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A joint report between Griffith Hack and its patent analysis partner Ambercite.
December 2010

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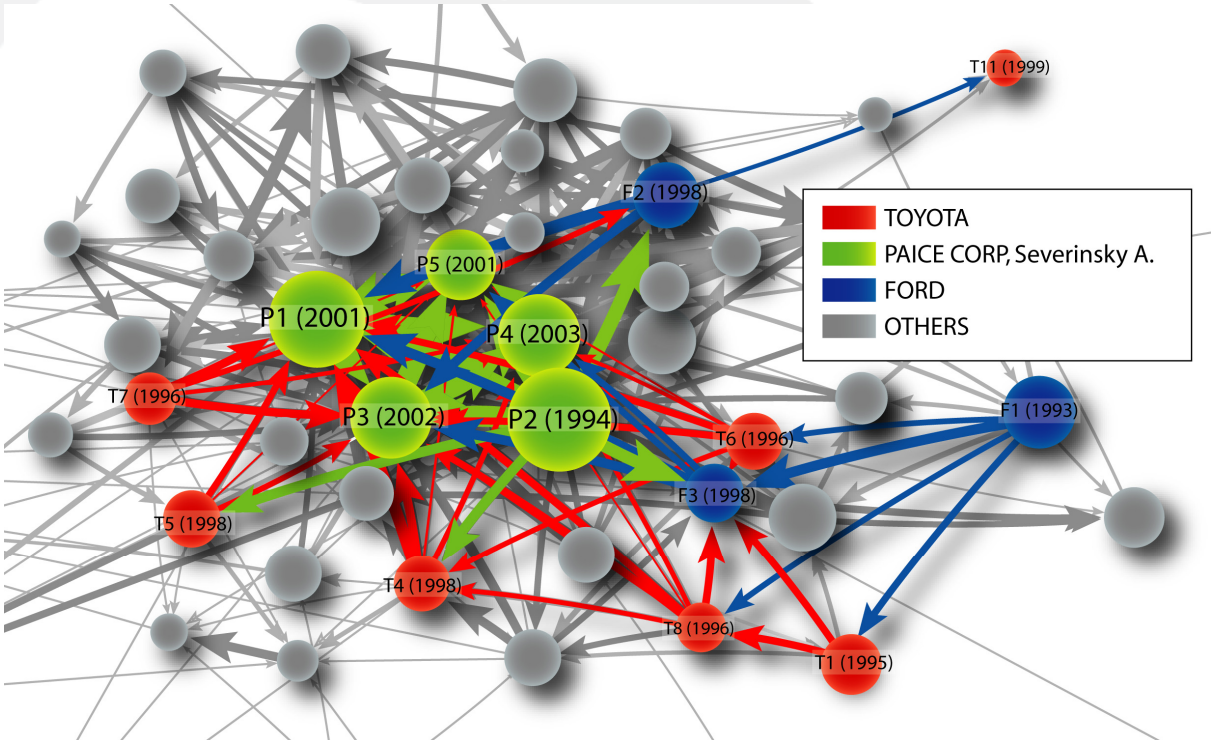

Ambercite White Paper 2010_1

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By Mike Lloyd and Doris Spielthenner,
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Hybrid car technologies – what can an advanced patent analysis method such as Network Patent Analysis (NPA) tell us about the leading companies and patents?

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Executive Summary

Network Patent Analysis™ (NPA™) is the sophisticated analysis and mapping of patent citation data for the purposes of determining the leading patents, patent applicants and technology trends in any area of technology. In this white paper NPA is applied to the area of hybrid car patents to illuminate the key developments.

Analysing 58,000 hybrid car patents and their inter-relationships, we found that the top ranked patents were filed by the hybrid drivetrain developer Paice Corporation, ahead of patents filed by Toyota, Ford and Honda who are better known for selling hybrid vehicles. NPA was also used to illustrate the 'apparent technology flows' (or similarities between patents) into and out of the top ten patents filed by these companies. The leading Paice hybrid car patents were shown to have strong self-citation relationships with other Paice patents. This contrasts with the top ten hybrid car patents filed by Ford, which were connected via citations to a variety of companies including Paice, Toyota, and Railpower Technologies, who have developed hybrid technologies for trains. Toyota's top ten hybrid car patents showed a strong citation relationship to patents filed by Suzuki as well as Paice, who has successfully asserted one of their key patents against Toyota in relation to hybrid vehicles.

Overall, our study identified and visualised the most relevant relationships between leading patents filed by Paice, Toyota and Ford, which we found to be consistent with known litigation and patent licensing agreements between these parties, thereby helping to confirm the ability of NPA to predict potential patent assertions.

Contents

Introduction – why analyse hybrid car patents?

Hybrid cars may end up changing the way we all drive. A hybrid car, in general terms, may be described as a car that obtains its power from two or more energy sources. Currently, the most common type of hybrid cars are those sold by Toyota, which use an electric motor to boost or completely substitute for short periods a petrol motor (known as a parallel hybrid because the engine and electric motor can work in parallel). Alternative hybrid car designs include limiting the role of the electric motor to boosting the power available from a petrol motor (Honda) or using a petrol motor simply to produce electricity for an electric motor, which directly drives the car (produced by Chevrolet, and also known as a series hybrid). In all three cases, one of the main reasons for the increased fuel efficiency of a hybrid car is that they are able to capture, and store as electric energy, the energy normally lost during braking.

General trends in hybrid car patent filings

Hybrid cars have been around since 1899, but it is only in the last 10 years that they have had significant commercial success. This history is reflected in the patent literature. While the first known hybrid car patent was filed in 1906, the number of patent filings was relatively low until around 1992, when Toyota made a public declaration to significantly reduce the fuel economy of its cars. As discussed in a 2009 Griffith Hack report on hybrid car filings, hybrid car patent filings exploded after this date, with patent filings led by Toyota, Figure 1, but supported by other Japanese car companies and Japanese suppliers to the car industry, Figure 2. By 2009 43% of the identified hybrid car patents[1] were filed by Toyota alone, in comparison to 8% filed by the US car industry and 7% by the European car industry (Figure 3). Toyota also dominated hybrid car sales in the later part of the last decade, with 77% of US hybrid car sales in 2007 and 2008 coming from Toyota or its Lexus subsidiary.

Figure 1. Summary of hybrid car patent family filing trends[2]

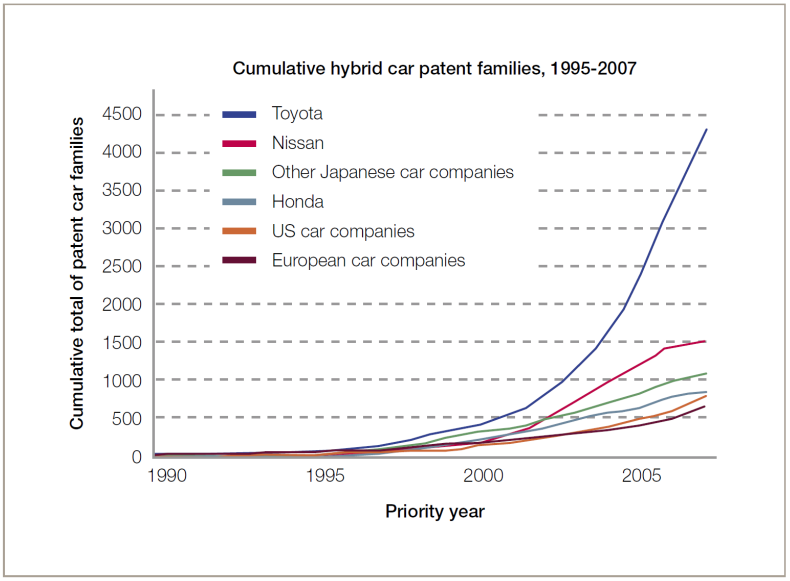


Figure 2. Car company patent filings are supported by patent filings by suppliers.

