Monitoring patent litigation for the purpose of market forecasting and technology road mapping in software-related industries

Abstract

The pace of technological change of the past few decades has been slowing and market-pull forces now exert increased force on product development. Therefore, technology road mapping needs to include a market-oriented perspective to aid in the streamlining of R&D efforts. Traditional patent indicators are good objective sources of technological information, but lack a connection to the market. Patent litigation has been shown to be a leading indicator of market growth and can act as an intermediary indicator between technology development and the market. This study proposes a method for monitoring patent litigation data for technology road mapping with a degree of market relevance. By appending appropriate ex ante patent indicators, a time sensitive method for the simultaneous identification of both market value and technological novelty is created. The efficacy of this framework is then demonstrated by applying it to software-related technologies in the auto industry; however, this framework has potential application across all hi-tech industries.

Keywords: patent litigation, market forecasting, technology road mapping, technology monitoring, automotive technology, intelligent vehicles

1.0 Introduction

Technological change provides a window of opportunity for firms (Schumpeter 1943, Porter, 1985; Nelson & Winter, 1982; Abernathy & Clark, 1984; Reinganum, 1989; Tushman et al., 1997; Eisenhardt, 1995) and those who can utilize superior resource management and organizational skills may take advantage. In business management, incorporating market-pull forces into technology road mapping is essential (Christensen, 1997; Narver & Slater, 1990; Phaal et al., 2003; Ernst, 2004; Ernst, 2006). Potentially disruptive technologies that find success in the marketplace need to be identified as early as possible in order to plan technology strategy activities such as R&D scheduling and budgeting, human-resource planning, cooperative ventures, and product development channels. In these times of subdued technological change (Philips, 2011), market-pull forces will promulgate product demand and are especially important to recognize and react to.

Resource-based assessment of competitive environments has dominated theories on competitive strategy (Penrose, 1959; Wernerfelt, 1984; Grant, 1991; Amit, 1993) in the past half century. Patent stocks or portfolios are commonly used to measure the knowledge and economic resources of a firm and patent thickets within industries create a racing completive environment where incumbents jockey

for rights to innovation. Assessment of firm patent resources can be used to compare competitors, but appropriate patent indicators are critical to valuation (Ernst, 1998; Ernst, 2003; Ernst, 2006) since a small number of patents generate most of the returns (Griliches, 1990; Harhoff & Reitzig, 2004). The utilization of patent indicators requires researchers and managers to ask these critical questions: "What can one use patent statistics for?", "What aspects of economic activity do patent statistics actually capture?" and "And, what would we like them to measure?" (Griliches, 1990). Some patent data is available ex ante, while other indicators are only available ex post. Patent indicators that are available ex post greatly increase the reliability over those that are immediately available ex ante on a patent application according to a recent study (Arts et al. 2012). However, the timeliness of data is a major concern, especially with respect to identifying potentially disruptive technologies (Ernst, 1998).

Litigated patents receive roughly twice as many forward citations as non-litigated patents (Lanjouw and Schankerman, 2001; Allison, 2003 & 2009; Chien, 2011; Su et al., 2012) and patents with higher forward citations in-turn earn much more income during their period of validity (Harhoff & Reitzig, 2004). This alone shows the strength of litigation as an indicator of value. However, patent litigation also represents significant economic expenditure, and can therefore be used to forecast market growth. Tang and Huang (2003) introduced patent litigation intensity (PLI) as a leading indicator of market growth and showed that patent litigation has lead market growth for PCs and cellphones since the 1980's. This makes sense, since spending millions of dollars per side per case to protect the future economic rights to a technology implies that future revenue will balance out the enormous cost of litigation.

The maturity of software industry as a whole is hard to measure; since it is *'soft'* it is boundless and so from one perspective it is never matured (Scherlis, 2009). From another perspective software is seen as being mature in the sense that risk of adoption is lowered because the benefits of business application software are clearly understood, and the cost of implementation is lowered. Regardless of software's status of being matured industry or not, large high-tech firms are continuously adopting massive software infrastructure. This is evidenced in one way by the fact that software and IT have dominated the current wave of M&A deals in terms of value and volume (Leger, 2009; Weier, 2007; PwC, 2012). Indeed, the new product paradigm of '*appliancized PCs'* is heavily software dependent and examining annual litigation trends provides quantitative data about potential market growth.

The purpose of this paper is to propose a framework for monitoring patent litigation data to enhance technology road mapping by ranking software-related United States Patent and Trademark Office (USPTO) subclasses and technology categories according to their relative litigation intensity, while also accounting for degree of technological novelty. An application framework is presented based on identifying strategic industry factors and comparing strategic assets. The ranked

list of technology categories resulting from this study's framework can be used for R&D resource planning, competitor assessment, human resource planning, etc.

2.0 Litigation as an indicator of value

Technology forecasting using patent-based indicators is objective, but limited because patents are disconnected from market forces. This limitation has been noted for some time and is described by Scmookler (1951), and later by Griliches (1990) among others. Much effort has gone into using patent information to assess the value of individual patents and patent families. For technology monitoring and road mapping, a patent indicator related to market growth is a point of interest, especially in industries or times when market-pull forces are shaping product demand rather than technology push forces. Patent litigation data provide a market-based approach because it points to enormous capital expenditure to protect exclusive economic rights. With the use of patent classifications and bibliometric analysis we can quantify these efforts by technology category, and identify the specific technologies in question.

The fees associated with litigation are in the millions per side per suit, and it has been empirically shown that firms may redirect funds away from R&D when facing litigation, causing hold-up (Tucker, 2011). Bessen and Meurrer estimate the total direct costs of patent litigation in the US at $29 billion in 2011 merely for cases brought by non-practicing entities (Bessen, 2012). The mean cost of litigation for suits has climbed from an estimated 1.5 million in 2000 per side per suit in 2001 to over between 3~4 million for cases with stakes over $25 million (Allison, 2012; Bessen, 2012).

Other literature on patent litigation shows significant litigation has been shown to cause innovative hold-up due to high costs (Yeh, 2012; Reitzig, 2008; Dodson, 2006, Raghoo, 2008) and in a case study by Tucker (2011) involving a medical imaging firm. Software industry experts have articulated the harmful impact litigation has had particularly on small software companies[1] (Mann, 2006; Bessen & Hunt, 2004; Levine, 2004). Millions of dollars are lost to legal fees and settlements or damages must also become part of a firms risk management assessment. Several damage settlements have surpassed $1 billion (Hoti, 2006), and these settlement and damage totals have been increasing steadily over time.

