees because of the fast-changing market and technological situation.

At the same time, propensity of organizations for continuous improvement of employees, and growth in their qualifications [1] results in extra costs on various resources. Such costs can be reduced through automation of HR management decision support system (recruitment, advanced training, career progression) [2]. However, the prerequisite for deploying such management decision support system (MDDS) is formalizing a task of comparing applicants taking into consideration their capabilities during further coaching that require spending some resources [3]. To formalize as specified above it is necessary:
- to investigate special aspects of possible learning paths [4, 5];
- to analyze various approaches to comparing applicants;
- to develop a formalized model and a relevant approach to identifying the choice of learning preferences.

2. Applicant and requirements
Let us assume that there is initially a certain set of requirements, i.e. S, for the specific specialty which an applicant (candidate) should meet as a result of recruitment and further coaching. Then, the professional general profile of an applicant, i.e. U [6, 7], should be \( U_S = \{u_{1S}, u_{2S}, \ldots, u_{nS}\} \). This tuple \( \{u_{1S}, u_{2S}, \ldots, u_{nS}\} \) is completed with names of only those characteristics, which are specified in a set of requirements identified as a certain master standard designed by the organization. It should be noted that the master standard of S specialist designed by a specific organization might often differ from the profile of similar specialist designed by another organization.

Let us further assume that the requirements developed by the organization in relation to specific characteristics of a specialist shall be a set of lower bounds for certain characteristics, i.e. \( b_{1S}, b_{2S}, \ldots, b_{nS} \), with the requirement to satisfy \( x_{iS} \geq b_{iS} > 0 \), \( i = 1, 2, \ldots, n \) inequalities, which specifies \( B_S \) set. \( A \in B_S \) expression means that A applicant fully meets all requirements imposed by S specialty. Besides, let us assume that all characteristics are normalized and the higher the value of this characteristic the better for applicant’s activities within this specific specialty.

Note 1. The above assumptions are required to avoid unnecessary restrictions on the convolution of characteristics and to ensure correct convolution of various parameters when defining a complex (integral) characteristic of a specialist.

Note 2. The normalization task is rather specific and can be solved in a number of ways.

Note 3. It is obvious that various master standards (requirements) imposed on specialties might differ from each other not only by boundary values, but also by a number and nomenclature of the required characteristics.

Let us consider the problem of establishing relations of equality and partial order.

Let us assume there are \( A_j \) and \( A_k \) applicants having particular characteristics: \( x_{j1S}, x_{j2S}, \ldots, x_{jnS} \) and \( x_{k1S}, x_{k2S}, \ldots, x_{knS} \). Let us compare two applicants as applied to the requirements imposed by S specialty.

Relation of equality. \( A_j \) applicant is equal to \( A_k \) applicant (\( A_j = A_k \)) in the sense of the requirements imposed by S specialty, if \( x_{jk} = x_{kj}, k = 1, 2, \ldots, n \) is satisfied, i.e. the values of all characteristics as set by the requirements imposed by S specialty are the same.

Relation of partial order. \( A_j \) applicant is better (preferable) than \( A_k \) applicant (\( A_j \succ A_k \)) in terms of certain \( k \) characteristic, if \( x_{jk} \geq x_{kj} \) is satisfied. We can observe that this relation is transitive. In like manner, we can derive a similar relation for a set (all) characteristics imposed by S specialty in
A_j applicant is better (preferable) than A_l applicant (A_j > A_l) in terms of all requirements imposed by S specialty, if the following relation is satisfied.

\[ x_{j,k} \geq x_{l,k}, k = 1, 2, \ldots, m, \text{ and } \exists n, \quad x_{j,n} > x_{l,n} \]

The above relationship results in transitivity of the relation of partial order, i.e. if

\[ A_{j,s} > A_{l,t}, \quad A_{l,s} > A_{k,t} \Rightarrow A_{j,s} > A_{k,t} \]

Note 4. It should be noted that this relation is true only at a particular time without regard to person’s progress (applicant’s coaching or learning) and, moreover, the bare fact that one applicant is better than the other does not mean that such applicant satisfies the entire set of requirements imposed by S specialty.

So, taking into account changes of certain characteristics over period of time we observe vector-functions of the characteristics of analyzed (compared) applicants

\[ A_j(t) = (x_{j,1S}(t), x_{j,2S}(t), \ldots, x_{j,mS}(t)) \]

and

\[ A_l(t) = (x_{l,1S}(t), x_{l,2S}(t), \ldots, x_{l,mS}(t)) \]

representing the improvement (coaching) process.