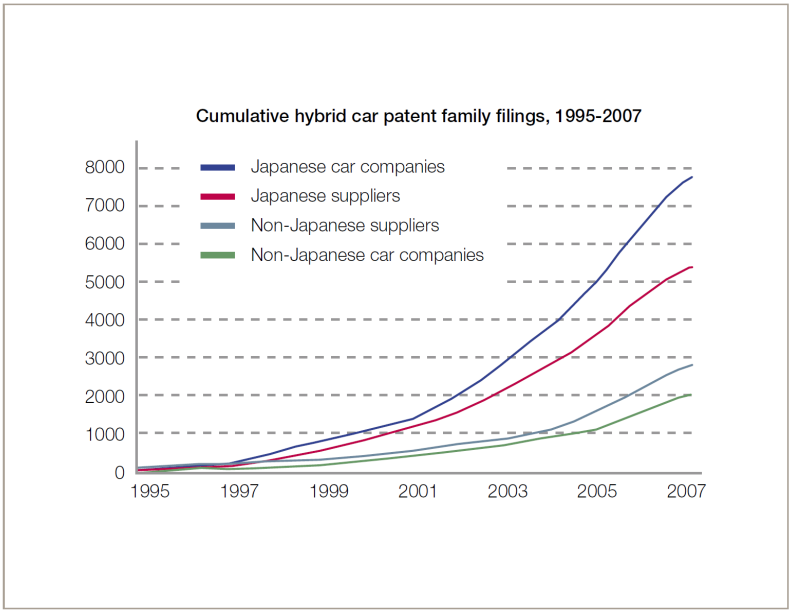
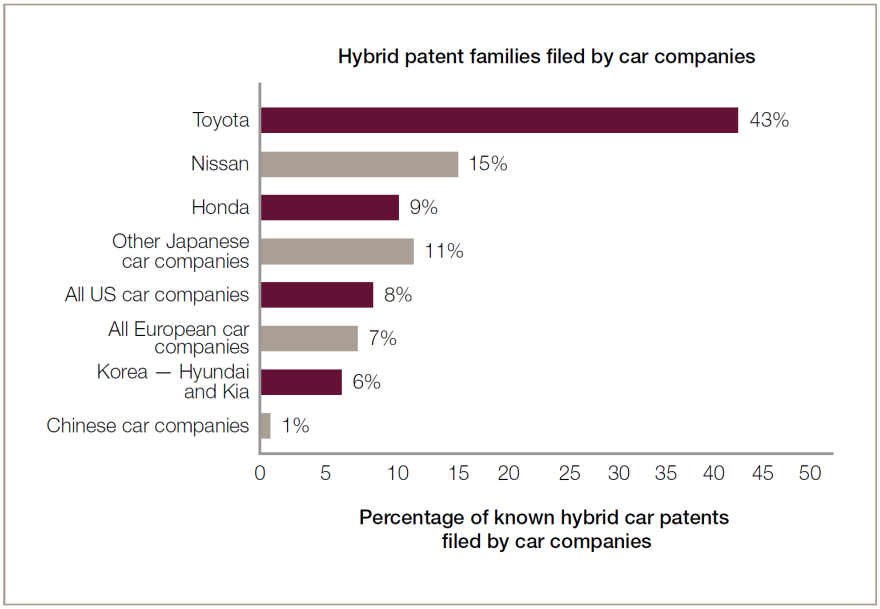


Figure 3. Relative filing proportions of different hybrid car applicants (hybrid cars filed by car companies)



Altogether Griffith Hack identified around 58,000 patents in the 2009 study, which came from around 19,500 patent families.

Section Summary – A 2009 review of hybrid car patent filings by Griffith Hack showed that Toyota was by far the dominant filer of hybrid car patent applicants. Other Japanese car companies such as Nissan and Honda, as well as Japanese suppliers, were also strong filers. In comparison, the US and European car industry filed comparatively few patent applications.

Application of Network Patent Analysis to determine patent quality

Patent specialists are always quick to point out that while large patent portfolios can have clear commercial benefits, patent quality is also important. For this reason in late 2009 the the Griffith Hack hybrid car report also applied the newly developed process of Network Patent Analysis[3] (NPA) to hybrid car patent data. NPA connects all identified patents to each other via their citations linkages (forward or reverse citations) and looks for the strongest relationships between patents, based on mutual citations. Patents that have the 'strongest' relationships to other patents (based on the number, strength and direction of direct and indirect citations) are thought to be the strongest and most important patents, or at least the strongest and most important patented inventions.

The use of citations linkages to form networks can be distinguished from other patent landscaping methods, which instead form landscapes based on keywords. One of the big advantages of NPA compared to keyword patent analysis is that NPA has an inherent capability to rank patents as well as group similar patents. There is no inherent mechanism we are aware of to rank patents when using keyword clustering; instead a separate process is required. Other differences between NPA and keyword clusters are discussed in Table 1.

Table 1. Summary of differences between NPA citation based and word based patent mapping

Feature	NPA citation based patent mapping	Text based patent mapping (Eureka, Themescapes etc)
Principle of grouping	Links and ranks patents based on citation linkages, including citations from linked patents	Links patents based on common keywords
Can the patent mapping rank as well as group patents?	Patent ranking is inherent in the NPA process	Keyword analysis has no inherent means of ranking patents
Precision	Can be very precise. Most citations are provided by examiners who identify the closest patents to a given invention after a search process. So patents are naturally grouped with very similar patents	Precision can suffer when trying to distinguish patents in a narrow field which uses similar keywords for patents for different inventions, for example different solutions for a common problem
Dependence on patent language	Providing that examiners are able to recognise the relevance of patents in another language (i.e. via patent abstracts), there is no dependence on language	May not work for patents filed in another language where keywords are different
Effect of synonyms (e.g. 'box' vs 'carton')	Providing that examiners are able to recognise that synonyms refer to the same concepts, synonyms do not affect NPA	Can be affected, unless all synonyms are known and used in the analysis
Objective vs subjective process	NPA can be regarded as an objective means of combining what can be hundreds of thousands of subjective opinions, i.e. a 'meta-opinion'	Text based patent mapping is purely objective.

