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A multi-expert system for ranking patents: An approach based on fuzzy pay-off distributions and a TOPSIS–AHP framework

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ABSTRACT

The aim of this paper is to introduce a decision support system that ranks patents based on multiple expert evaluations. The presented approach starts with the creation of three value scenarios for each considered patent by each expert. These are used for the construction of individual fuzzy pay-off distribution functions for the patent value; a consensual fuzzy pay-off distribution is then determined starting from the individual distributions. Possibilistic moments are calculated from the consensus pay-off distribution for each patent and used in ranking them with TOPSIS. It is further showed how the analytic hierarchy process (AHP) can be used to include additional decision variables into the patent selection, thus allowing for a two-tier decision making process. The system is illustrated with a numerical example and the usability of the system and the combination of methods it includes for patent portfolio selection in the real world context is discussed.

1. Introduction

Ranking and selection of patents is an important issue from the point of view of intellectual property (IPR) managers everywhere. It is most often a recurring task in companies that commonly have their IPR managers visit the patent and R&D portfolios once or twice per year, analyzing the composition of the portfolios and making decisions about the modification of portfolio composition. New patents may also be considered on continuing basis, emphasizing the need for tools even further.

One way to quantitatively rank and to select patents is to use estimation of their future value from the point of view of the firm owning them as a measure of goodness. Value to the firm may very well be the single most important characteristic of a patent. Other issues that are important in analyzing and ranking patents are most often non-financial and have to do with strategic criteria, such as fit of the patents to the corporate portfolio and to the future plans of the firm. Generally, we can say that a good ranking is able to consider both of these types of information, financial and non-financial.

Commonly there are three main approaches for the valuation of patents, these are the "cost approach", the "market method", and the "income approach" also known as the discounted cash-flow method (DCF) (e.g., see Reilly & Schweihs, 1998; Smith & Parr, 2000). Of these, the cost approach and the market method are meant only for market valuation of patents that is to say, for the derivation of an estimate for a sale price for a patent. The DCF method is based on the well known principles of present value (PV) and the same principles can be used also in the "in-house" valuation of patents, that is, to derive the "value to the firm" of patents.

It is important to note that patent analysis is a forward-looking exercise, as patents are an enabling class of assets that is most often used to secure the future of the firms' business. This means that methods used in the valuation and analysis of patents should be able to take into consideration the (sometimes considerable) estimation inaccuracy present in forward-looking estimation, as the estimation of future cash-flows for patents, since it is not realistic to expect anyone to be able to produce precise estimates for future (patent) cash-flows (Karsak, 2006). Using cash-flow scenarios is a widespread practice of modeling the inaccurate and uncertain future cash-flows, and it can also be applied to patent analysis (Collan, Fuller, Mezei, & Wang, 2011). Information to support the creation of cash-flow scenarios can come from systems specifically designed for supporting patent analysis, such as are presented (for example in Camus & Brancaleon, 2003; Huang, Liang, Lin, Tseng, & Chiang, 2011; Littman-Hillmer & Kuckartz, 2009; Park, Kim, Choi, & Yoon, 2013), or it can come directly from experts, most often from within the firm itself. Fuzzy logic is an established way to express imprecision precisely and as such is a usable tool also when patent cash-flows are considered. Fuzzy pay-off method, introduced in Collan, Fullér, and Mezei (2009a, 2009b) and further presented in

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Collan (2012) is a tool for investment analysis and is based on using cash-flow scenarios to create an asset's pay-off distribution that is considered as a fuzzy number. The fuzzy pay-off method can be employed in the valuation of patents (Collan & Heikkilä, 2011).

As already observed above, patent analysis is a forward-looking procedure and there may be differing views about the direction that the future will take. This observation can be interpreted in the way that it makes sense to include more than one expert opinion when patent analysis is done. This is true for both, for cash-flow information, as well as, for non-cash-flow information.

As budgets for patent portfolios are tight, the firm can afford to keep only the best patents. This calls for the ranking of the patents as a basis of selection. It is a fair assumption that the value to the firm is a key driver in the selection of patents and can be used as a first basis for patent selection into portfolios. Important other (secondary) considerations may include different non-financial strategic selection criteria. This means that one plausible approach to go about with patent selection is to first rank the patents that are competing for a place in the firm's portfolio based on their value to the firm, second do a pre-selection of a sub group of the best patents, and third do a complementary analysis to narrow down the number of patents to fit the budget, based on the non-financial strategic criteria.