Empirically, litigated patents have been associated with significantly higher rate of forward citations (Lanjouw and Schankerman, 2001; Allison, 2003 & 2009; Chien, 2011, Su et al., 2012), and acquire roughly twice as many forward citations. Higher forward citations have been exhaustively validated as an indicator of higher technological impact and patent value (Carpenter et al., 1981, Griliches, 1990; Trajtenberg, 1990; Narin, 1995; Hall et al. 2000; Harhoff et al., 1999; Bessen &

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[1] The Computer History Museum: *'Software Patent Debate'* is an hour-long debate

Meurer, 2008). Bessen and Meurer (2008) showed litigation is a stronger indication of value than citations, and that all else equal a litigated patent is nearly 6 times more valuable than a non-litigated patent.

In economics, '*leading indicators'* have the ability to predict future changes. Defining patent litigation intensity (PLI) as cumulative sum of patent litigation, Tang and Huang (2003) showed litigation was a leading indicator of economic growth for PCs and cellphones from the 1970s, and claimed it is a stronger indication of market growth than mere patent citations. PLI's ability to predict market growth makes it an effective tool for technology road mapping considering that patents are good objective measures, and can be classified into technological areas. Patent litigation can therefore act as an intermediary indicator between technology development and the technology market.

Also, patent case dockets often include multiple patents and defendants. In a preliminary study, the median average number of patents litigated per docket was found to be 2.38, and number of defendants was 2.02 for all dockets in the Litalert database from 2000-2012. The Pearson's r value was calculated to determine correlation between total dockets to total patents and total defendants by UPC class from 2000-2012. The results showed r= 0.84592 and 0.98937 respectively. Therefore the number of patents and defendants per case docket is strongly similar across all USPTO classes at the three-digit level. This consistency means that measuring PLI by total dockets, litigated patents, or defendants would all produce similar results, and that all measures can used for comparisons effectively across USPTO classes. No. of dockets was chosen to represent PLI in this study.

The authors also considered the question of whether to include case dockets filed by non-practicing entities (NPEs), and patent trolls. Finally, all patent litigation data was included because all patent suits have associated costs and therefore imply efforts to protect a marketable product. Eliminating NPE firms from the calculations would alter the resulting rankings somewhat since some NPEs file multiple case dockets against large groups of defendants.

3.0 Additional Patent Indicators

The timely identification of potentially disruptive technologies is vital to resource planning and road mapping for a firm (Ernst, 1998). For this purpose, additional patent indicators were selected based on their ability to identify emerging technologies. Patent age, technology cycle time (TCT), and number of backward citations (BWCI) further highlight technological novelty and emergence. TCT and BWCI both use backward patent citations, which are available ex ante. Patent citations included in a patent are reviewed by patent examiners at the USPTO and considered reasonably objective due to their legal significance. Although the indicators used in this study may not be an exhaustive list of appropriate indicators, they demonstrate the proposed method of increasing the performance of PLI-based forecasting.

3.1 Age

In the pharmaceutical industry generally, the age of a patent positively relates to its value. This is because young patents in the pharmaceutical industry have much uncertainty since the underlying drugs have not passed clinical trials for FDA approval (Wu, 2011). However, young patents have more validity period remaining and can theoretically produce more revenue during their remaining lifespan than an older patent with the same annual licensing fees. Therefore in this study, age has been negatively correlated with value, that is, younger litigated patents are considered more valuable than older ones. Also, patent litigation data predicts future market growth, but is only available ex post, therefore conjunctive indicators that can aid the timely identification are most helpful. Scoring patents according to their age at the docket filing date accommodates that goal.

3.2 TCT

Technological changes are windows of opportunity for incumbents to innovate and earn rents from the products or processes they improve (Schumpeter 1943, Porter, 1985; Nelson, 1982; Abernathy & Clark, 1984; Reinganum, 1989; Tushman et al., 1997; Eisenhardt, 1995). Reasonably then, technologies with a faster pace of technological turnover also have more room for opportunity. Larger incumbents can differentiate themselves and strengthen their position, while smaller firms may be able to gain entry by exploiting a window of opportunity presented by technological change.

TCT was developed by CHI Research Inc., in conjunction with the U.S. National Science Foundation as a method to calculate the age of the innovations that a particular invention is based on (Kayal, 1999). TCT is measured by calculating the average age of the backward citations of a patent and lower TCT implies that the technology protected by the patent is based on younger prior art. The TCT indicator can accurately reflect the pace of technological progress of a technology category as demonstrated through comparing the TCT of semiconductor and superconductor patents of the past three decades (Kayal et al., 1999).

3.3 Backward Citation Count

Radical technological changes or disruptive technologies can cause disaster for incumbents if they do not adjust their strategy to deal with the disruption (Christensen, 1997; Ernst, 2003; Tushman et al., 1997). Radical disruption also has a more extreme effect on market competition than incremental change. History tells us that failure to react appropriately to radical disruptions can cause firms to enter bankruptcy as Kodak did in 2012. Identifying radical disruptions early gives firms a better chance to react.

Radically innovative technologies are based on different underlying core technologies and science than predecessors (Henderdson and Clark, 1993; Chandy and Tellis, 2000). A patent with few or no backward citations is more novel since prior art is non-existant (Ahuja and Lampert, 2001; Dahlin and Behrens, 2005). Therefore, in this study backward citation has been negatively correlated with novelty and thus patents with fewer backward citations are valued higher.

4.0 Research Model

The goal of this paper is to address how patent litigation data can be combined with other patent data for timely technology road mapping. These assessments can be directly applied internally manage resources or externally in competitor assessments. The following paragraphs review supporting management theory.