When we applied NPA to the hybrid car patents, we found the unexpected result that the first, second, fourth and seventh strongest patents belonged to the little known Paice Corporation in the US. Paice was founded in 1992 to develop and commercialise inventions in the hybrid car field, in particular inventions related to the systems needed to connect electric motors to conventional petrol powertrains. In 2004 Paice commenced hybrid car patent litigation against Toyota. In 2005 a US jury held that Toyota infringed Paice's US 5,343,970 patent, and in 2010 Paice and Toyota settled all outstanding matters in relation to this litigation. US 5,343,970 was the second highest ranked patent according to the NPA analysis, and this helped us gain confidence in the inherent worth of NPA.

In the period since late 2009 Ambercite and its associate Griffith Hack have continued to develop NPA and its capability to analyse complex patent areas, including in relationship to infringement analysis. Many of these developments have come at the request of our commercial customers who have challenged us to push NPA into new areas, and we thank them for this. However, for obvious reasons, we are not able to share the results of these commercial studies.

The purpose of this report is to revisit the 'public domain' NPA data set and apply some recently developed NPA techniques to show the type of insights that can be achieved by the advanced NPA analysis of complex patent data.

Readers of the 2009 report will recognise that we have repeated some of the material from the first report into this white paper, but it should noted that this report contains a significantly enhanced analysis of the leading hybrid car patents.

Section Summary – Network Patent Analysis can be used show the strongest patents in a technology area, and has given results that were consistent with patent litigation.

What was the shape of hybrid car patent data structure, and what can this tell us?

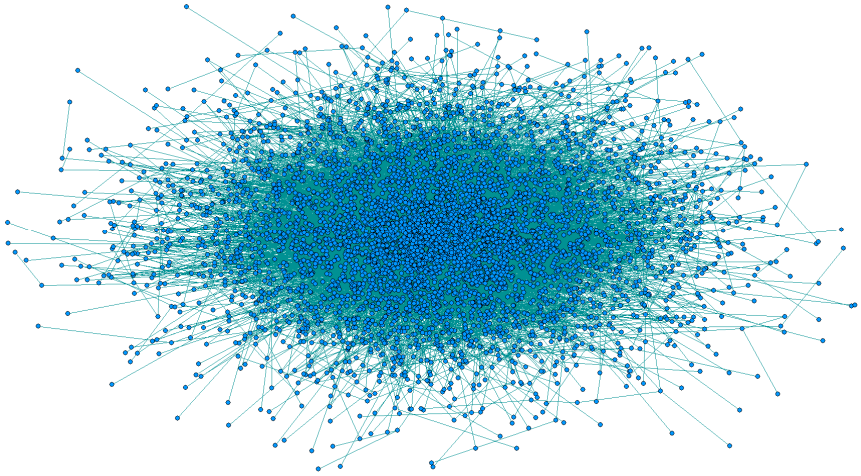
The initial hybrid car patent search query searched for all patents where the words ‘hybrid’ and ‘car’ were found within two words of each other. This search yielded about 58,000 patents in total. This patent data set was extended by including all first order (forward or reverse) citations to these patents which were not included in this dataset, which increased the number of patents to around 72,000 patents. These patents were linked together into networks through their citation linkages. Altogether 295 networks were formed, and in addition there were 8,100 patents that were not linked to any other patents though known citation data.

The largest of these patent networks contained 58,239 patents, and a review of the subject matter of patents within this network showed that this network referred to hybrid cars. The second largest of these networks contained 541 patents and appeared to be focused on hybrid filters. Similarly the third and fourth largest networks were focussed on other topics. For practical reason we decided to focus on the leading network of 58,000 patents, and discarded all other networks and the unlinked patents.

This example demonstrates a useful feature of NPA, namely its ability to objectively separate large patents into distinctly separate subject areas.

This leading network of 58,000 patents was reduced in its size to make it more meaningful by identifying the most strongly connected patents. As an example of this reduction, Figure 4 shows the network of the leading 5500 hybrid car patents according to NPA, which shows that the patents form into a homogeneous cluster. Of note, the cluster becomes more tense towards the centre, showing a strong highly interlinked core of key patents.

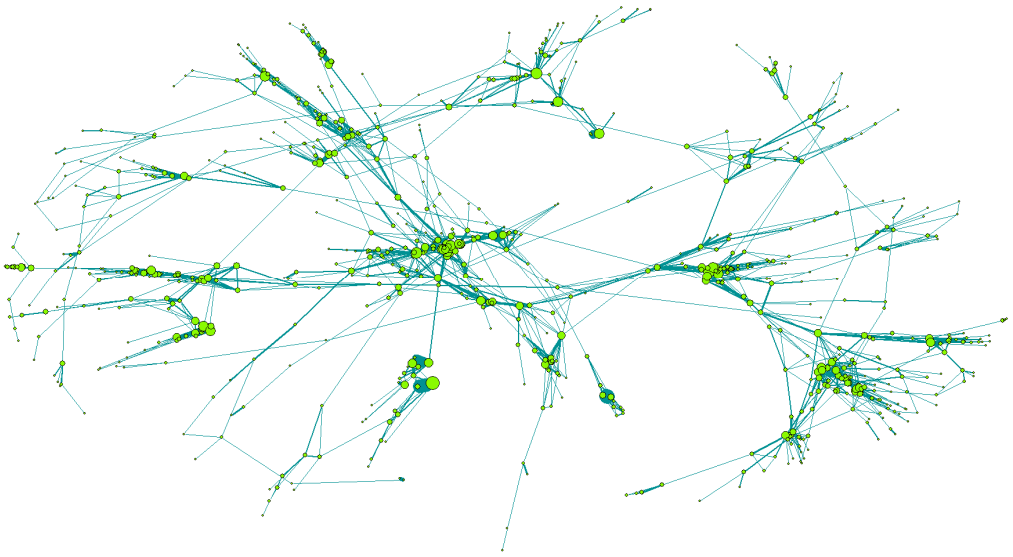
Figure 4. Network diagram of leading 5,500 patents in the hybrid car patent data set



This homogeneous data structure is relatively unusual in NPA analysis. For example, Figure 5 shows the network structure for the leading 1012 patents for a more mature engineering technology. The patents appear to be forming into ‘clusters’. Investigation of the subject matter of the patents in these clusters showed that each of the patent cluster represented a separate aspect of the technology. In this example the leading clusters referred to the

composition of the material used in the engineering process, and different elements of the design of the engineering equipment applied in this technology.

Figure 5. Network diagram of leading 1,016 patents in an engineering technology patent data set.



Subsequent experience with other NPA patent network structures is starting to suggest that the degree of homogeneity of an NPA patent cluster may be indicative of one or both of:

- The breadth of the patents included in the patent search, with a more uniform structure suggesting a narrower spread of technology.

  [It should be noted that the breadth of the search is an important factor to consider when analysing patents using Network Patent Analysis. Some clients like to use NPA to provide a high level landscape overview of a commercial area, i.e. to identify the key clusters, their subject matter areas, and the key patents and patent owners in these subject matter areas. This can be compared to how people might use a map of a country to identify the key cities. Other clients like to zoom into a tightly defined area. They already know which subject matter areas are important to them, and they are mainly interested in the key patents and patent owners. This can be compared to looking at the street map for a city to identify tourist highlights. In fact the NPA process allows both types of search; NPA can start with a high level overview, and then the client can select area(s) of interest to focus in on, to bring more detail of the structure into the picture. This process of looking at technology area at different scales can be compared to the process of using the zoom function in Google Maps; using higher degrees of zoom to bring in additional detail hidden at lower degrees of zoom.]

