THE MODEL OF IT-STARTUP THAT GROWS IN UNIVERSITY ECOSYSTEM AND APPROACH TO ASSESS ITS MATURITY

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Abstract: *This paper is dedicated to description of method of the maturity estimation of startup and spin-off IT-companies created with the help of University Business Centers as an approach for cooperation between universities and industrial companies. The control loop, based on the formation and subsequent evaluation of organizational maturity of IT-start-up based on CMMI model is shown. The conception of tool for assessment of IT companies maturity is proposed and theoretical ground for implementing it on the basis of the apparatus of fuzzy logic is provided.*

Keywords: *academic IT entrepreneurship, IT start-up, maturity of IT companies, fuzzy logic, CMMI.*

ACM Classification Keywords: *K.6.1 Management of Computing and Information Systems - Project and People Management*

Introduction

In the end of XX century lead western countries face to the problem of universities graduates not readiness to the requirements of industry and work market needs. One of the emerging problems in Europe is shortage of IT personnel. According to estimates of the European Commission in 2020, a shortage of skilled IT professionals in the EU could reach 825 thousand [European Commission, 2013]. And that happen when the number of graduates in the EU in the IT field is kept at the level of 100 thousand professionals per year.

One of the solution of that problem is involving University to cooperation with business. But this subject is not well studied especially in European countries that formerly were the part of the Soviet bloc and which have no tradition of entrepreneurship and the free market.

The formalized University-Business Cooperation (UBC) models were offered and the first practical experience of such cooperation was analysed by Prof. V.Kharchenko and Prof. V.Sklyar [Kharchenko, 2012]. The model of cooperation between University and companies through academic consortiums was presented in work of Prof. Y.Kondratenko [Kondratenko, 2015]. Interaction between Industry and

Universities was topic of the works of such scientists as C.Phillips, S.Lange, A.Tormasov, H.Edmondson et al.

One of the promising approach for UBC is the academic entrepreneurship when University acts as an ecosystem for growing new start-ups [Lytvynov, 2015]. As a rule Universities have a specific department called Business-Center (BC). Such BCs cultivate companies which main capital is new unique technology or “know-how”. In fact BCs specialized in providing services that is not directly related to company «know-how», but to the functioning of the company as a business structure.

The process of growing IT companies is multifaceted and difficult, especially if this company consists of young students united by one idea but completely without any real experience. On each stage of growing IT-startup from unformal group to independent business it requires from University making difficult decisions to provide or cancel support the company. Such decisions require objectively proved models, methods and tools to estimate different characteristics of IT-start-up and its project. And it should be noted that the problem of such tools is not well studied for now and need to be solved.

This paper will describe a model Academic IT-start-up – a newly created small company formed in University ecosystem which general activity belongs to creation of IT product or service and the tool to assess the maturity characteristics of IT-start-up as an IT business company.

The model of IT-start-up in University ecosystem

There are 4 main component of IT-startup described in work «Business models dynamics for start–ups and innovating e-businesses» by Bouwman at al. [Bouwman, 2007].

Product – that describe value proposal for the market.

Technology – the functionality required to implement the product.

Organization – structure of actors, people and stakeholders required to create the product.

Finance – mechanism of financial support product development and its entrance to the market.

Software Quality Institute in Texas defines three categories that must be managed with a view to the successful implementation of IT projects (creating software), they are: product, project and staff. Moreover, each category requires its own set of skills.

It should be noted that not all factors and characteristics inherent to mature and big companies are belong to IT-startups that grows in university ecosystem. It is possible to distinguish 5 main components that have direct impact to the goal state of IT-startup on its way to independent company. Here it is.

Team – group of individuals who work together for reaching common Project goal.

Technology – a set of methods, technics, equipment and knowledge required to implement the Product.

Processes – organization and business processes and functionality of the Team required managing the development of the Product at the defined level of quality.

Product – product or service that IT-startup wants to create and present to the market.

Project – Team activities, aimed at creating a unique Product (service).

Fig.1 is representing this model in graphics.