3. Models of characteristic changes (analysis of specific properties)

It is well founded in Change Models for Characteristics (Personal Qualities) article [8] that under rather natural conditions imposed on special features of change (improvement) function of certain characteristic, i.e. non-negativeness, monotonic increasing, some initial value (A_initial), boundedness (A_max is a limit value) and horizontal asymptote, a convexity starting from a certain point, etc.), its change can be described by simple differential equation

\[ \frac{dA(t)}{dt} = \lambda(A_{\text{max}} - A(t))^k \]

where \(\lambda\) represents personal (psychological, psycho-physiological, etc.) properties of applicant, and \(\lambda\) represents his or her capabilities to fast improvement of specific characteristic. See figure 1 for a solution family of the above differential equation.

![Figure 1](image-url)  
Figure 1. A solution family of differential equation

Various trajectories of characteristic change.

Let us consider a possible change in relation of partial order in the course of person’s learning. Let us consider a time point \(t_0\) and \(t > t_0\). If \( A_j(t_0) > A_l(t_0) \) relation is true at \(t_0\) time point, then this equation may be not true at \(t\) time point.

Let us consider and analyze several special cases of possible change in certain characteristic of two applicants.
Example 1. See figure 2 for trajectories of characteristic changes $x_{jk}(t)$, $x_{lk}(t)$, $x_{lk}(t)$ - solid line, $x_{jk}(t)$ - dotted line.

Let us perform a comparative analysis of changes in $k$ parameter of two applicants $x_{jk}(t)$, $x_{lk}(t)$ in the course of improvement (coaching, learning) as shown in figure 2.

At $t_0$ time point $x_{jk}(t_0) > x_{jk}(t_0)$ relation is true, i.e. at some initial time point $A_j$ applicant is somewhat better (preferable) than $A_l$ applicant concerning the characteristic in question, though both do not meet the requirements imposed by the specialty so far. It means only that such a characteristic is more developed by a certain applicant, and this significantly depends on his or her life experience, and not only on professional activities.

At $t_1$ time point $x_{jk}(t) > x_{lk}(t)$ relation is not true already, since both applicants become similar to each other and starting from this time point $A_l$ applicant becomes preferred over $A_j$ applicant concerning the characteristic in question.

At $t_2$ time point $x_{jk}(t_2) > x_{lk}(t_2)$ characteristic of $A_j$ applicant achieves $b_{ks}$ minimum value specified in the requirements imposed by $S$ specialty, i.e. starting from this time point $A_j$ applicant meets the requirements imposed by $S$ specialty concerning the characteristic in question.

At $t_3$ time point $x_{jk}(t_3)$ characteristic of $A_j$ applicant also achieves $b_{ks}$ value required by $S$ specialty, i.e. starting from this time point $A_j$ applicant also meets the requirements imposed by $S$ specialty concerning the characteristic in question.

At $t_4$ time point $x_{jk}(t_4)$ characteristic of $A_j$ applicant achieves $A_{jk\text{ max}}$ value, that is maximum possible (because of various circumstances) for $A_j$ applicant.

Note 5. As is evident from Fig.2, $A_j$ applicant (despite a not very high initial value of characteristic in question ($x_{jk}(t_0) > x_{lk}(t_0)$), not only catches up with and overtakes $A_j$ applicant in

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**Figure 2.** Possible changes in certain characteristic of two applicants.
the course of improvement, but what is equally important has greater potential for improving the characteristic in question ($A_{l_{\text{max}}} > A_{j_{\text{max}}}$). Moreover, once overtaking $A_j$ applicant $A_l$ applicant leaves him or her farther and farther behind.

However, the relative positions of characteristics might change more significantly in the course of their improvement.

Let us observe the case when the relation between the characteristic of two applicants changes for several times (figure 3).

Example 2.

![Figure 3](image)

**Figure 3.** Possible changes of certain characteristic of different applicants.

Let us analyze a change in relations of $x_{j_k}(t)$, $x_{l_k}(t)$ characteristic in the course of improvements as specified in figure 3.

At $t_0$ time point $x_{j_k}(t_0) > x_{l_k}(t_0)$ relation is true, i.e. $A_j$ applicant is initially preferred over $A_l$ applicant concerning the characteristic in question, and this relation remains unchanged until $t_1$ time point.

At $t_1$ time point $x_{j_k}(t) > x_{l_k}(t)$ relation in not true already, since the applicants become similar to each other and further on (until $t_4$ time point) $A_l$ applicant is preferred over $A_j$ applicant concerning the characteristic in question.

At $t_2$ time point $x_{l_k}(t_2)$ characteristic of $A_l$ applicant achieves $b_{ks}$ minimum value required by the specialty in question, and starting from this time point $A_l$ applicant meets the requirements imposed by $S$ specialty concerning the characteristic in question.

