# Postdraduate development: an intriguing journey from a graduate to the IT professional

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***Abstract*****—On one hand, the universities typically offer the graduate programmes and degrees in computer science, computer engineering and information technology, on the other hand, IT companies look for IT professionals in dozens of different positions, such as programmers/ developers, analysts, consultants, administrators, database specialists, testers etc. For many positions, a degree in computer science or related discipline is just a necessary, but far not sufficient condition, deep knowledge in specific areas and technologies as well as several years of experience after graduation are required. At the same time, a lot of discussions about neccessity of cooperation between academia and praxis has been done. Observing that the university study is a quite structuted process and the requirements for particular positions are (more or less) clearely formulated with the attempt to standardize them, the process in between – here called postgraduate development – is fairly unstructured, ad hoc and individual from case to case. One of the possible answers from academia in several countries, such as Australia, Great Britain, USA and Netherland is so called professional doctorate as an alterantive to the PhD degree, to close the gap between the requirements of IT job market and the graduation at the university. We discuss the issue of postgraduate development of IT professionals with the aim to answer in a structured way not only what should be the skills for particular positions, but also how they can be gained.**

## I. Introduction

In last decades we have observed a tremendeous development of Information Technology, and with Cloud, Big Data, Mobile Computing and Internet of Things this development becomes even faster and faster. It is accommpied with still increasing numbers and fastly changing types of positions in IT job market. Paradoxly, with continuous globalization not only the big players, such as Apple, Google, Microsoft and IBM grow, but also new startups are rising in very few years to gigants, such as Facebook, Twitter or LinkedIn. The success of such startups revolutionized the view on the role of tradition in brand building, with many of young technology companies between 100 most valuable brands in the world [1]. In addition, still more IT professionals decide to work as freelancers. Information Technology is still more an more an innovation accelerator and cathalyst for innovations influencing and intersecting with many other fields, from social aspects in form of social networks, through applications of IT in healthcare commonly known as eHealth applications, eEducation and eLearning, eBusiness with Amazon and eBay, to the next revolution in Industry, known as Industry 4.0. Succesful applications of IT, build on rock solid background from Computer Science, become more and more interdisciplinary.

The official answer of Europian union to this development is formulated in so called European Commision Priority „Digital Single Market“, which could according to the official web page of the initiative [2] brings hundreds of thausends of jobs. Among others, the idea of Digital Single Market is supported by Google [3]. As a part of Europa 2020 Initiative - Digital agenda for Europe, European Commision announced „the largest collaborative effort” with IT industry called “Grand Coalision for Digital Jobs“ [4].

Field of Information Technology represents a high-tech area with high added value, which is mostly based on skills and knowledge of IT professionals. In other words, success of IT companies is highly dependent on the quality of human resources. If one read an opening for a position in IT, one will usually find a semi-structured text file with requirements. Usually, it will include information about required education, about experiences, and required knowledge, skills and competencies (KSCs) [5,6]. The question is, what activities should the candidate perform to acquire the knowledge, skills, and competecies required in a job opening?

The European Centre for the Development of Vocational Training (Cedefop), the European Union's reference centre for vocational education and training, in its publication “Typology of knowledge, skills and competences” writtes that “ICT occupattions … have developed without the rigidities associated with the sort of regulation that applies to health professions“ and continues “every area of economic activity is affected by ICT”, concluding that “there has been neither a commonly agreed classification of ICT jobs nor elaboration of the necessary KSCs associated with them.” [7, page 13].

## II. Framework for Knowledge, Skills and Competencies Aqusition - Ability Activity Model

To investigate the question which activities could lead to KSCs required for a specific position in IT, we will start with a simple and abstract model of personal development process, which we call AA model. The notion of activity and the notion of ability will be crucial for the model.

An ability will be an abstract notion modelling knowledge, a skill and/or a competence, but may also cover different concepts such as talent or experience (which may often be understood as skills). An activity is an abstract notion representing any process of changing abilities. With AA model, one may simply and on an abstract level model how performing activities (courses, jobs, education, training) by a person with a set of abilities (knowledge, skills, competencies) may change her/his abilities (add new knowledge, skills, competencies or increase the expertise in knowledge, skills, competencies).