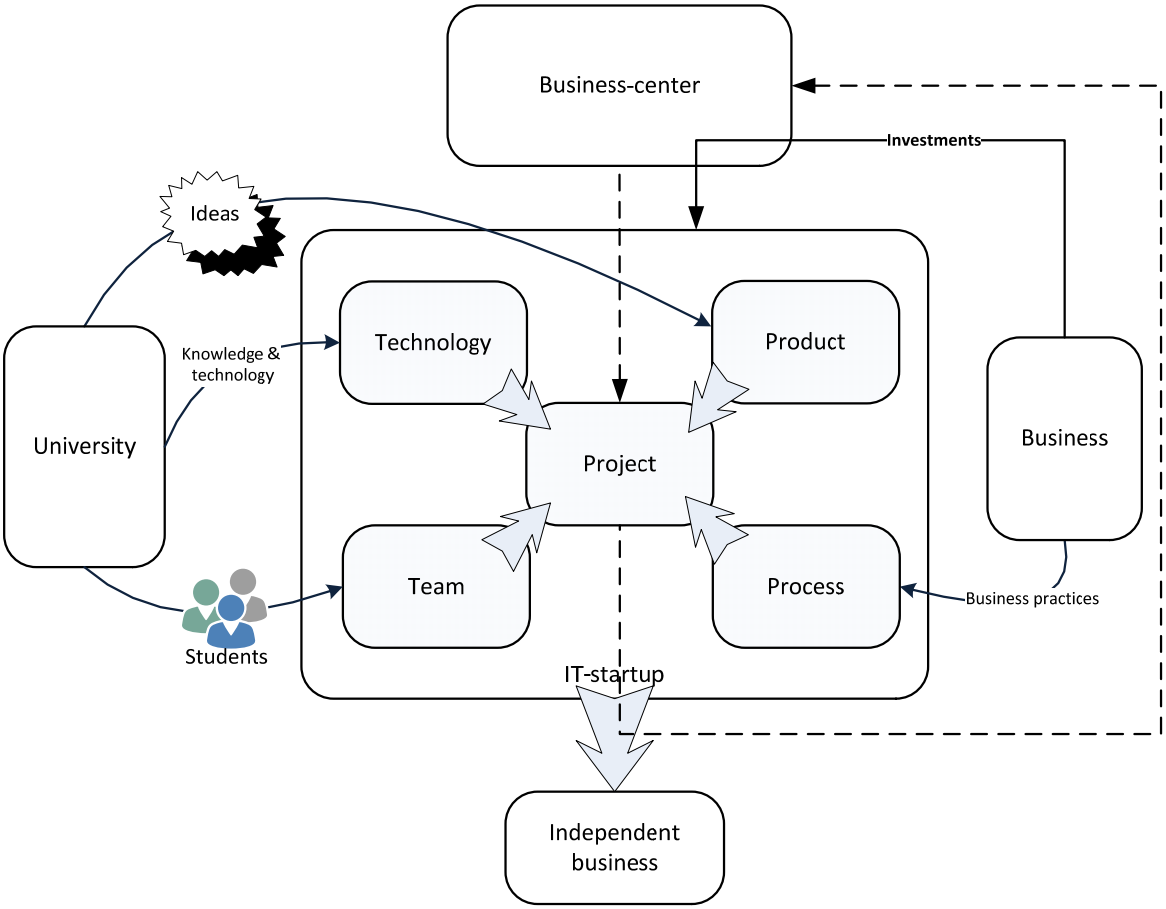

Figure 1. Conceptual model of academic IT-start-up

In university ecosystem, the University feeds startup with ideas for new business linked with modern technology and new know-how that usually born here. The University also feeds startup with students and young scientists who want to transfer their ideas to new business. Startups itself draw knowledge from University about modern technology and methods of its usage.

From its side, the Business provides financing and investments and also time proved business and engineering practices that helps to organize technological business processes in startup as for a business organization. Normally it happens directly or indirectly through University Business-Centre.

And here the control loop for BC to manage it-startup to the stage of independent business could be defined. This control loop uses indicators of project state like delays from baseline schedule or project risks and trends, and indicators of IT-start-up maturity like development in organization of different business processes.