At $t_3$ time point $x_{j_k}(t_3)$ characteristic of $A_j$ applicant also achieves $b_{ks}$ value and starting from this time point $A_j$ applicant also meets the requirements by the specialty concerning the characteristic in question.

At $t_4$ time point the values of the characteristic under analysis becomes equal for both applicants again $x_{j_k}(t_4) = x_{l_k}(t_4)$ and starting from this time point $A_j$ applicant starts overtaking $A_l$ applicant.
At $t_5$ time point $x_{jk}(t_5)$ characteristic of $A_j$ applicant achieves $A_{jk}\max$, that is maximum possible for $A_j$ applicant.

Note 6. Based on the analysis and Fig.3 we observe that $A_i$ applicant (despite a not very high initial value of characteristic in question ($x_{ik}(t_0) > x_{jk}(t_0)$) catches up with $A_j$ applicant and overtakes his or her in the course of improvement within a short period of time, and he or she starts meeting the requirements imposed by the specialty earlier (concerning the characteristic in question). However, in the future this applicant would be less preferred, since he or she has less potential for improving the characteristic in question ($A_{jk}\max < A_{ik}\max$).

The above examples highlight the fact that it is by no means always possible to make a precise (correct) choice, preferring this one or another specific applicant comparing them using a certain characteristic, since different applicants improve the characteristic at different rate and their boundary values can differ as well.

Note 7. Instead of independent variable (time in the above cases) we can use some multivariate or complex resource.

Note 8. Improvement of a specific applicant’s characteristic or the entire set of characteristics significantly depends on a learning (coaching) technology to be used.

4. Learning technologies

Let us consider a set of learning technologies $Q = (q_1, q_2, ..., q_v)$ and choose the technologies allowing us to provide learning (coaching) as required by S specialty $Q_S = (q_1, q_2, ..., q_v)$. $Q_S \subseteq Q$, $v_s \leq v$. Notably, not all technologies can be used for each applicant.

Let us choose $Q_{jS} = (q_{j1}, q_{j2}, ..., q_{jv_j})$, $Q_{jS} \subseteq Q_S$, $v_{jS} \leq v_S$ learning technologies suitable for $A_j$ applicant. Further, let us assume that the coaching is provided only up to the boundaries of the corresponding area of requirements, i.e. as soon as the last (worst in the terms of requirements by this specialty) characteristic starts meeting the requirements imposed by S specialty, the coaching stops. In this case, it could be any point, in which values of applicant’s characteristic (coordinates) satisfy the following relation:

$$x_{jk} \geq b_{kS}, \forall k = 1, 2, ..., m_s, \exists l, x_{jl} = b_{lS}$$

This relation defines one of boundary points of set of requirements imposed by $B_S$ specialty in question.

Let us analyze possible results of using various learning technologies for one applicant. Using $q_{jk} \in Q_{jS}$ learning technology turns $A_j$ applicant into $A_{jk} \in B_S$ specialist, who meets the requirements imposed by S specialty.

Note 9. In addition, all $A_{jk}, k = 1, 2, ..., v_{jS}$ specialists resulted from using various learning technologies can be distinguished by their characteristics.

As can be seen from the above, a special focus should be put on the resources required when using learning technologies.

5. Resources

When coaching (training) specialists it is necessary to use various types of resources (financial, technological, human, time, etc.), and each resource in its turn consists of smaller (detailed) components. For example, the human resources include not only coaches, but also staff supporting their activities (dean's office team, system administrators, technicians, executives, etc.) Let us introduce $R = (r_1, r_2, ..., r_m)$ resource vector where $m$ means a number of types of various resources.
To use a learning technology one need to spend some resources, i.e. $q_{jk}(r)$, $k = 1, 2, ..., v_{jk}$ learning technology can be defined by \( \tilde{r}_{jk} = (r_{jk1}, r_{jk2}, ..., r_{jkm}) \) vector.

Note 10. \( r_{jk} \) vector is a characteristic of the required resources of learning technology, which is used to improve \( A_{ij} \) applicant to make him or her compliant with the requirements imposed by \( S \) specialty (\( A_{jk} \in B_{S} \)), i.e. it can depend both from specific properties of the learning technology, and from specific properties of the applicant.

Note 11. Since the demand in various types of resources can differ depending on various stages of applicant coaching process, the components of resource vector can depend on time \( \tilde{r}_{jk}(t) = (r_{jk1}(t), r_{jk2}(t), ..., r_{jkm}(t)) \).