The resource-based view of evaluating strategic position has remained dominant for over the past half-century (Penrose, 1959; Selznick, 1957; Wernerfelt, 1984; Grant, 1991; Amit, 1993). Wernerfelt (1984) identifies four key issues that a resource based perspective can aid in addressing: (1) which current resources should be diversified, (2) sequencing and planning of resource development, (3) selecting markets in which to diversify and (4) what type of firms are preferable for join ventures or acquisition. Market based indicators are essential ingredients in objectively planning (Ernst, 2003; Phaal, 2003). In order for firms to reconcile their resource-market discrepancies in such a way as to gain competitive advantage and increase rents with respect to market-pull forces, *market-related strategic industry factors* must be weighted against *strategic assets* (Amit, 1993). Current strategic management discussions also place emphasis on monitoring for disruptive technologies (Arts et al., 2012).

USPTO data and Thompson Reuters' Litalert database comprised the major data sources used for this study. A methodology for identifying software patents was published by Stuart Graham (2013), an expert advisor to the USPTO and its efficacy was examined below in the auto industry scenario. Graham acknowledges that his definition of software is both overly-inclusive and overly-exclusive, but advises that due to software's integration into many aspects of manufacturing and its inseparability from computer hardware, a broader definition of software is advised when identifying software patents.

4.1 Regression study of PLI vs R&D output

Griliches (1990) describes a method for better understanding the significance of patent data as a measure of R&D input and output as "looking for correlations between patent counts and other variables". Griliches (1990) noted parallel changes to patenting activity after changes to firm R&D spending and showed patents can be used as an alternative measure for R&D spending. In light of this, as a preliminary study the authors have opted to assess the correlation

between patent litigation intensity R&D efforts as measured by awarded patent grants and compared by USPTO class at the three-digit level (figure 1). Patent litigation is considered a measure of R&D output here since litigation is a way to protect marketable products, and patent grants are considered a measure of patent input (Griliches, 1990). The authors proposed hypothesis is that the correlation should be neither very strong, nor weak, but in the range of moderate to strong. The variance between an expected level of litigation based on a best-fit regression model and a class's actual level of litigation represents disproportionate efforts to protect the technology in that class, and implies higher market value.

The regression analysis compared long-term patent grant activity and patent litigation intensity for: (1) 732 UPC subclasses and (2) software-related UPC classes (72 classes) using linear, polynomial, exponential, and logarithmic regression models (Table 1). R&D expenditure has previously been shown to have strongest correlation to patent grants using linear, and exponential regression models, and logarithmic regressions have worse performance (Kondo, 1999; Prodan, 2005). The preliminary regression study comparing PLI and patent grant activity similarly showed better performance for linear, polynomial, and exponential models of regression. The R^2 values for the best-fit regression models are described in table 1. All classes with either zero patent grants or zero litigations were excluded from the exponential and logarithmic regression models.
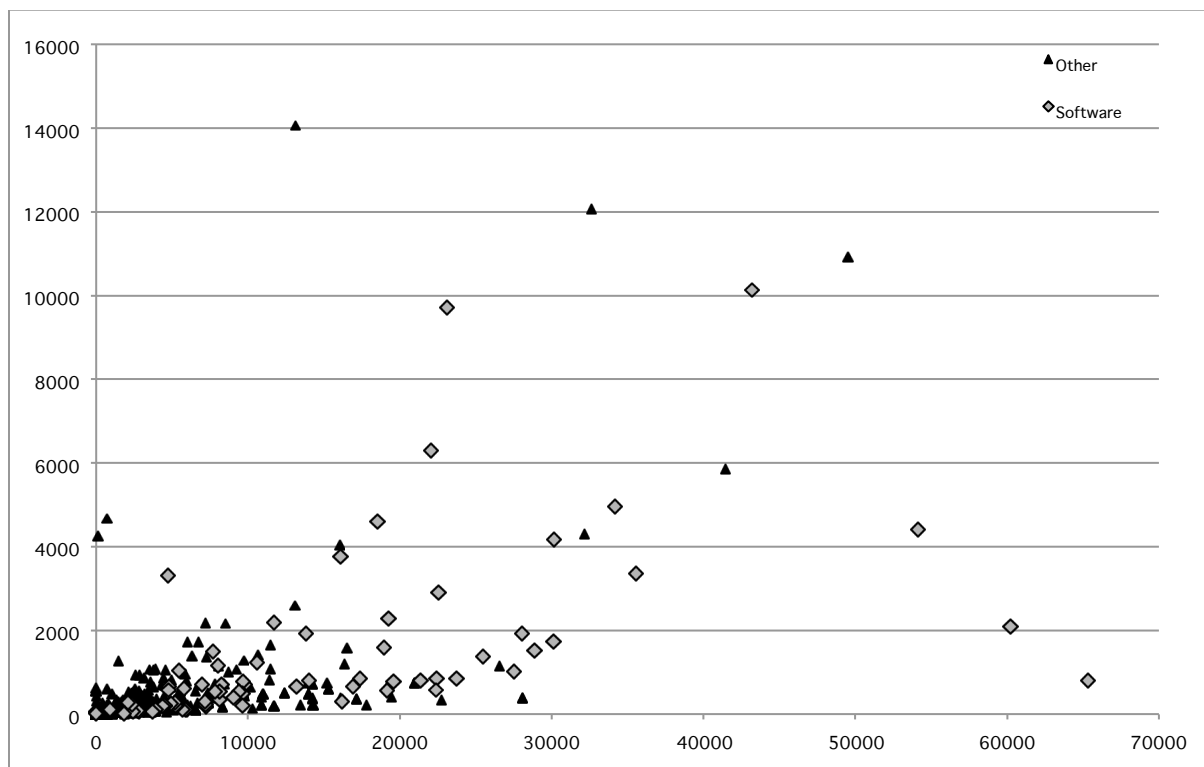
Figure 2: Scatter plot diagram for patent grants vs. PLI for 72 software-related UPC classes (grey diamonds) and 661 other USPTO classes (black triangles).

*Table 1: R² values for various regression models comparing all patent grants to patent litigations (2000-2012) for 732 patent classes. (*609 classes in the model)*

	No of Classes	Lin.	Polyn.	Expon.	Log.
Software Classes	72	0.2761	0.3468	0.3709	0.1373
All Classes	732	0.3659	0.3675	0.3523*	0.1271*

The Pearson's r correlation value was in fact found to be within a range that can be characterized as moderate to strong (r=0.6049 for all classes and r=0.5316 for software classes only). Following our hypothesis, there is suggestive variance between R&D input and output that can be interpreted as disproportionate efforts to protect the rights of some technological areas more than others. This further supports the exploitation of this data as a leading indicator of expected market growth.