- The degree of technology ‘maturity’, i.e. whether dominant aspects of the technology have been able to emerge. The hybrid car space currently involves a variety of different solutions to the problem of how to build a hybrid car. A Toyota hybrid is different to a Honda hybrid, and both are very different to the way a Chevrolet hybrid works. While all three cars recapture energy normal lost during braking, the way that this energy is reconverted to mechanical drive is very different. Because of this, patent examiners may have been citing patents based on the problems to be solved (for example ‘how to build a hybrid car powertrain’) as well as based on the different solutions to this problem.

Both of these factors may have explained the homogenous network structure in the hybrid car patent network. Accordingly, in the future we would expect hybrid car patent data set to become more heterogeneous as dominant technologies emerge, and patent examiners become more likely to cite patents referring to similar solutions as well as similar problems.

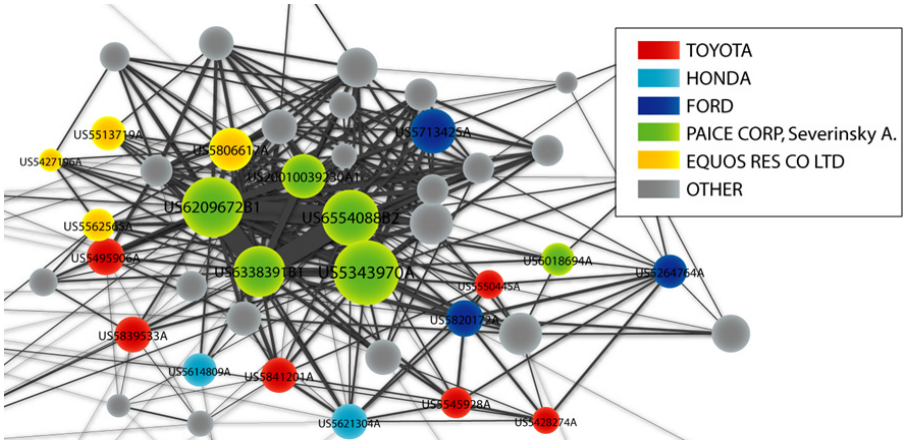
Section Summary – The relatively homogeneous NPA 'patent structure' within the area of hybrid car patents suggests that this area is still maturing, with dominant technologies yet to emerge.

What were the leading hybrid car patents?

If we continue to zoom into on the structures shown in Figure 4, and add patent numbers and colour coding for leading patent applicants, we end up with the very most central patents in this data set, shown in Figure 6. Of note, these patents appear to be dominated by patents filed by the car companies Toyota, Honda and Ford, and the technology suppliers Paice Corporation and Equos Research.

Some of the lines connecting these leading patents are thicker than others. A thicker line represents a stronger connection, as evidenced by the number of mutual citations, in the same way as the strength of a relationship between two colleagues can be partially predicted by the number of mutual friendships. These leading patents can also be represented in table form, Table 2.

Figure 6. Leading patents at centre of hybrid car data set.



NPA can also be used to list the leading patents filed by selected patent applicants. The ten highest ranked patents altogether are discussed in Table 2. The five leading patents filed by Paice are shown in Table 3, with the ten highest ranked hybrid car patents filed Toyota and Ford are given in Tables 4 and 5.

Table 2. Top ten hybrid car patents (all applicants) according to NPA analysis

NPA patent ranking	Patent number	Priority year	Summary of patented invention	Owner	# of forward citations	Ranking according to forward citation count alone	# of reverse citations
1	US 6,209,672	1998	Hybrid car with two electric motors, one connected to engine and one connected to car wheels	Paice Corporation	114	10	174
2	US 5,343,970	1992	Improved hybrid electric vehicle where both engine and electric motor power the car, and energy is capture via regenerative braking	Paice Corporation	256	1	37
3	*US 5,806,617*	1995	Control system for combining electric and motor power in transmission	Equos Research	103	14	18
4	US 6,338,391	1999	Electric motor coupled to turbocharged motor, and control system	Paice Corporation	30	280	185
5	*US 4,351,405*	1978	Engine driving one set of wheels, and electric motor partially powered by regenerative braking driving the other set of wheels	Hybricon Incorporated	142	4	15
6	US 5,428,274	1991	Control system for electric motor powered by internal combustion motor or battery	Toyota	33	238	23
7	US 6,554,088	2001	Hybrid only runs engine when high torque needed	Paice Corporation	49	115	216
8 =	US 5,264,764	1992	Controller for requesting an engine driven generator to top up the vehicle batter	Ford	70	51	18
8[4] =	US 6,470,983	1999	Controls battery level on hybrid drive according to navigation plans of drive	Hitachi	40	171	47
10.	US 6,943,460	2002	Control system for a hybrid car including cylinder deactivation	Honda	4	3374	21

Table 3. Top five Paice hybrid car patents according to NPA analysis

NPA patent ranking- (Paice ranking)	Patent number	Publication year	Summary of patented invention	# of forward citations[5]	# of reverse citations
1 (P1)	US 6,209,672	2001	Hybrid car with two electric motors, one connected to engine and one connected to car wheels	114	174
2 (P2)	US 5,343,970	1994	Improved hybrid electric vehicle where both engine and electric motor power the car, and energy is capture via regenerative braking	256	37
4 (P3)	US 6,338,391	2002	Electric motor coupled to turbocharged motor, and control system	30	185
7 (P4)	US 6,554 088	2003	Hybrid only runs engine when high torque needed	49	216
174 (P5)	US 20030217876	2003	Control of a hybrid vehicle so that the engine is only run under conditions of high efficiency	11	440

Table 4. Top ten Toyota hybrid car patents according to NPA analysis

NPA patent ranking –(Toyota ranking)	Patent number	Publication year	Summary of patented invention	# of forward citations[6]	# of reverse citations
6 (T1)	US 5,428,274	1995	Control system for electric motor powered by internal combustion motor or battery	33	23
12 (T2)	US 5,856,709	1999	Connection/clutch between engine and electric motor	64	17
16 (T3)	US 6,687,580	2002	Controller for switching between car engine and electric motor.	5	15
18 (T4)	US 5,841,201	1998	Control system for selecting both engine and electric motor drive	67	15
33 (T5)	US 5,839,533	1998	Controller for regenerative brake that applies normal brakes during heavy braking	81	22
35 (T6)	US 5,550,445	1996	Controller for determining when to charge the batteries	49	14
48 (T7)	US 5,495,906	1996	Controller for determining when to transmit engine power to wheels or generator	82	11
48 (T8)	US 5,545,928	1996	Controller for balancing engine speed and generator load	68	13
50 (T9)	EP 511,654	1992	Use of regenerated energy from braking to heat catalytic convertor	44	5
51 (T10)	US 6,563,230	2003	Controller for balancing the fuel injection for the engine and generator load	26	20