In this paper, an approach that enables both the financial and non-financial merits to be included in ranking of patents is proposed, while taking into consideration the estimation imprecision, and the differing estimates of multiple experts. This combination is a new contribution that allows a more holistic analysis on patents to be performed. The way in which the methods used are combined is new and new to the field of application. Furthermore, we use possibilistic moments in characterizing fuzzy financial information and rank patents according to the moments, to the best of our knowledge the first proposed approach of its kind.

The remainder of the paper is organized as follows. In Section 2 the general framework of the system for performing ranking and selection of patents is presented. In Section 3 we continue by presenting the construction of pay-off distributions from cash-flow scenarios by each expert for each patent takes place. In Section 4 the consensus modeling mechanism to be used to build consensus pay-off distributions from each expert's pay-off distributions is introduced. Section 5 starts with the definition of possibilistic moments of fuzzy pay-off distributions and continues with the description of the main steps of TOPSIS, used then for producing a preliminary ranking of patents. In Section 6, after a short presentation of AHP we show how it can be used to include strategic criteria in ranking the patents. In Section 7 the two-tier process is illustrated with a numerical example that includes the selection of four patents out of twenty candidate patents. Finally, the paper is closed with a discussion and some conclusions.

2. A blueprint for a multi-expert consensus reaching system for supporting patent selection

The focus here is to present a system for supporting investment decision-making with regards to patents that is, the selection of patents. The circumstances under which the system is usable are such that there are a number of possible patents that are competing for funding (inclusion in a portfolio) under a budget constraint. The system is based on using three scenarios of managerial cash-flow estimates for each patent, these cash-flow scenarios are used in the creation of a pay-off distribution for each patent, by each expert.

The pay-off distributions for the patents by different experts are likely to be different from each other, and in order to get an overall single pay-off distribution for each patent a consensus among the experts' pay-off distributions must be reached. For this a consensus facilitating method is used and a single consensus pay-off distribution for each patent is created.

From the consensus pay-off distribution for each patent, three possibilistic moments are calculated: the possibilistic mean, the possibilistic standard deviation, and the possibilistic skewness. The calculated possibilistic moments are then used in a TOPSIS ranking of the patents. This ranking is based on the cash-flow information for each patent and thus depends on the perceived value for each patent.

The TOPSIS ranking can be used as a basis of a first selection of patents. Here it is however proposed that more information is included into the selection by continuing the analysis with AHP for the selected number of best patents as ranked by TOPSIS. The AHP analysis is carried out by a team of "elected" decision-makers, based on "strategic" criteria that take into consideration different, non financial, aspects of the patents.

The approach is illustrated graphically in Fig. 1. The method can also be described as the following process:

(i) Each expert creates three cash-flow scenarios for each investment alternative: "maximum possible", "minimum possible", and "best estimate" scenarios.
(ii) From each experts' scenarios an individual fuzzy value distribution function (pay-off distribution) is created.
(iii) Consensus pay-off distribution is determined from the multiple experts' pay-off distributions.
(iv) Values of three possibilistic moments are calculated for each patent from the consensus pay-off distributions. These are the possibilistic mean, the possibilistic standard deviation, and the possibilistic skewness of the pay-off distribution.
(v) The calculated possibilistic moments are used in a ranking of the patents with TOPSIS.
(vi) "Elected" decision-makers perform an AHP process, based on relevant strategic criteria, to create the final ranking of the patents.

The resulting ranking of the patents can be used in supporting the patent portfolio selection, a problem that has been considered, for example in Hassanzadeh, Collan, and Modarres (2012). The steps of the approach, with background information, are explained in more detail in the following sections.

3. Creation of cash-flow scenarios and construction of fuzzy pay-off distributions

Using scenarios is a widespread practice of modeling the uncertain future of projects and assets under imprecise information. The idea with scenarios is that different future scenarios are thought out according to different possible future 'states of the world' and cash flows or value connected to these states, are estimated. Creating scenarios for patent alternatives can be done based on the available information about the future (markets, technology, and other issues); the information need not be precise, because the scenarios allow for even a very wide variation of the states of the world/value. The information used in creating the scenarios can come from qualitative information gathered and even from existing patent/IPR analysis/management systems (Jain, Murty, & Flynn, 1999; Littman-Hillmer & Kuckartz, 2009). Scenarios can be used to complement all three of the above mentioned patent valuation method categories.

When the DCF method is used the scenarios normally include the estimation of (yearly) cost and revenue cash-flows for the different scenarios. The yearly cash-flows are estimated by managers