The two most active classes with respect to R&D input are 438 and 257; semiconductors and solid-state devices. A strict emphasis on planning (Cakanyildirim & Roundy, 2012), extremely high costs of R&D (Peng et al., 2011), and the fact that semiconductor firms license large portfolios (Bessen, 2003), attributes for very low levels of litigation. Barrier to entry keeps the number of competitors low, and cross licensing is managed effectively in a cost risk-averse manner. Classes with the highest positive variance are 340 and 455, electrical communications and telecommunications respectively. M&A deal value and volume do corroborate the hypothesis that these classes actually represent the highest market value (Leger, 2009; Weier, 2007; PwC, 2012).

A quadrant diagram below (figure 2) characterizes the nature of patent classes based on their level of patenting and litigation intensity. The horizontal dividing line represents a best-fit line of any chosen regression model applied to the data. The quality of fit for various models is described above (table 1). The mean number of patents grants (2000-2012) per USPTO class at the three-digit level is 3928.0 and the median is 851.
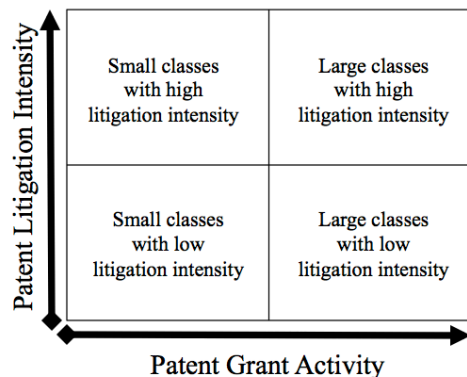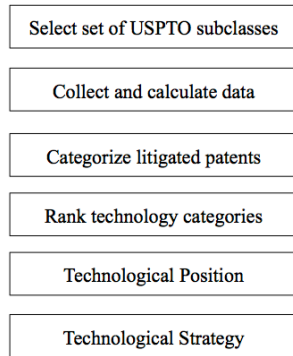
Figure 2: Quadrants of patent litigation intensity and patent activity.

4.2 Strategic Industry Factors and Strategic Assets Approach

The research framework is depicted below in figure 3. In the final stage of this study, a scenario was used to assess the auto industry from both inside out and outside in perspectives. Technology areas were ranked by grouping litigated patents into categories then calculating the respective shares of PLI and then supplementing with other patent indicators to highlight novelty and emergence (section 3). Although three supplementary indicators (Age, TCT, and BWCI) are suggested for this framework, other patent indicators could be substituted. The method proposed by this paper for combining the indicators is described below. Finally, the patenting activities of major global automakers are then compared to the ranked patent families.

Select set of USPTO subclasses

Collect and calculate data

Categorize litigated patents

Rank technology categories

Technological Position

Technological Strategy

Figure 3: Research Framework

5.0 Weighted Scoring Algorithms

Two PLI-based indicators and three additional patent indicators are suggested for ranking USPTO subclasses at the three-digit and six-digit level. Ranking patent families using a cumulative sum of several indicators of patent quality is an important method for competitor monitoring (Ernst, 2003).

A patent family's share of PLI, average age of litigated patents, average TCT and average backward citation counts were calculated for all scenario classes (equation 1). The metric data were then adjusted to scores on a scale of 1 to 0 and added together to get a final score for each class (equation 2). Although the possibility to weight each indicator is suggested, the models in this study do not attempt to weight the algorithm towards any particular indicator such as age, TCT or BWCI. The discretion of managers should be applied to setting any additional weighting configurations. In other words, while the indicators themselves are largely objective, their application within the context of the weighing algorithm is subjective and many configurations are possible.

$$MS = (M_c - M_{min})/(M_{max} - M_{min})$$

Equation 1: Equation for transposing a metric (M) of patent class (c) into a metric score (MS) between 0 and 1 according to its share among all classes.

$$FS = \Sigma \, (wMS) \, / \, \Sigma \, w$$

Equation 2: Final score of a patent family is the sum of selected metrics scores (MS) multiplied by the weights (w) assigned to each metric divided by the sum of all weights in order to give a score between 0 and 1 for each patent family in the list being compared.

Table 2: Description of the scoring algorithm used for a combined metric of docket numbers and average age of litigated patents within a subclass.

PLI-based Metric	Equation	Description
PLI	$(PLI_C - PLI_{MIN})/$ $(PLI_{MAX} - PLI_{MIN})$	UPC subclasses' share of the total 2012 litigation for all included subclasses as a score between 1 and 0.
Other Indices	Equation	Description
Age	$(Age_C - Age_{MAX})/$ $(Age_{MIN} - Age_{MAX})$	The average age of litigated patents in a UPC subclass described as a score between 1 and 0. Patent age is negatively correlated to value for this study.
TCT	$(TCT_C - TCT_{MAX})/$ $(TCT_{MIN} - TCT_{MAX})$	The average TCT of litigated patents in a UPC subclass described as a score between 1 and 0. Lower TCT implies faster rate of technological change, and is negatively correlated to value for this study.
BWCI	$(BWCI_C - BWCI_{MAX})/$ $(BWCI_{MIN} - BWCI_{MAX})$	The number of backward citations is indicative of a patents novelty. Fewer back citations imply a patent is unlike prior patents. BWCI is negatively correlated to value for this study.

6.0 Software Industry

Corporate spending on software is increasingly critical, and now supports nearly every aspect of business making up 60% of total investments according to McKinsey Quarterly (2013). The benefits effect front-end such as new product and communication channels, as well as back-end benefits like greater automation, standardization, and integration (Sarrrazin et al., 2013), and the current wave of M&A in hi-tech has been dominated by software-related industries for the past decade (Leger, 2009; Weier, 2007; PwC, 2012). Also, according to some, the

software market has reached a mature stage in latter half of the past decade (Leger, 2009), which is a possible reason for its increasing importance and integration into business strategy since mature technologies are more profitable and viable to adopt (Kauffman and Li, 2005). However, describing the relationship of hardware and software innovation cycles, Scherlis (2009) proposes that the nature of software it self being *'soft'* means that it will theoretically never become a fully mature industry. Scherlis also emphasizes that improved hardware depends fundamentally on software innovation to fuel the need for hardware innovation in the market. It also seems that new hardware paradigms are also important for providing radically new functionality that can create new products such as light sensitive diodes, touch capacitors, or optical waveguides to name but a few.