Table 5. Top ten Ford hybrid car patents according to NPA analysis

NPA patent ranking – (Ford ranking)	Patent number	Publication year	Summary of patented invention	# of forward citations[7]	# of reverse citations
8 (F1)	US 5,264,764	1993	Controls the engine used to recharge the battery for parallel hybrid vehicles	70	18
36 (F2)	US 5,713,425	1998	Hybrid powertrain that combines conventional engine and electric motors	119	17
58 (F3)	US 5,820,172	1998	Method of operating hybrid car to combine electric and engine drive to minimise fuel cost	81	24
76 (F4)	US 5,291,960	1994	Using surplus energy from regenerative braking to provide heat to car or occupants	131	14
89 (F5)	US 5,255,733	1993	Cooling system for hybrid vehicle that can preheat engine prior to startup	67	19
93 (F6)	US 5,345,761	1994	Use of electrical energy from braking or engine to heat catalytic convertor	73	13
120 (F7)	US 6,581,705	2003	Method for starting a parallel hybrid powertrain	14	22
124 (F8)	US 6,427,794	2002	Detects when a generator or electric motor has been demagnetized	7	15
127 (F9)	US 6,553,287	2003	Controller for a hybrid powertrain to deliver maximum acceleration	14	16
132 (F10)	US 6,196,344	2001	Controller for a hybrid powertrain	14	8

Section Summary – Paice Corporation filed the highest ranked patents within the hybrid car technology area, with Toyota, Ford and Honda also filing top 10 patents. The top ten patents filed by Paice, Ford and Toyota were reviewed and found to cover similar areas.

What can NPA tell us about litigation in the hybrid car technology area?

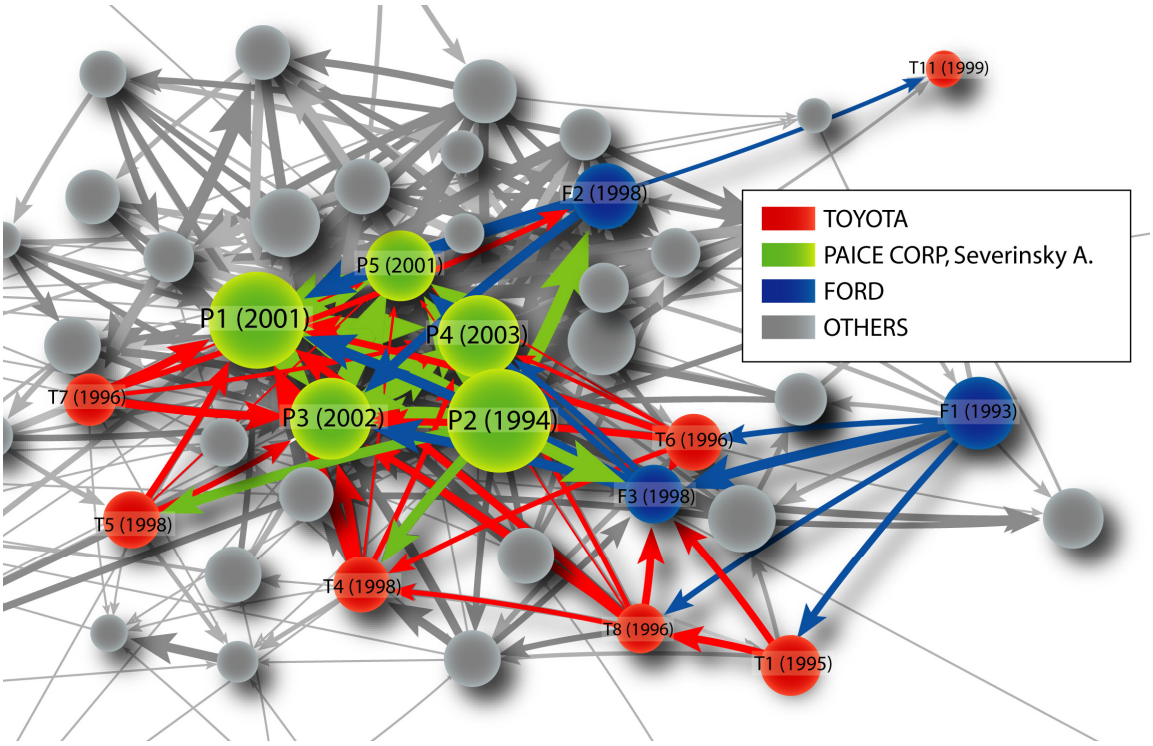
In 2007 the United States Court of Appeals for the Federal Circuit affirmed that Toyota had infringed the Paice US patent 5,343,970 patent, which as previously discussed was the #2 ranked patent in our dominant patent list.

A question that has been asked of us is why Toyota was found to infringe the #2 ranked Paice patent (according to NPA) and not the #1 patent. The first and original answer to this question is that any patent ranking system, whether objective or subjective, can only ever be an estimate and the ranking needs to be considered as a starting point for further analysis. In this light, the #2 position for the Paice patent still provides solid support for the performance of NPA.

The second and more recent answer to this question is that NPA does, in fact, predict that the #2 Paice patent is the more likely Paice patent to be infringed by Toyota.

This can be explained by considering Figure 7 below. In this diagram, patent colors refer to different patent owners, but only for Paice, Toyota and Ford. The label on each patent refers to its rank within the portfolio of an owner and the publication date. For example P1 (2001) refers to the number 1 ranked hybrid car patent within the Paice portfolio, which was published in 2001.

Figure 7. Leading patents at centre of hybrid car data set, but with arrows shown to indicate the direction of technology 'flow'.



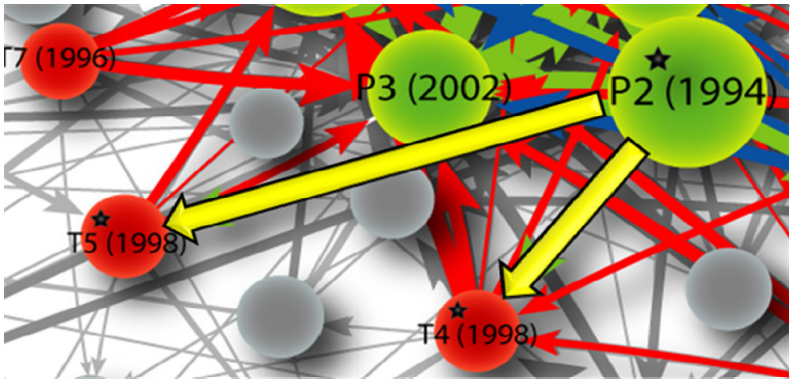
Note that arrows have replaced lines between patents linked by citations. The lines point from an earlier patent to the later patent that cites it, i.e. toward the forward citations for this earlier patent. While it can be difficult to prove outside of litigation, it is possible that a later patent applicant benefited from the knowledge disclosed by the earlier patent applicant, either indirectly (e.g. via publication of the inventions as new products or in the media), or more

directly by reading the patent application. This can be regarded as an apparent 'technology flow'. Technology flows can also be seen between earlier and later patents filed by the same applicant, and are likely to be actual technology flows as the patent owner applies knowledge from the earlier invention to the later invention.