An ability may be associated with a level from a level scale. If an ability has associated a level we call it evaluated. It is not important, which scale would be taken, it just have to be a fully ordered set with a minimum, where minimum is interpreted as an entry level. A maximum of the scale is not necessary, but for the sake of simplicity, we consider that a level scale is a set of integers with minimum and maximum denoted as $L$.

A set of abilities will be called configuration. An evaluated configuration is a pair $(C,l)$, where $C$ is a configuration and $l$: $C \rightarrow L$ is an evaluation function evaluating each ability $a$ from configuration $C$ with a level $l(a)$.

Given two configurations $(C,l)$ and $(C',l')$ such that $C \subseteq C'$ and $l(a) \leq l'(a)$ for each $a$ from $C$, we will say that $(C,l)$ is covered by $(C',l')$.

An activity $q$ will have associated an evaluated configuration $(C_q,l_q)$ called requirements. Further, an activity $q$ will have associated a mapping $o_q$ which for any evaluated configuration $(C,l)$ such that $(C_q,l_q)$ is covered by $(C,l)$ computes an evaluated configuration $o_q((C,l))$ called activity outcomes. This mapping is called outcomes mapping.

The interpretation of the model is quite simple, an activity may be performed by a configuration of abilities only if the configuration has all required abilities and level of each ability is not smaller than required by the activity requirements, resulting in new abilities and/or new levels of abilities defined by the outcomes mapping.

If we consider that abilities may model skills, and activity may model a course, and a configuration may model a person with a set of skills on a certain level, then the interpretation is as follows. Imagine that John wants to take a course about advanced programming in Java. He may succesfully take a course only if he has all the skills required to take the course and these skills have at least the same level as are minimal requirements for the course. Then, after the course his level of skills in programming in Java, but according to the curriculum of the course also other skills (such as object oriented programming skills) will change, in this case they will increase.

Starting with an initial evaluated configuration $(C_0,l_0)$, a finite sequence of activities $s = q_1 \ldots q_n$ can be performed if there exists a sequence of evaluated configurations $(C_1,l_1) \ldots (C_n,l_n)$ such that $(C_{q_i}, l_{q_i})$ is covered by $(C_{i-1}, l_{i-1})$ and $(C_i, l_i) = o_{q}((C_{i-1}, l_{i-1}))$ for each $i \in \{1, .., n\}$. The outcome $o_s((C_0,l_0))$ of the sequence $s$ for evaluated configuarion $(C_0, l_0)$ equals $(C_n, l_n)$, i.e. $o_s((C_0, l_0)) = (C_n,l_n)$. In this way, a sequence of activities may itself be understood as an activity, to build modular and hierarchical AA models.

Given a person, his career path may be modelled by a sequence of activities performed from her/his evaluated configuration of abilities (her/his knowledge, skills and competencies) resulting in an evaluated configuration given as an outcome of that sequence of activities.

Requirements for a position may be in the simplest form given by an evaluated configuration and we say that a person fulfills the requirements for a position if the requirements for the positions are covered by his actual evaluated configuration (of knowledge, skills, competencies).

However, sometimes requirements for a position in praxis define which skills and at which level are necessary and which are optional, or define a set of skills from which at least one is necessary (for example programminng in Java or C required). Such requirements can generally be described by logical formulae over a set of evaluated skills. Any such formula derscibing requirements for a job may than be converted into a disjunctive normal form. In such a disjuctive normal form the conjucntions represent alternatives, I.e. evaluated configurations, from which at least one has to be covered by the actual configuration of the succesfull candidate.

Observe that in its general form we do not have restrictions on the outcomes mappings of activities in the AA model. This enables to deal with decreasing an ability level as an outcome of an activity, or loosing an ability as an outcome of an activity.

An activity $q$ is called covering activity if $(C,l)$ is covered by $o_q((C,l))$ for any evaluated configuration covering $(C_q,l_q)$. It means, that if a person has actual set of skills which are sufficient to meet minimal requirements to perform the covering activity $q$, then performance of the activity will not decrease level of any of her/his skills. A special form of AA models are Covering AA models (CAA models), where each activity is a covering activity.