In other words, the control action on the IT-startup will be implemented through the issuance of recommendations for inclusion in the project schedule works related to the improvement of its organizational maturity, production processes, as well as the necessary competences, both at the individual level of individual roles in the team and at the company level generally. These impacts will be supported by the terms of access to the resources of the business center (funding, laboratories, data centers, etc.). And BC will require a number of assessment tools for defining right control action on the IT-startup and its project. One is the maturity assessment tool of Academic IT-startup.

Conceptual model for the assessment of IT-startup maturity level

One well-known approach in assessment of business structures maturity is Capability Maturity Model Integration originally proposed as Software CMM in the 1989 by Watts Humphrey in his book “Managing the Software Process” [Humphrey, 1989]. Now this model is supported successfully by the Carnegie Mellon Software Engineering Institute (SEI).

CMMI groups Key Practices into Special Goals. Then Special Goals are grouped into Process Areas. Process Areas are linked to maturity levels. The development of the key practices of CMMI is evaluated by experts using linguistic variables that could take one value from the set {“not implemented”, “partially implemented”, “largely implemented”, “fully implemented”}.

It means that the level of maturity could be assessed using hierarchical fuzzy logic system [Kondratenko, 2011]. In this case maturity of IT companies will be determined by the following equation:

$$M = f\left(f_1\left(P_1, P_2, \ldots, P_7\right), f_2\left(P_8, P_9, \ldots, P_{18}\right)\right) \quad (1)$$

where

- M is the maturity of IT-startup;
- $f_1(\cdot)$ and $f_2(\cdot)$ are functions to assess maturity for 2 and 3 levels;
- $P_1, P_2, \ldots, P_{18}$ are the fuzzy value of development of process areas in CMMI-DEV model.

In turn, the development of each area of process will be determined by the relation:

$$P_i = h_i\left(g_{i1}\left(p_{i11},\ldots,p_{i1l}\right),\ldots,g_{in}\left(p_{in1},\ldots,p_{inm}\right)\right) \quad (2)$$

where

- $h_i()$ is a fuzzy function to output the development of process area with index ***i*** ;
- $g_{ij}()$ is a fuzzy function to determine how IT-startup reach Special Goal with index ***j*** for the Process area with index ***i***;
- p_{ijk} is a fuzzy linguistic variable for assessment of special practice with index ***k*** development in IT-startup that belongs to Special Goal with index ***j***, that in its turn linked with Process Area with index ***i***.

Let define NI, PI, LI, FI as fuzzy numbers for the linguistic variable p_{ijk} . This numbers are defined as fuzzy sets *N, P, L, F* belongs to the set of real numbers R. Carriers sets of *N, P, L, F* are defined as intervals on *R* – [n_L, n_R], [p_L, p_R], [l_L, l_R], [f_L, f_R] respectively.

There are functions $\mu_i(x)$ such that $\forall x \in R \mid \mu_i(x) \in [0,1]$ where $i \in \{N,P,L,F\}$ defined on *R* for each number NI, PI, LI, FI.

For fuzzy numbers with so called L-R type functions $\mu_a(x)$ that is defined by relation (3) it exists distance metric.

$$\mu_a(x) = \begin{cases} 0 & x < a1 \\ left\left(\dfrac{x-a1}{a2-a1}\right) & a1 \le x < a2 \\ 1 & a2 \le x \le a3 \\ right\left(\dfrac{a4-x}{a4-a3}\right) & a3 < x \le a4 \\ 0 & x > a4 \end{cases} \quad (3)$$

It was shown at Grzegorzewski works [Grzegorzewski, 1998] that best metric is expansion of the Euclidean distance, see relation (4).

$$d^2(a,b) = \int_0^1 \left(A_L(\alpha) - B_L(\alpha)\right)^2 d\alpha + \int_0^1 \left(A_U(\alpha) - B_U(\alpha)\right)^2 d\alpha \quad (4)$$

where the fuzzy number is defined by the concept of α-section, such that $\forall \alpha \in (0,1)\ \exists a1 \le x \le a4$ and $\mu_a(x) \ge \alpha$ and $A_L(\alpha) = \mu_{a\uparrow}^{inv}(x)$ - function reverse to $\mu_a(x)$ over the interval of increase and $A_U(\alpha) = \mu_{a\downarrow}^{inv}(x)$ - function reverse to $\mu_a(x)$ in the interval of its decrease.