Technology flow can also be used as a simple predictor for patent infringement; a later patent applicant may possibly be using the invention disclosed by the earlier patent applicant to apply the invention claimed by the later patent, and so may, subject to the normal subjective analysis, need to take a license to use the earlier patent. The idea of using forward citations as the basis for infringement analysis is already known in the field of patent analysis. However, NPA empowers this concept by identifying the strong relationships (thicker lines) between higher ranked patents filed by the companies being investigated. Higher ranked patents are more likely to be more important inventions, and hence are more likely to be commercialised by the patent owner. This allows the infringement analysis to focus in on the most likely infringements. In practice a patent owner can be provided with a list of patents owned by an licensing target in an approximate order of potential likely importance of infringement (i.e. which potential infringements to investigate first).

This principle is seen very clearly in Figure 8. The P2(1994) [US 5,343,970] patent filed by Paice Corporation has arrows pointing towards the T4 and T5 patents filed by Toyota, both published in 1998, suggesting an apparent 'technology flow'. These arrows are highlighted in Figure 8, which shows an extract from Figure 7.

Figure 8. Suspected technology flows between the P2 Paice patent, and the T4 and T5 Toyota patents.



From Tables 3 and 4, we know that these patents cover very similar technologies, Table 6.

Table 6. Comparison of the subject matter of leading Paice and Toyota patents

Patent applicant	Applicant NPA patent raking	NPA patent ranking	Patent number	Publication year	Summary of patented invention
Paice	2	2	US 5,343,970	1994	Improved hybrid electric vehicle where both engine and electric motor power the car, and energy is capture via regenerative braking
Toyota	4	18	US 5,841,201	1998	Control system for selecting both engine and electric motor drive
Toyota	5	33	US 5,839,533	1998	Controller for regenerative brake that applies normal brakes during heavy braking

It is also worth noting the Paice P1 and P3 patents are receiving an apparent technology flow from a number of the Toyota patents (T4 to T8), suggesting a) a potential infringement risk for Paice Corporation, and b) that these Toyota patents may be relevant prior art to P1 and P3.

Both suggestions would require a subjective patent attorney review to confirm these findings. It is also worth noting that Paice Corporation is not selling hybrid drive-trains, making this potential infringement much less likely in practice.

Paice has also asserted its P2 patent against Ford in May 2010[8], but the parties settled on confidential terms in July 2010[9]. Of note, P2 has solid green lines pointing to Ford patents F2 and F3. Conversely, Ford patents F2 and F3 have arrows pointing to Paice patents P1 and P3, but once again Paice may avoid infringement issues by not selling hybrid drive trains.

In 2005[10] Ford signed a license agreement for about 20 hybrid car patents held by Toyota, in return for Toyota licensing technologies for 'nitrogen oxide emissions control, variable valve timing, and direct injection spark ignition from Ford'. The fact that Ford chose to take a license from Toyota for their hybrid car technology is supported by Figure 8, which shows arrows pointing from Toyota patents T1, T6, and T8 to Ford patent F3. There is also an arrow pointing between Toyota patent T7 and Ford patent F2.

On the other hand, there also appears to be a citation relationship between Ford patent F1 (engine control for hybrid cars), and Toyota patents T1 (control system for electric motor for hybrid cars), T6 (controller for determining when to charge the batteries) and T8 (controller for balancing engine speed and generator load). There is also a weak arrow flowing from Ford patent F2 to Toyota patent P11 (US patent 5,873,426, which discloses the principles of altering gear ratios when running in hybrid or non-hybrid modes).

Section Summary – NPA was able to show that relationships between leading patents filed by Paice Corporation, Ford and Toyota were consistent with patent litigation and publicly available licensing agreements between these companies. For example, NPA showed how Paice's successfully asserted US patent US 5,343,970 had strong citation relationships with leading hybrid car patents filed by Toyota and Ford.

Can NPA be used to show apparent technology flows between patent applicants?

NPA can be used to show the similarity between patents filed by different companies. This can in turn can be used to suggest 'apparent' technology flows in and out of companies. Many innovators will recognise that invention does not happen in a vacuum, and instead inventors learn from earlier inventions, whether filed by the inventor itself, their employer, or other companies. New inventions often inspire later inventions, whether filed by the same or other companies. Since the patent literature can be regarded as a record of inventions, it is possible to use NPA to review the patent literature to determine where inventions might have come from, and where they went to.

It should be noted that this analysis, while suggestive of similarity in the patents (and hence underlying inventions) filed by different companies and hence apparent technology flows, cannot confirm such flows. In practice it may be impossible to prove if Company A learnt from Company B, no matter how strongly that patent data may suggest this. However technology flow analysis may suggest where to look for such 'cross-pollination'. It should also be noted that technology flows may be of more than academic interest, and may have practical value in suggesting possible infringement risks, in close conjunction with a full legal review.

This concept is best shown by way of example. In this analysis, NPA was used to perform the following analysis:

a) The ten highest ranked patents for Ford, Toyota and Paice were determined;

b) All direct citations (forward and reverse) citations were counted;

c) The strength of these citation linkages were determined by determining the number of mutual citations between these top patent and their citations;

d) The above data was used to suggest which companies had the strongest influence on the Ford, Toyota and Toyota patents, and in a separate analysis which companies were most influenced by Ford, Toyota and Paice.

e) Steps b) to d) were repeated for the successfully asserted Paice patent US 5,343,970, to see which companies had filed the most similar earlier and later patents.

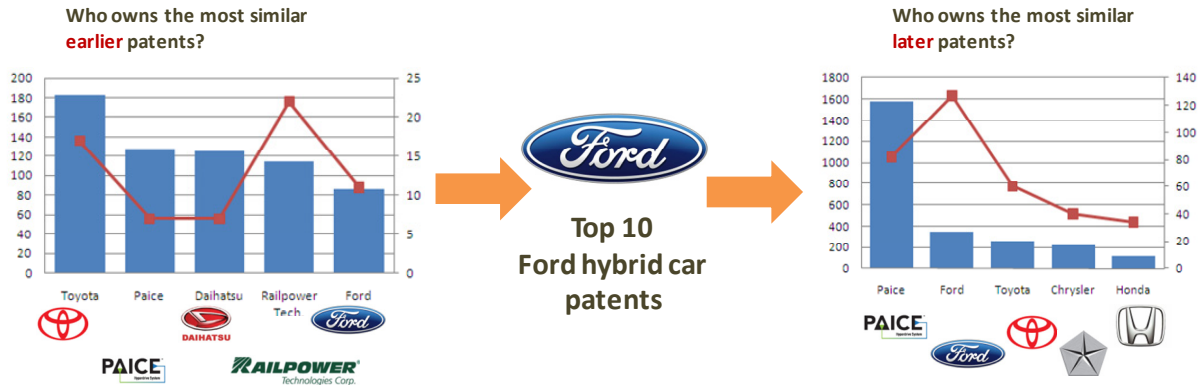
This process is illustrated by considering the results, shown in Figures 9a to 9d.