6. Metrics and their use

To compare various applicants and learning technologies it is possible to use both individual resource characteristics and integral resource characteristics $V(\tilde{r}_{jk})$ taking into account the importance of certain resources and possible errors in estimations [9, 10], e.g. $V(\tilde{r}_{jk}) = \sum_{i=1}^{m} a_i \cdot r_{jki}$, where \( \bar{a} = (a_1, a_2, ..., a_m) \) vector depicts the importance of some resource components. While calculating the consumption of resources required to coach \( A_i \) and \( A_j \) applicants using the chosen sets of learning technologies \( Q_{is} = (q_{i1}, q_{i2}, ..., q_{in}) \), \( Q_{js} = (q_{j1}, q_{j2}, ..., q_{jn}) \), we obtain \( \tilde{V}_i = (v_{i1}, v_{i2}, ..., v_{in}) \), \( \tilde{V}_j = (v_{j1}, v_{j2}, ..., v_{jn}) \) (\( v_{jk} = V(\tilde{r}_{jk}) \)) vectors.

Let us call \( \rho(A_i, A_k) = v_{ik} \) integral resource (required to coach \( A_i \) applicant to make him or her compliant with the requirements of \( S \) specialty using \( q_{ik} \) learning technology) a conditional distance between \( A_i \) applicant and a set of requirements imposed by \( S \) specialty.

Definition 2. Let us call $v_i = \rho(A_i, S) = \min_k v_{ik} = \min_k \rho(A_i, A_k)$ minimum integral resource (required to coach \( A_i \) applicant to make him or her complaint with the requirements of \( S \) specialty) a distance between \( A_i \) applicant and a set of requirements imposed by \( S \) specialty.

If the choice of applicant and learning technology is based on the resource saving, then to make the choice it is enough to compare all components of \( \tilde{V}_i = (v_{i1}, v_{i2}, ..., v_{in}) \), \( \tilde{V}_j = (v_{j1}, v_{j2}, ..., v_{jn}) \) vectors both inside the groups of the used technologies (to choose the most cost effective learning technologies for a certain applicant) and between the groups when it comes to harsh resource austerity measures.

If similar learning technologies are used to coach applicants, then by analogy with Definition 1 and 2 we can derive the next Definitions.

Definition 3. Let us call a modulus of difference (between $\rho_i(A_i, A_j / q_k) = |\rho(A_i, A_k) - \rho(A_j, A_k)|$ integral resources required to make \( A_i \) and \( A_j \) applicants complaint with the requirements of \( S \) specialty using \( q_k \) general technology) a conditional distance between \( A_i \) and \( A_j \) in terms of requirements imposed by \( S \) specialty.
Definition 4. Let us call a minimum value of modulus of difference (between $\rho_s(A_i, A_j) = \min_k \rho_s(A_i, A_j/q_k) = \min k \left| \rho(A_i, A_k) - \rho(A_j, A_k) \right|$) integral resources required to make $A_i$ and $A_j$ applicants complaint with the requirements of $S$ specialty using a single learning technology) a distance between $A_i$ and $A_j$ in terms of requirements imposed by $S$ specialty.

If $A_i$ and $A_j$ applicant are coached using different technologies, i.e. $Q_{is} \neq Q_{js}$ is true, then let us introduce the definition of absolute distance.

Definition 5. Let us call a minimum value of modulus of difference (between $\rho_s(A_i, A_j) = \min_k \left| \rho(A_i, A_k) - \rho(A_j, A_k) \right|$) integral resources required to make $A_i$ and $A_j$ applicants complaint with the requirements of $S$ specialty) an absolute distance between $A_i$ and $A_j$ in terms of requirements imposed by $S$ specialty.

To solve practical tasks of recruitment or choice of respective learning technologies it is enough to find a minimum value of one of the above (as applicable) definitions.

Note 12. It should be clearly understood that the results of coaching applicants and using various learning technologies might be represented by various boundary points of a set of requirements imposed by $S$ ($B_s$) specialty, which might entail some extra and vaguely worded preferences by relevant executives.

7. Conclusions and opportunities

The metrics of distances developed based on notions of multivariate or complex resource are scientific and methodological framework for the core of decision support system aimed at solving the tasks of human capital management. The suggested approach and defined set of models allow us to reasonably and correctly formulate and solve a number of various problems related to the choice of the best applicants and learning technologies from a variety of available things. Solving a wide range of similar problems based on using the suggested results and relevant information resources would assist in improving efficiency of organizations (companies) and improving specialists. Using the framework of expert assessments and Bayesian networks [11] would, in its turn, speed up the process of creating intelligent systems for the human capital management [12, 13].

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