Footprint Analysis – The Example of Metamaterials

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Introduction

Cronin (1984) called citations the "frozen footprints on the landscape of scholarly achievement; footprints which bear witness to the passage of ideas". Taking up this metaphor, we develop a methodology which enables one to identify and follow these "footprints". We consequently name this method "Footprint Analysis". Specifically, we develop a methodology with which to assess where on a landscape spanned by applied and fundamental science certain technologies or discoveries are located. We also try to determine whether there are typical "paths" (in the sense of a direction of typical development) that footprints take in different quadrants of fundamental and applied science. This is motivated by the interest of some research organizations (like e.g. the Fraunhofer Gesellschaft) in technologies, which are on the transition between fundamental and applied science or vice versa. Our approach combines qualitative and quantitative measures. Similar approaches have already been suggested by Schmoch (2006).

Methodology

The Footprint Analysis starts with the identification of a "Genesis Article" (GA), which is defined as an article, "that describes a great discovery or development that has up-to-then not been known and which serves as an intellectual seed for further scientific work and/or the emergence of a completely new scientific discipline". Since each scientific paper describes (or at least should describe) a new discovery, one has to rely on a qualitative and retrospective identification of such articles. Up to now, the GA chosen for our analysis have been identified by experts in their respective disciplines. The GA for the Metamaterials (artificial macroscopic composites of three-dimensional periodic structure enabling for negative refraction indices) is Veselago's (1968) paper on their theoretical foundation. We also investigate in finding some objective criteria which allow an automatic or semi-automatic identification of a GA. But this aspect is not part of this poster. The analysed data set consists of the GA and all articles citing it. This set is called Citation Level 1 (CL1). In our example it consists of 2228 articles as downloaded on the 30th of October 2008. To define different kinds of research, we chose a rather simple approach, inspired by Stokes (1997). According to his definition, basic science is defined as research that aims to further the understanding of the problems and phenomena of a discipline. Correspondingly, applied science is defined as research that aims to solve a problem. The distinction between both kinds of research is blurry. Thus we decided pragmatically to set up a two dimensional landscape, the one dimension being the quest for knowledge and the other the consideration of use. Both dimensions are independent aspects of science. To identify which scientific papers belong to which kind of research we use the subject categories (SC) as compiled in the Web of Science. We asked a hundred experts from various disciplines on how they characterize the SC considering these two dimensions. Their answers were then plotted unto a coordinate plane that is subdivided into four quadrants (see figure 1).

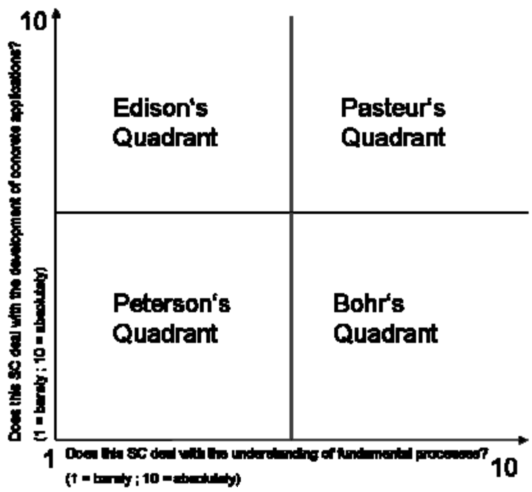

Figure 1. The subdivision of the coordinate system for plotting the answers of the experts.

These quadrants represent different kinds of research and were, consistent with Stokes, named after prototypical researchers. Thus, Edison's quadrant comprises SC that are mostly driven by considerations of use, Bohr's quadrant the SC that are driven by the quest for knowledge and Pasteur's quadrant showing the SC that are driven by both aspects. Peterson's quadrant is a peculiar quadrant because, in our view, it represents the SC, which are part of "background research". As defined by Bush (1960), "background research" comprises the compilation of data, for example for topographic maps, the description of plants and animals or measures of physical constants. We use this experts-based SC-classification to allocate a Journal Application Level (JAL). Thus it is possible to keep track of how the numbers of contributions to Journals with different JAL vary over time. This observation was used as one of the indicators to locate where on the coordinate plane a given technology's or discovery's articles are situated. There are a number of other indicators we employ for the Footprint Analyses: number of papers that were published by non-academic institutions (e.g. companies); number of patents that cite publications from CL 1 and the extrapolation of known patterns. For determining the number of papers that were published by non-academic institutions, we created an "Institution Thesaurus" and used a script for sorting the publishing institutes of CL1 into different categories. We consider the number of papers from non-academic institutions as an indicator for the application of technology, similar to Schlögl (2007). Patents are by definition an indicator for applied research, since a patent has to be applicable for commercial use. The link between the patents and the CL1 is the "Cited Literature"-Field. We interpret these citations as an indicator for the knowledge transfer between fundamental and applied science. Finally, we use typical patterns of paths between fundamental and applied science to extrapolate possible trends. An example for a pattern is Schmoch's "Double-Boom" (2006). These four indicators are combined into a profile for each technology or discovery in order to characterize it. Possible profiles are technologies whose CL1-publications predominantly appear in Journals that are situated in Edison's quadrant, that have many patents citing CL1 and whose publishing institutions are mainly companies. A scientific finding that has been profiled in this way clearly would be part of applied science and thus potentially interesting for organizations like the Fraunhofer Gesellschaft. An alternative is a profile showing a high number of patents, but little or no publications in Journals. A feasible explanation for such a profile is that companies conduct research on this technology/discovery and that they prohibit their researchers to publish, but that the results are used to apply for patents. The examiners of the patent applications then enter the original GA as a citation into the patent. Profiles can also show that a technology is firmly placed within the fundamental sciences with a high number of research papers published in Journals within Bohr's quadrant, almost no patents and with predominantly academic institutions publishing.

Ongoing Research

The question how these four indicators should be weighed is part of our continuing efforts in this field. Whether the criteria for possible weighting factors under consideration will be subjective or objective is still a point of discussion. Also, the chance for the occurrence of typical patterns is still not sufficiently answered in our results. Finally, we are testing various visualization techniques for appropriateness concerning presentation of the results of the Footprint Analysis (to e.g. policy makers) in a reasonable way. There also remains the question of how to interpret the different quadrants in regard to policy questions.

Results

Our present results suggest that the profiling of technologies or discoveries by means of the Footprint Analyses described here is viable and that the results can be used for discriminating where between fundamental and applied science a specific technology or discovery is situated. For this poster, we would like to present our results with applying the methodology to the emerging field of "Metamaterials".

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