The pace of technological innovation has slowed during the past decade but the rate of social change has increased (Philips, 2013). However, the pace of innovation and change in the software industry remains faster than other industries (Mann, 2006; Scherlis, 2009). While the pace of technological change slows, software has been instrumental in developing a new product paradigm of '*appliancized PCs'* and hybrid PC-appliances such as smartphones, smart-TVs, intelligent automobiles, or intelligent refrigerators that can order your groceries automatically. The market for this novel product-paradigm has enormous potential to drive revenue in the next decade.

6.1 Software Patent Data

Identifying software patents for the purpose of industry analysis is an issue that has been solved in several bodies of research using various strategies such keyword analysis and isolating whole USPTO classes (Bessen, 2004; Graham & Mowery, 2003; Graham et al., 2012; Bergstra & Klint, 2007). One problem is that software is increasingly integrated into various products and technologies. For example, any modern electronic hardware also includes software. The intended research purpose is important to consider when choosing a method to identify software patents. For this study, a method of identifying software patents in the USPTO was taken from Stuart Graham (2013)[2]. Graham acknowledges the method itself is one of convenience and is both overly inclusive and overly exclusive but nonetheless uses it for broad statistical analysis of USPTO patents. For this study, only the first position class and subclass listed on a patent grant were used.

Using the definition provided by Graham, we found that software-related patents have been increasing their share of all patent grants and all patent litigation (Figure 4 and Figure 5). Instances of software-related patent litigation have increased from 42% in 2008 to 70% in 2012. Figure 6 shows the top-ten software-related UPC classes for cumulative PLI for 2011 and 2012.

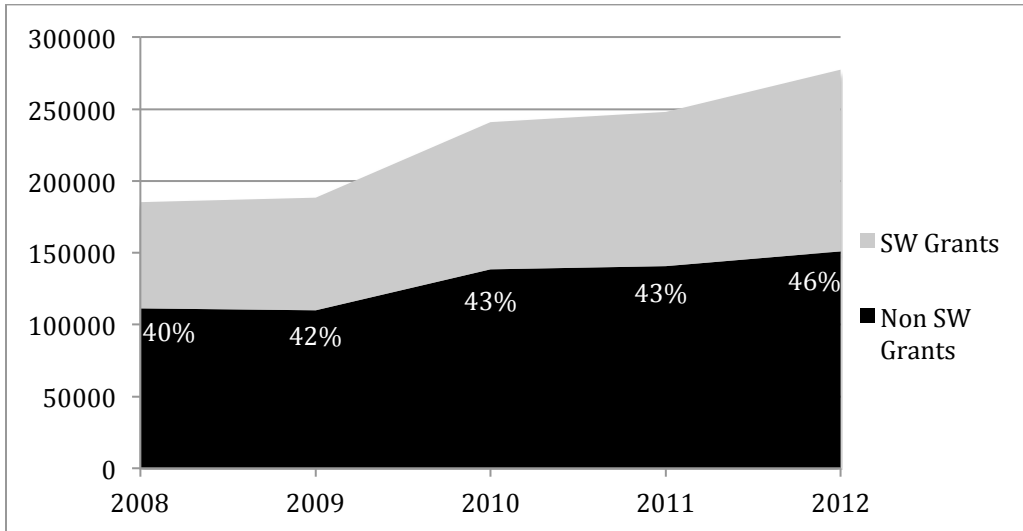[2] Stuart Graham is an advisor to the USPTO

Figure 4: Software-related patents share of all patent grants from 2008-2012.
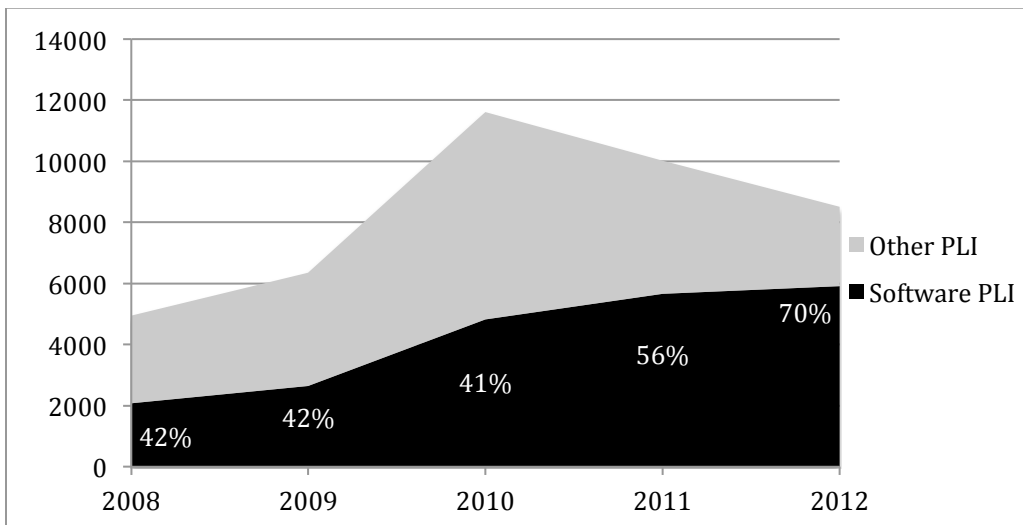

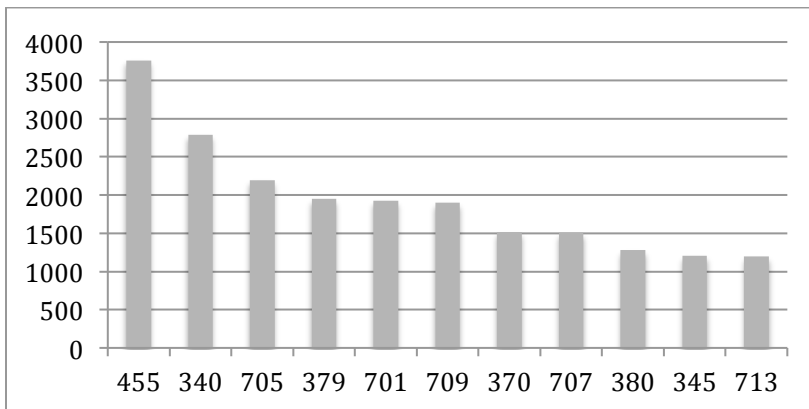*Figure 5: Software-related patents share of all litigation from 2008-2012*

Figure 6: Top ten software related UPC classes for cumulative 2011-2012 PLI.