Consider the function (5) to determine the reachability an IT company specialized goals in CMMI process area:

$$g(x_1, x_2, \ldots x_n) = x_1 \oplus x_2 \oplus, \ldots \oplus x_n \quad (5)$$

where the operation $\oplus$ is the operation of addition of fuzzy numbers according to the formula (6).

$$a \oplus b = \int_{a1+b1}^{a2+b2} \frac{\min\left(\mu_a(x), \mu_b(y)\right)}{x+y} \quad (6)$$

Achievement of special goal G_i of process development by the IT-startup could be described by the linguistic values: fully reached (FR); partially reached (PR); not reached (NR).

Let consider that special goal G_i is fully reached (G_i = FR) if the sum of experts answers regarding development of key practices as fuzzy number $g(x_1, x_2, \ldots x_n) = x_1 \oplus \ldots \oplus x_n$ close to fuzzy number $FI * n = FI_1 \oplus \ldots \oplus FI_n$.

Let consider that special goal G_i partially reached (G_i = PR) if fuzzy number $g(x_1, x_2, \ldots x_n) = x_1 \oplus \ldots \oplus x_n$ close to fuzzy number $Mean = (LI * n \oplus PI * n)/2$.

Similarly, we shall consider, in general, that the special goal G_i is not reached (G_i = NR) if fuzzy number $g(x_1, x_2, \ldots x_n) = x_1 \oplus \ldots \oplus x_n$ close to fuzzy number $NI * n = NI_1 \oplus \ldots \oplus NI_n$.

Let apply the same reasoning to assess the area of CMMI process development by IT-starup. The development process area could be defined as a sum of fuzzy values G_i obtained in the previous step. Let define development of Process area by another linguistic variable that could have one of the

following values: NF, PF, FF that corresponds to «area not mastered», «area mastered partially» и «area fully mastered». Which will be calculated in a general form by the following rules:

- Process area $F_j = NF$ if $\sum_{i=1}^{n} G_i$ close to fuzzy number $\sum_{1}^{n} NR$;
- Process area $F_j = PF$ if $\sum_{i=1}^{n} G_i$ close to fuzzy number $\sum_{1}^{n} PR$;
- Process area $F_j = FF$ if $\sum_{i=1}^{n} G_i$ close to fuzzy number $\sum_{1}^{n} FR$.

To assess the maturity level of IT-startup, functions $f()$, $f_1()$, $f_2()$ from equation (1) should be defined. For functions $f_1()$ and $f_2()$ similar reasoning could be applied, defining it as a sum of process areas development. But similar reasoning could not be done for the function $f()$.

The CMMI defines that company reach 3d “Repeatable” level of maturity if it already reach 2d “Defined” level and mostly developed process areas that specific to the 3d level. In this case, if values of functions $f_1()$ and $f_2()$ defined by the term-set {NM, PM, FM} = {non mature, partially mature, fully mature} then following fuzzy rules could be defined:

$$\text{IF } (f_1(P_1,\ldots,P_7) = \text{NM}) \text{ THEN } M = I.$$

$$\text{IF } (f_1(P_1,\ldots,P_7) = PM) \text{ THEN } M = D.$$

$$\text{IF } (f_1(P_1,\ldots,P_7) = FM) \text{ THEN } M = D.$$

$$\text{IF } (f_1(P_1,\ldots,P_7) = PM) \text{ AND } (f_2(P_8,\ldots,P_{18}) = NM) \text{ THEN } M = D.$$

$$\text{IF } (f_1(P_1,\ldots,P_7) = PM) \text{ AND } (f_2(P_8,\ldots,P_{18}) = PM) \text{ THEN } M = R.$$

$$\text{IF } (f_1(P_1,\ldots,P_7) = FM) \text{ AND } (f_2(P_8,\ldots,P_{18}) = PM) \text{ THEN } M = R.$$

$$\text{IF } (f_1(P_1,\ldots,P_7) = FM) \text{ AND } (f_2(P_8,\ldots,P_{18}) = FM) \text{ THEN } M = R.$$

IT-startup maturity calculator

The mentioned above theoretical consideration became a basis in creation of the tool to assess IT-startup maturity. This tool, named “IT-startup maturity calculator” was designed to identify “bottlenecks”

in IT-startup organizational processes. It also helps to provide recommendations in fixing problems and improving efficiency of business process. The formal results of IT-startup maturity assessments could be used by University Business Center to support decision making regarding IT-startup.