Top 10 Ford hybrid car patents

The top ten Ford hybrid car patents appeared to have had the strongest influence from Toyota patents, followed by patents filed by Paice, Daihatsu, and then Railpower Technologies, a developer of hybrid technologies for trains, Figure 9a. Ford patents (via self-citations) were the fifth strongest source. The relatively low position of Ford self-citations suggests that the later Ford patents were not heavily based on earlier Ford patents.

Paice patents were by far the dominant citer of the top ten hybrid car Ford patents, ahead of self-citations by later Ford patents, Toyota, Chrysler and Honda.

Figure 9a. Most similar earlier patents (reverse citations) and later patents (forward citations) for the top 10 Ford hybrid car patents



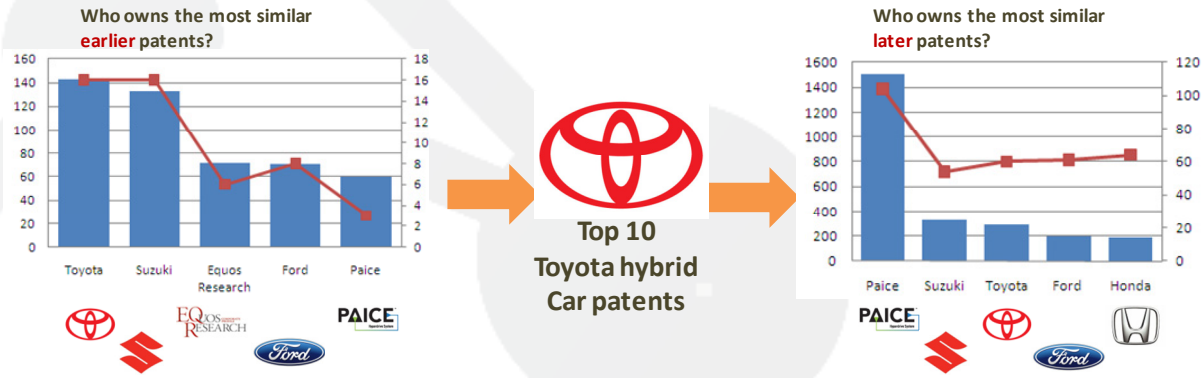
Blue bars = Total Citation Relationship Strength (left hand axis)
Red line = Number of citation linkages (right hand axis)

Top 10 Toyota hybrid car patents

Self citations were the strongest apparent technology source for the top ten Toyota hybrid car patents, just ahead of patents filed by Suzuki, Figure 9b. Patents filed by Equos Research, Ford and Paice were also similar to these top ten Toyota hybrid car patents.

Paice patents were by far the dominant citer of the top Toyota hybrid car patents, ahead of patents filed by Suzuki, self-citations from Toyota, and then Ford and Honda.

Figure 9b. Most similar earlier patents (reverse citations) and later patents (forward citations)) for the top 10 Toyota hybrid car patents



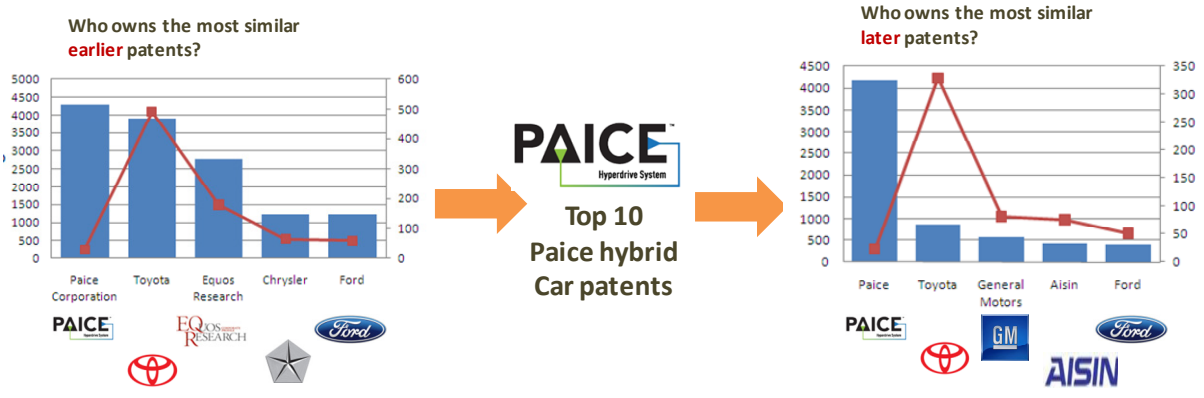
Blue bars = Total Citation Relationship Strength (left hand axis)
Red line = Number of citation linkages (right hand axis)

Top 10 Paice hybrid car patents

The citation relationship strength data suggests that earlier Paice patents (self-citations) were the leading source of technology for the top ten Paice hybrid car patents, ahead of patents filed by Toyota, Figure 9c. Chrysler patents (filed prior to the 1988 purchase of Chrysler patents by Daimler Benz) patents also appeared to have a strong apparent influence on Paice patents.

Paice (again by self-citations) was the company whose later patent most strongly influenced by the top ten Paice patents, ahead of patents filed by Toyota, General Motors, Aisin (a supplier of vehicle components) and Ford. It is worth noting that while a disproportionate number of later Toyota hybrid patents had Paice patents as nominated prior art, this large number of citations was not fully reflected in the citation relationship strength data. This may been because while the average individual strength of these citation linkages was comparatively low.

Figure 9c. Most similar earlier patents (reverse citations) and later patents (forward citations) for the top 10 Paice hybrid car patents

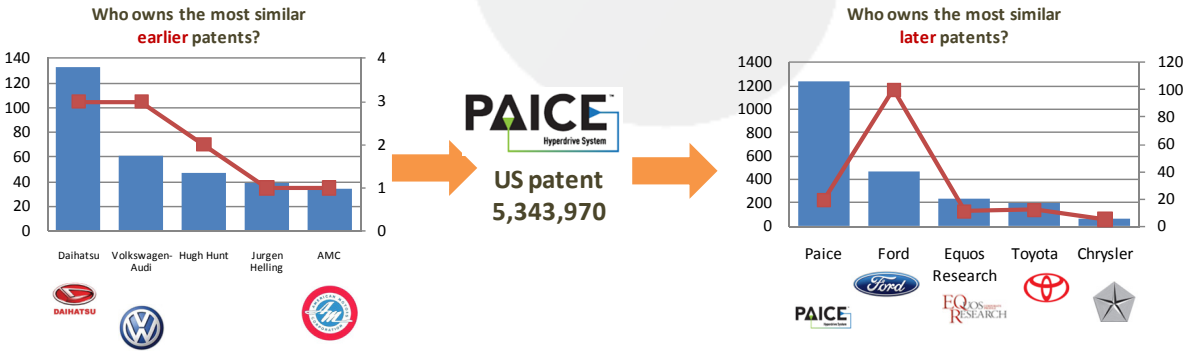


Blue bars = Total Citation Relationship Strength (left hand axis)
Red line = Number of citation linkages (right hand axis)

Paice patent US 5,343,970 (successfully asserted against Toyota)

Earlier patents filed by Diahatsu and Volkswagen-Audi were thought to be the most similar to the Paice patent US 5,343,970, Figure 9d. There was a strong self-citation similarity from later Paice patents, with Ford, Equos Research and Toyota owning the next most similar patents. It is also worth noting that the quality and the relationship strengths of the forward citations is a lot higher than for the reverse citations, showing that this patent had a major influence in this field.