7.0 Scenario: Auto Industry

The auto industry was selected to highlight the efficacy of the ranking algorithms for two reasons; (1) vehicle-related classes are a large portion of 2011-2012 PLI (figure 6 shows that UPC class '701' ranks 5th of all software-related classes for 2011-2012 PLI combined, and (2) the market for intelligent automobiles is expected to grow significantly in the next decade. Sergey Brinn from Google expressed confidence to the media that autonomous vehicles will be a market reality before the turn of the next decade[3]. Also worth noting is that China's unit sales of new automobiles has grown 25% per year since 2005[4]. Intelligent automobiles exist on the road today employing computer enhanced safety, navigation, and maintenance features. Autonomous vehicles will be a significant improvement on these intelligent technologies, incorporate machine learning, sophisticated radar and image analysis functions to drive without human control.

A list of top automakers was accrued from Forbes 2012 list of top 2000 global firms[5]. 27 automakers were identified from that list and although data was collected for all firms, only 8 firms' data are included for comparison here.

7.1 Evaluating Value Using the Outside-in Approach

The outside-in approach to resource-based assessment focuses on the litigation directed at the auto-industry. In total, 176 unique patents were identified through Litalert that were litigated against major automakers in 2011 and 2012. Relevant data was collected and calculated for each patent including (1) first USPTO class and subclass codes and titles, (2) age at filing date, (3) patent TCT, (4) number of backward citations, (5) patent title and (6) abstract. The software patent classification method of Graham (2013) was checked using bibliometric analysis of patent titles and abstracts. In total Graham's method identified 137 from the 176 litigated patents as being software-related. Although Graham's method performed well, 16 (10.4%) of the software-related patents were missed by Graham's method. 153 software-related patents were finally included in the model.

The patents were then classified into broad technological categories and more specific subcategories based on UPC classification, patent title and the

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[3] Sergey Brin predicted that autonomous vehicle technology will be market reality within 5 years: (Sept 25, 2012)
http://www.computerworld.com/s/article/9231707/Self_driving_cars_a_reality_for_39_ordinary_people_ 39_within_5_years_says_Google_39_s_Sergey_Brin
[4] November 2012. McKinsey Quarterly Industry Report: Bigger, better, broader: A perspective on China's auto market in 2020
[5] Top global automakers were identified from Forbes Global 2000 list.
http://www.forbes.com/global2000/list/

technical description provided in the abstract. A sample of the patent data collected is provided in table 3. The patent displayed in table 3 was classified as *'Subsystem Control and Indication'*. The top ten subclasses by final score are shown in table 4. Table 5 shows the list of technological categories identified, data, and final rank and figure 7 is a visual comparison of category performance with respect to each indicator of novelty.

Table 3: Sample of data collected for each litigated patent

Patent No.:	7959177
Title:	Motor vehicle operator identification and maximum speed limiter
Assignee:	Kar Enterprises, LLC
Class Code:	280/271000
Class Title:	LAND VEHICLES: WHEELED: Occupant propelled type: With steering: One-wheel controlled: Centering
Age at filing:	0
TCT:	8.68
BWCI:	38
Abstract	A programmable device that interfaces with a motor vehicle. The device is programmed to identify the operator who is gaining access to the motor vehicle. The device is further programmed to associate a maximum allowable speed with each person allowed to operate the motor vehicle. The device incorporates an access and operation means together with a computer that is compatible with the motor vehicle on board computer. The computer includes in it's output a signal that controls the maximum allowable speed that the on board computer will permit the motor vehicle to operate at for the identified operator.

Table 4: Top-ten ranked USPTO subclasses for software-related technologies using 2011-2012 litigation of top global automakers as search criteria.

Class	Final Score	Class Title
701/208	0.740	DATA PROCESSING: VEHICLES, NAVIGATION, AND RELATIVE LOCATION: For use in a map data base system
701/207	0.669	DATA PROCESSING: VEHICLES, NAVIGATION, AND RELATIVE LOCATION: Employing position determining equipment
701/209	0.652	DATA PROCESSING: VEHICLES, NAVIGATION, AND RELATIVE LOCATION: NAVIGATION: Including route searching or determining device
701/212	0.651	DATA PROCESSING: VEHICLES, NAVIGATION, AND RELATIVE LOCATION: NAVIGATION: Having variable map scale
704/251	0.610	DATA PROCESSING: SPEECH SIGNAL PROCESSING, LINGUISTICS, LANGUAGE TRANSLATION, AND AUDIO COMPRESSION/DECOMPRESSION: Word recognition
701/211	0.588	DATA PROCESSING: VEHICLES, NAVIGATION, AND RELATIVE

701/070	0.580	LOCATION: Having audio or visual route guidance DATA PROCESSING: VEHICLES, NAVIGATION, AND RELATIVE LOCATION: VEHICLE CONTROL, GUIDANCE, OPERATION, OR INDICATION: Indication or control of braking, acceleration, or deceleration
717/121	0.578	DATA PROCESSING: SOFTWARE PROGRAM DEVELOPMENT TOOL: Managing software components: Software configuration
340/005.5	0.574	COMMUNICATIONS: ELECTRICAL: LAND VEHICLE ALARMS OR INDICATORS: Suspension Control
342/357	0.572	COMMUNICATIONS: DIRECTIVE RADIO WAVE SYSTEMS AND DEVICES E.G., RADAR, RADIO NAVIGATION