Given two evaluated configurations $(C,l)$ and $(C',l')$, let $max((C,l),(C',l'))$ be a minimal evaluated configuration which covers both $(C,l)$ and $(C',l')$, i.e. there is no other evaluated configuration which covers both $(C,l)$ and $(C',l')$ and is covered by $\max((C,l),(C',l'))$.

Observe that $\max((C,l),(C',l')) = (C \cup C', l'')$ with $l''(a) = l(a)$ if $a \notin C'$, $l''(a) = l'(a)$ if $a \notin C$ and $l''(a) = max(l(a), l'(a))$, if $a \in C \cap C'$ where $max$ is the standard maximum function on integers.

Let an activity $q$ have associated an evaluated configuration $(C'_q,l'_q)$ called independent outcomes, which covers requirements $(C_q,l_q)$. Let further $o_q((C,l)) = max((C,l),(C'_q,l'_q))$. Then $q$ is called autonomous activity. A special form of AA models are Autonomous AA models (AAA models), where each activity is an autonomous activity.

Observe, that an autonomous activity is a special form of covering activity and an AAA model is a special form of CAA model.

The interpretation of an autonomous activity is that it has given not only minimal requirements, but also outcomes defined independently from actual level of skills of a person, just increasing level of required skills (of prerequsities). If a person fulfilling minimal requirements for an activity is performing the activity, his level of skills will increase on the level given by the independent outcomes of activity, unless his level of skills were greater before the activity starts.

Usually, AAA models make some simplification of really acquired skills and their level, but the same holds for many real cases in education and real courses and their certification. As an example of autonomous activity modelling, consider an introductory course on Java programming, with no requirements. At the end of the course succsesful applicants will get the certificate, that they gained new skill Programming in Java at level 1 and new skill Object oriented programming with level 1. From the certificates (from avaliable data) course will has following independent outcomes: it adds new skill Programming in Java (shortly Java) and increases the skill level to 1 and it adds new skill of Object oriented programming (shortly OOP) and increases the skill level to 1. Now, John who has skill in Object oriented programming at level 2 and who is able to program in C++ at level 2 will take the course and Alice with no skill in C++ and OOP will take the same course. Using autonomous modelling, John's level of skill in OOP will remain 2, he will gain the new skill Java with level 1 and his C++ skill remain 2. So, using autonomous modelling based on available data (i.e. based on the course certificate) course will neither increase John's level of OOP, nor influence his level of skill in C++, despite the fact that even training with simple programmes and basics of Java may increase the level of skills in other similar object oriented programming languases, such as C++. Alice will gain new skill in Java at level 1. Thus, autonomous modelling is often a simplification and measures not really the real skills, but skills and their levels according to certicication. However, this simplification may be acceptable, as any attempt to categorize skills and measure the level of their maturity is a simplification and approximation.

Finally, we also use notion of ability tree, which is a rooted tree in which leaves are abilities and other nodes are called categories (of abilities). However, in this paper the ability tree will be treated independently from previous definitions and will not affect the previous definitions. However, it may be helpful to define similarity relation of abilities such as the minimal distance to the common category and based of this to compute similarity based on distance between two configurations. Such similarity may be used to encourage candidates, which do not fulfil the minimal requirements exactly, but fulfil similar requirements and therefore may be interesting for the employer. Moreover, such similarity may be quantified, as it is based on distance in graphs. Another possible scenario of applying the similarity is to determine similarity of requirements of different job positions, i.e. to compute the distance between job profiles.

In this way, one may characterize what skills sould be gained in order to transit from covering one configuration to covering another configuration. Based on the distances between configurations, one may design a development process for a job position, which could consists from series of courses and/or training and or practices in such a way that anybody covering with his/her skills the requirements will after taking part at these activities have skills sufficient to get the job.

Another advantage of the approach is that the AA models may be incomplete and with collecting and analyzing new data they can be instanteously updated inserting new abilities and activities.