There are several structured modules of IT-startup maturity calculator:

- "Questionnaire", that forms database of expert assessments of IT-startup performance indicators;
- IT-startup "maturity calculation" module, that assess the level of maturity of the company performing its fuzzy calculations;
- "Bottlenecks" identification module, which is based on a comparison of the actual assessments of process areas development to the proper level of maturity;

Module of retrospective analysis of performance indicators and it changes, which is based on a comparison of previously collected data.

The identification of "bottlenecks" is not a problem, because in fact, it is ether the lack of or weak development of the company's key practices in CMMI. Another thing is that the reasons for the existence of such "bottlenecks" can be different. The first is the lack of necessary skills and experience on the part of employees. Second is the lack of resources because special practices will require allocation of separate roles for their support.

A retrospective analysis of changes of maturity indicators of company plays a role in the assessing of the IT-startup's dynamics. It can serve as an indirect indicator of changes in the values of the team, the objectives of the project and other activities, the difficulties faced in front of the team. In addition, a stable negative dynamics of the maturity of IT-startup could be a criterion for withdrawal of support provided by the University Business Centre.

Created tool was tested to evaluate the maturity of the IT start-ups created by students of Slavutych branch of National Technical University of Ukraine "KPI" named Igor Sikorsky, as well as for the existing small IT companies that operates in Slavutych region.

It should be noted that both standard and proposed fuzzy method gives same results in assessment of the level of IT-startup maturity. However, the lack of possibility the result de-fuzzing of the standard method assessment does not allow to monitor the dynamics of changes in the company's maturity. It makes the proposed fuzzy method in the evaluation of maturity more attractive relative to the standard.

Conclusion

Finally, we can draw the following conclusions:

University-Business Cooperation and especially the academic entrepreneurship are promised approach to solve the problem of universities graduates not readiness to the requirements of industry and work market needs.

The process of growing IT companies is multifaceted and difficult, especially if this company consists of young students united only by common idea. University Business-Centers have to make difficult decisions to provide or cancel support the company. The proposed model of IT-startup in University ecosystem provides a control of IT-startup on its way to independent business.

One of the tools of such control is IT-startup maturity calculator, which could be successfully implemented using apparatus of fuzzy logic.

Bibliography

[European Commission, 2013] Digital Agenda Scoreboard 2013. European Commission, Brussels, 2013

[Kharchenko, 2012] Kharchenko V., Sklyar V. The concept and model of interaction between university research and the IT industry: S2B–B2S. In: KARDBLANSH, N.8-9, P.45-52, 2012. (in Russian).

[Kondratenko, 2015] Kondratenko Y. at al. Models of universities and IT-companies cooperation , decision-making system on fuzzy logic: monograph. Ed. Y.Kondratenko, Kharkov, 2015. (in Ukrainian).

[Lytvynov, 2015] Lytvynov V. at al. Tool-Based Support of University-Industry Cooperation in IT-Engineering. Lytvynov V., Kharchenko S., Lytvyn S., Saveliev V., Trunova E. and Skiter I. National University of Technology, Chernihiv, 2015.

[Bouwman, 2007] Bouwman H. Business models dynamics for start–ups and innovating e-businesses. M. de Reuver, H. Bouwman, I. MacInnes. In: Int. J. Electronic Business Vol. 7, No. 3. pp 269–286, 2007.

[Humphrey, 1989] Humphrey W. Managing the Software Process. Watts Humphrey, Addison-Wesley Professional, 1989

[Kondratenko, 2011] Kondratenko Y. Features of synthesis and modeling of hierarchically-organized DSS based on fuzzy logic. Kondratenko Y., Sidenko E. In: Vestnyk Khersonskogo natsionalnogo technicheskogo universiteta, N.2(41), pp. 150–158, 2011 (in Ukrainian).

[Grzegorzewski, 1998] Grzegorzewski P. Metrics and orders in space of fuzzy numbers. P. Grzegorzewski In: Fuzzy Sets and Systems, Vol. 97, Issue 1, pp. 83–94, 1998.

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