Table 5: Technological categories identified, PLI, metric averages, final score, weighted final score and weighted rank for auto industry patent litigation

|	PLI (2011-2012)	Avg. Age	Avg. TCT	Avg. BWCI	Total Score	Weighted Rank
Speech Recognition	1	0	7.67	24	0.652	1
Computer Networking	3	6.67	4.52	14	0.646	2
Radar-aided Navigation	8	12.5	5.11	8.5	0.562	3
Subsystem Control & Indication	16	6.06	8.57	33.82	0.577	4
Vehicle Location and Navigation	72	6.41	9.41	82.81	0.703	5
Data processing systems	6	7.5	7.84	23	0.548	6
Semiconductors	6	11	7.04	6.25	0.53	7
Database management	3	1.5	10.67	84	0.503	8
Cryptography	4	16	4.72	10.5	0.502	9
Graphics and Visual Display	18	6.7	10.23	51.8	0.514	10
Artificial Intelligence	1	4	12.67	21	0.46	11
Image Analysis	1	14	6.24	37	0.459	12
Automatic Maintenance	4	3.43	12.98	59.57	0.437	13
Accessory Subsystems	15	7	9.53	123.43	0.454	14
Telecommunication & Messaging	19	5.87	9.39	241.43	0.384	15
Bank & Shopping	5	2.13	14.04	286.5	0.231	16
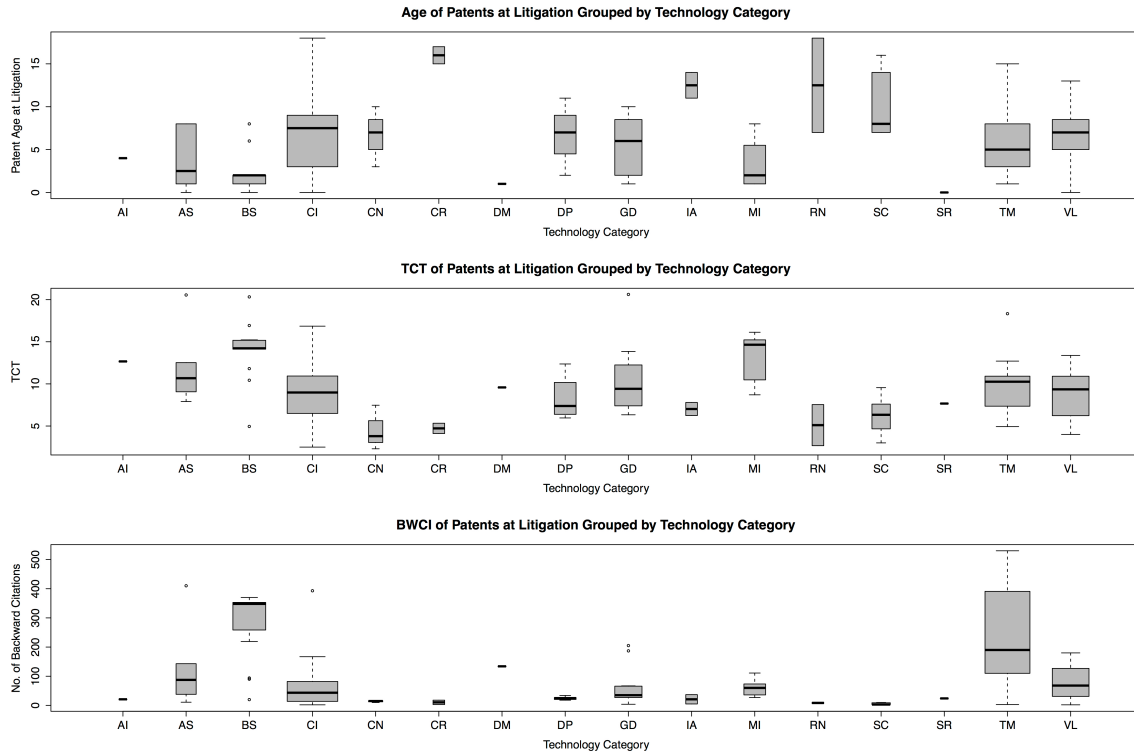
Figure 7: A comparison of technology categories for three indicators of novelty. Width is varied to show the no. of litigated patents in each category. (AI=artificial intelligent algorithms, AS=accessory subsystem control, BS=banking and shopping, CI=subsystem control and indication, CN= computer networking, CR=cryptography, DM=database management, DP=data processing, GD=graphics and display, IA=image analysis, MI=maintenance indication, RN=radar navigation, SC=semiconductors, SR=speech recognition, TM=telecommunications, and VL=vehicle location.

7.2 Evaluating Value Using the Inside-out Approach

The inside-out approach was also used to investigate the potential market growth of technologies related to the auto industry. Top automakers patenting activity was used to form a list of USPTO subclasses that represent the interests, knowledge resources, and capabilities of the auto industry. These patent classes were then used to search for litigated patents and data was collected. For example, several shipping companies also experienced litigation for automobile related technologies in 2011-2012. By applying this perspective, automakers can look from the *'inside'* meaning from the perspective of their resources, to the *'outside'* to assess the value of these resources across all industries.

Pooling all automaker patents since 2000 led to the identification of 2091 software-related patents by Graham's software patent identification method, which comprised 774 USPTO patent subclasses. USPTO subclasses were used to sort the patents into broad technology categories since there were too many patents to make manual bibliometric sorting feasible. The relatively good performance of Graham's

list of software-related classes in the outside-in approach lends support to this approach. In the case of very general USPTO classes, individual patent assignment was used. Table 6 shows the top ten USPTO subclasses ranked according to their final score and Table 7 shows the sorted technology categories, metric data, final scores, and rank.

Table 6: Top-ten ranked USPTO subclasses for software-related technologies from 2011-2012 patent litigation using top global automaker patent portfolio as search criteria.