Thus, the "only thing" to do is to collect big data from different sources, as much as one can, to analyze them in order to construct a suitable AA model with set of abilities, join them to categories, determine suitable level scala, identify and or design tasks, accurate outomes mappings. And to further develop the theory directing in more sophisticated relationships between abilities.

On the other hand, it should remain simple and comprendius, in order to have potential to be used in practice. There are many nice theories about personal development, career development and KSCs in literature, but not many of them are widely spread.

## III. Related Work and Future Wor

When looking around in the area of job description or KSCs implementation in form of a data sctructure, there are some recent and promising approaches. In area of job description, we refer to the portal onetonline.org with 58 detailed IT job descriptions with 14 categories of attributes, describing requirements, namely Tasks, Tools and Technology, Knowledge, Skills, Abilities, Work Activities, Detailed Work Activities, Work Context, Job Zone, Education, Credentials, Interests, Work Styles and Work Values [8]. The portal is run by Occupational Information Network (O*NET) operated by the North Carolina Department of Commerce and sponsored by the US Department of Labor/Employment and Training Administration [8].

European e-Competence Framework 3.0, developed by the European Committee for Standardisation (CEN), which is funded by the European Commission, identifies 40 competencies together with examples of skills and knowledge [9]. It is a sector-specific implementation of the European Qualifications Framework (EQF)[10].

ESCO, European Commision project European Skills, Competencies, Qualifications and Occupations list actually 549 IT skills [11]. ESCO is still under development and fully revised version should appear in 2016 [11].

The KSCs implementation which fits best for our framework is the result of the European Union funded project DISCO which stand for the Dictionary of Skills and Competences [12]. DISCO has more than 104,000 skills and competence terms in 11 languages. DISCO follows EQF reccomendation on KSCs and learning outcomes [12]. Actually, the terms of DISCO are arranged into a rooted tree, thus, compared to our terminology, some of them describe names for categories and those, which are the leaves of the tree descibe names for abilities. In this setting, the DISCO thesaurus can be understood as the ability tree. As DISCO thesaurus has a tree structure, it is quite simple and comprendius. For example, the skills about programming in Java, C++ and Object/oriented programming will be found in the DISCO thesaurus very intuitively: the root category has a subcategory domain specific skills and competencies, which has a subcategory programming, which has a leaf object-oriented programming as well as a subcategory programming languages, which has among others a leaf Java and a leaf C++ [13].

Disco is already used by several other projects, services and applications. OntoJob is a startup focused on parsing of candidate CVs to get the set of skills of the candidate, parsing the text of Openings to get the set of requirements and match the canditates with job openings [14]. JobStairs is a startup focused to fill in skills from the DISCO thesaurus while writing a CV [14], while SAP Deutschland uses the Disco thesaurus to map learning outputs to a set of KSCs from the thesaurus [14].

As the education process at the universities is quite well structured, with courses having clear curiculum [15], it seems that to define learning outcomes using a reference ability tree is a relatively straightformawd process. Even if there would be some knowledge or skill which is not present in the ability tree, but is distinguished by many job descriptions or it will become evident that it is a necessary prerequisite for a new skill required by market, it may be inserted as a new leaf at the suitable place in the tree. Eventually, one may split and/or add a category.

As an example consider the DISCO reference tree [13]. We have that the root category has a subcategory domain specific skills and competencies, which has a subcategory operating systems, with has two two leaves – operating system concepts and system administration [13]. However, you do not have listed any specific operating system, in contrast to category programming, where you have both the conceptual knowledge about programming and knowledge and programming skills in concrete languages. Thus, one could add a subcategory for concrete operating systems and add most used operating systems as leaves, such as Android, iOS, Linux, Windows and Unix. Similarly, new and emerging fiels, such as Mobile Computing, Internet of Things and Big Data deserve to have their own category.

Although there is a space for improvment in curriculum of university education, it is unrealistic to expect that the fresh graduates may fulfill all the requirements for senior positions or requirements for a specialist, as the main purpose of the university education is to gain durable fundamental knowledge, methods and skills, to understand the basic principles and to learn how to apply them to solve new problems. The innovation cycle is so short and the development in IT is so fast, that for example the most used operating system Android did not exist on the market in july 2008 [16], so the graduates who graduated 7 years ago could not have any knowledge of the Android. However, if they have good competence to learn as well as good competence in " operating system concepts" (which is a leaf in the DISCO tree [13]) gained from university, then they easily can acquire knowledge of Android.