Class	Final Score	Class Title
380/046	0.875	CRYPTOGRAPHY: KEY MANAGEMENT: Having particular key generator: Nonlinear (e.g., pseudorandom)
709/206	0.824	ELECTRICAL COMPUTERS AND DIGITAL PROCESSING SYSTEMS: MULTICOMPUTER DATA TRANSFERRING: COMPUTER CONFERENCING: Demand based messaging
701/201	0.808	DATA PROCESSING: VEHICLES, NAVIGATION, AND RELATIVE LOCATION: NAVIGATION: Determination of travel data based on the start point and destination point
709/219	0.803	ELECTRICAL COMPUTERS AND DIGITAL PROCESSING SYSTEMS: MULTICOMPUTER DATA TRANSFERRING: REMOTE DATA ACCESSING: Accessing a remote server
340/825.34	0.776	COMMUNICATIONS: ELECTRICAL: SELECTIVE: Program control: Of audio systems.
713/168	0.758	ELECTRICAL COMPUTERS AND DIGITAL PROCESSING SYSTEMS: SUPPORT: MULTIPLE COMPUTER COMMUNICATION USING CRYPTOGRAPHY: authentication technique
340/431	0.742	COMMUNICATIONS: ELECTRICAL: LAND VEHICLE ALARMS OR INDICATORS: For trailer
709/203	0.742	ELECTRICAL COMPUTERS AND DIGITAL PROCESSING SYSTEMS: MULTICOMPUTER DATA TRANSFERRING: DISTRIBUTED DATA PROCESSING: Client/server
709/218	0.741	ELECTRICAL COMPUTERS AND DIGITAL PROCESSING SYSTEMS: MULTICOMPUTER DATA TRANSFERRING: REMOTE DATA ACCESSING: Using interconnected networks
705/014	0.739	DATA PROCESSING: FINANCIAL, BUSINESS PRACTICE, MANAGEMENT, OR COST/PRICE DETERMINATION: ELECTRIC SIGNAL MODIFICATION (E.G., SCRAMBLING): Distribution or redemption of coupon, or incentive or promotion program.

Table 7: Technological categories identified, PLI, metric averages, final score, and rank litigation using top global automaker patent portfolio as search criteria.

Technology Categories	PLI	Avg.	Avg. TCT	Avg.	Final	Rank

	(2011-2012)	Age		BWCI	Score	
Computer Networking	606	5.00	8.38	80.37	0.665	1
Speech Processing	29	7.18	6.74	14.47	0.629	2
Telecommunication and Multiplex Communication	782	9.25	8.77	88.49	0.599	3
Database Management	239	7.29	8.20	34.11	0.596	4
Graphical and Video Display Systems	245	6.20	8.66	41.49	0.588	5
Software Management	38	2.11	10.05	25.55	0.584	6
Vehicle Navigation and Position Indication	625	7.11	9.05	94.90	0.570	7
Cryptography	217	11.57	6.58	31.29	0.570	8
Collision Avoidance and Airbag Deployment	40	5.17	8.63	32.54	0.563	9
Light Systems	37	6.97	8.25	22.70	0.558	10
Solid State Devices/Semiconductors	386	12.36	7.84	30.64	0.557	11
Dynamic Information Storage	11	10.42	7.28	7.25	0.547	12
Image Analysis	48	4.65	9.83	26.49	0.539	13
Vehicle Subsystem Control and Indicators	141	7.61	8.46	57.63	0.501	14
Vehicle Security and Anti-Theft	37	5.82	9.71	40.05	0.489	15
Battery and Power Conversion	63	7.66	9.39	32.48	0.486	16
Radar-based Navigation and Radio Antennas	90	12.74	6.67	40.29	0.483	17
Optical Waveguides	10	7.36	9.76	36.45	0.453	18
Laser and Optical Systems	38	10.67	9.07	20.97	0.449	19
Artificial Intelligence Algorithms	1	4.00	12.67	21.00	0.433	20
Modeling and Simulation Software	6	4.13	12.41	27.37	0.430	21
Business Software	484	5.09	11.77	115.04	0.417	22
Timing Systems	30	13.78	8.92	10.57	0.407	23
Temperature Control	7	6.69	11.63	43.08	0.377	24
Audio System	11	11.27	10.98	13.09	0.365	25
Manufacturing Control Systems	105	3.78	10.41	135.43	0.340	26

8.0 Conclusions and Discussion

8.1 Conclusions

Broadly, the strategic importance of software to business operations is increasing, and the integration of software into appliances is increasing. The proportion of software-related patent grants and litigation reflects these changes. In this paper, PLI-based indicators highlighted the market value of specific categories of software technologies for the purpose of market-based technology

road mapping. Litigation intensity was combined with other patent metrics specifically selected to identify novelty. This was done to facilitate the timely identification of the emergence of important technologies into the market.

The outside in approach was selected for the purpose of giving an automaker firm a perspective from which they could interpret the market value of technologies litigated against automakers. From the outside-in dataset, the top-ten ranked USPTO subclasses referred primarily to the technologies: (1) mapping and route planning, (2) speech recognition, (3) vehicle subsystem control, and (4) radar-assisted navigation. By grouping subclasses into technology categories, a final ranked list of those technology categories was made. The market for these technologies is expected to grow significantly and automakers positioning with respect to IP strategy, licensing strategy, human resources, etc. should be planned carefully.

In the inside-out approach a larger set of litigated patents are considered. This approach is a perspective from which automakers can investigate the value of their knowledge-resources across all industries. All automaker patent activity since 2000 were used to build a group of patent classes and then litigation activity was collected for these patent classes, grouped, and ranked using the scoring algorithm. Although vehicle related technologies did appear on the top-ten class list, the list was dominated by IT-related categories such as: (1) cryptography, (2) telecommunications, and (3) data processing reflecting the enormous importance of IT security, mobile, and telecommunications. However, many intelligent automobile-related technologies were also found. Automakers should strategically look to develop their resources and core competencies in these areas and take advantage of, acquisitions, joint venture and out-licensing opportunities.

8.2 Limitations

The use of patent litigation to determine market growth potential may not be fully exhaustive of all value represented in the market. It's highly possible that non-litigated, or unpatented technology may have more potential for market growth. However, the framework outlined in this paper does provide reliable form of objective quantitative data for technology road mapping. Also, there is the concern of how to group patents in to technology areas. In this study, the problem was handled in two ways: (1) in the outside-in approach, 176 patents were classified using a combination of bibliometric analysis and using the USPTO patent class titles. Using this method for a small group of patents showed that patent class title was an effectively consistent but imperfect method for grouping patents into broad technological classifications. (2) Only class title was used to classify the 1821 patents included in the inside-out approach. Finally, rankings were calculated using non-weighted final scores and other possible configurations of weighted indicators (PLI, age, TCT, BWCI) were not explored in this paper.

8.3 Contributions

Patent litigation has received much attention in academic literature in the past decade or so. It has been validated as an indicator of value from several perspectives. However, to the authors' knowledge its application to technology road mapping has not been explored. The framework in this paper has offered several ways that patent litigation data can be applied across broad industries or narrowly to individual firms to assess the market-importance of technologies.

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