Similar situation is with the courses which end up with a certification. To map the learning outcomes of the courses to ability three is quite straightforward, as the courses are usually well structured, with clear prerequisites and learning outcomes. Let us mention that in recent years the market with new ways of education based on set of courses, which are quite flexible and can bring a value to the postrgadual development, is booming. To mention just the most evident example, let us mention Coursera, which offers online courses with over 13 million users [17], with innovative concepts such as virtual classes with classmates helping each other, cooperating with world leading universities such as Stanford, Yale and Princeton [18].

A bit more effort have to be done, when one wants to identify, which knowledge, skills and competencies are aquired during a specific job position, based on experiences, by individual work. Here big data methods analyzing careers and real changing of posititions may help to deduce, which skills are gained by an experience in jobs. For example, if one will identify a significant number of jobs with the similar requirements and similar working tasks, say A, and one would find out that a significant subset of the keepers of the job changed their job to another position, say B, for which requirements are known, one could conclude that the experience in job A bring the KSCs given as a difference between job B and A and is sufficient to be qualified for job B. In fact, LinkedIn made such a research analyzing data from around 94 million of LinkedIn profiles resulting in a career graph which is in fact a graph whose vertices represent positions (job titles) and arcs represent transition from one position to another [19, 20]. Actually, LinkedIn, social network of more than 400 millions of professionals with their profiles [21], with many of them using LinkedIn to find a job, has the data as well as the financial power to adapt graph based techniques to get new insight and structure into the problem of matching job candidates with job offerings based on KSCs. LinkedIn works with more than 45 thousand standardized skills they offer if one creates a profile [22]. At the same time, the profiles with skills are visited 13 times more than others [22]. Altogether 380 millions of skills were added by people to their LinkedIn profilles [22].

An introduction of context relations between skills may be investigated: for example, for a potential employer looking for a Java developer combination of programming in C on an expert level together with ability to learn could be better than programming in Java on an intermediate level.

In general, methods could be developed to rank candidates if there is not exact matching, giving the highest ranking to the candidate with the smallest distance to requirements and to encourage which steps (courses, traning) should be taken by the candidate to close the gap between her/his abilities and the job requirements.

It should be investigated how to determine the whole process of development, i.e. to determine what should a person do (what to learn, to experience, to train, at which courses to take a part, with which certificates, which endorsement of skills to have) in order to help her/him to get from point A, where the person is now, to the point B, where he could be, including estimation of time needed, costs needed, etc. It could motivate either a person or his potential employer to invest to the personal development of the person.

The possible scenarios of application of the methods discussed in this paper include scenario when a person looks for a position, scenarionn when a freelancer looks for a contract and scenarios when a company looks for an employee or for a contractor. If one could identify the required skills for a startuper, it even may be used to match together startupers with investors. In general, the approach may be adapted for each scenario where matching of needs and offers is crucial.

## IV. CONCLUSION

Less than 20 years ago Google got the biggest market share in web seaching just because it offered better results using its PageRank algorithm [23], which searched the most relevant web pages based on the searched term. It would be no wonder, when similar situation will happen in matching job seekers with job offerings: the professional social network, which will find the best candidates for a job offering and the best jobs for its members, will win the game. It may be expected, that such matching algorithm will use new approaches. Imagine that an algorithm would update your configuration of skills in your profile based on your activities on computer and web. So if you write a code in a programming language, your skill score may increase, if you communicate via e-mail or via a social network with colleagues in foreing language, the written or spoken text from your Skype sessions may be analyzed to increase your score in that language skills. Even this paper could be analyzed to answer the question to which extent the authors speak English. So, everything you do (and allow) would be analyzed to determine your skills, and if you want, you could share it with others in a controlled way. The fantasy has no limits. Actually, the technologies are there to do it. There are other issues, like privacy and security, that may limit such an approach. But the acceptance of social networks shows, that people are often more open to innovation and less afraid than we believe.

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