Figure 9d. Most similar earlier patents (reverse citations) and later patents (forward citations) for the successfully asserted Paice patent US 5,343,970



Blue bars = Total Citation Relationship Strength (left hand axis)
Red line = Number of citation linkages (right hand axis)

How do Paice, Ford and Toyota compare?

The above data also suggests that both the total number of citation linkages, and the total citation relationship strength values, are much higher for the top ten Paice hybrid car patents than for the top 10 Ford and Toyota hybrid car patents. This is confirmed in Figures 10a and 10b below, which show the total number of citation linkages, and the total citation linkage strength, for the top ten hybrid car patents filed by each of Paice, Ford and Toyota.

Figure 10a. Comparison of the total number of citation linkages for three leading hybrid car patent applicants

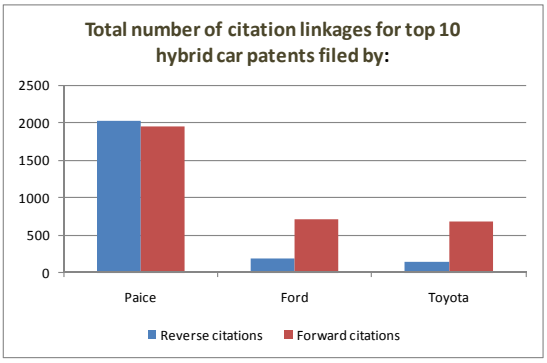
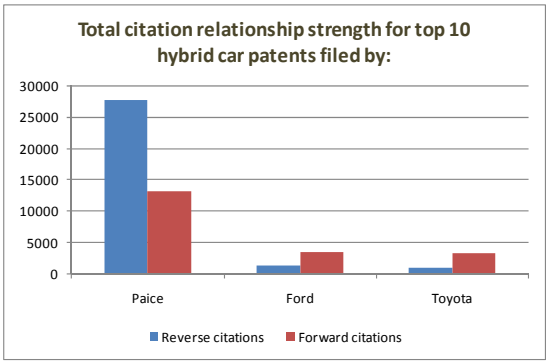


Figure 10b. Comparison of the total strength of citation linkages for three leading hybrid car patent applicants



Figures 10a and 10b can be interpreted as:

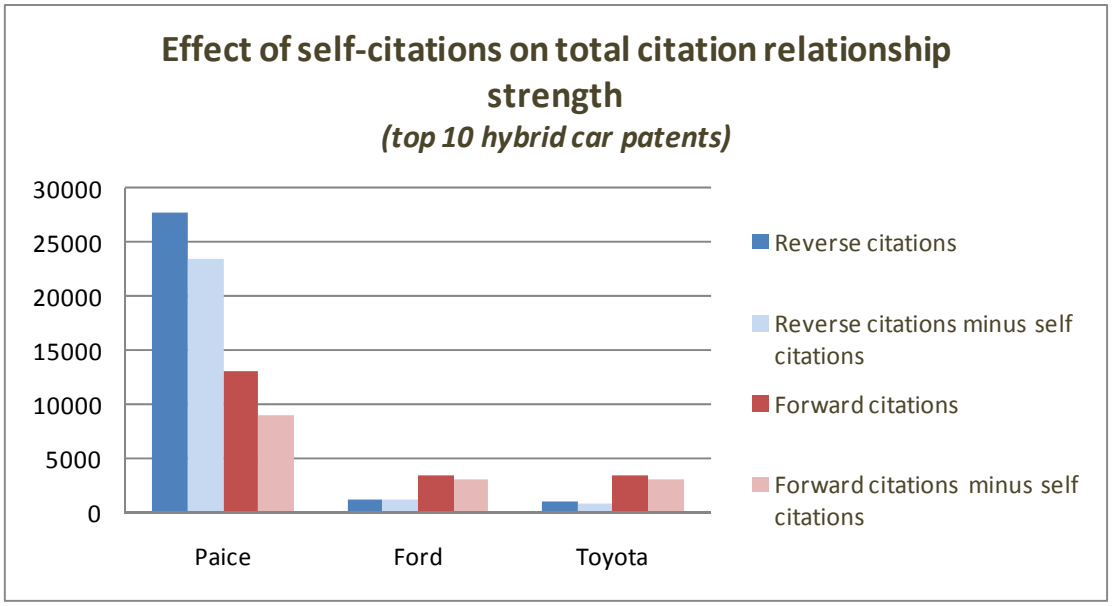
- The top 10 Paice hybrid car patents have a very high number of both reverse and forward citations compared to the top ten Ford and Toyota patents. It is possible that a high

number of reverse citations suggests that a patent applicant has disclosed a high number of known citations to the patent examiners (applicants for US patents are required to disclose all known prior art documents). However, a patent applicant has only limited control over the number of forward citations to its patents, apart from the later patents it files itself (and Paice only filed 28 patents in total in the hybrid car field). Therefore the strong dominance of the Paice patents in the citation data set is likely to be real, and indicate that the examiners or applicants for later hybrid car patents thought that the top ten Paice patents were relevant to these later patent applications.

- The top ten Paice hybrid car patents, unlike the top ten Ford and Toyota patents, have lower number of forward citations and a lower forward citation strength than the equivalent value for reverse citations. This suggests that the top ten Paice hybrid car patents were either rigorously examined, or Paice supplied a large number of known prior art citations as part of the examination process.

Because the Paice patents had such strong citation linkages, and appeared to be strongly inter-connected to other Paice patents, we also checked to see what effect self-citations had on the total citation linkage strengths. We did this by removing data related to self-citation linkages from the citation relationship strength data. Figure 11 shows that while removing self citation linkages did reduce the citation relationships strength values as expected, the remaining citation relationship strength data for the Paice top ten patents, was still very high compared to the same values for Ford and Toyota patents. This applied to both reverse and forward citations.

Figure 11. Effect of self-citations on the total strength of the citation linkages for the top 10 hybrid car patents filed by Paice, Toyota and Ford.



Section Summary – NPA was able to show apparent technology flows (and by implication similarity) in and out of the top ten patents filed by Paice, Ford and Toyota. As examples of what could be shown in these analyses, the top 10 hybrid car Paice patents were highly interconnected, in contrast to the top 10 hybrid car patents filed by Ford which were connected via citations to a variety of companies including Paice, Toyota, and Railpower Technologies were developed hybrid technologies for trains. Toyota's top 10 hybrid car patents showed a strong citation relationship to patents filed by Suzuki.

How do different patent applicants compare over their entire portfolio?

NPA has the capability to directly and objectively compare patent owners by the strength of their portfolio. This comparison considers relative strength of the patents in each portfolio by the strength of the citation links of the patents in each portfolio. Only patents with known citation links to other citation links are considered in this analysis

Table 7 below shows that, not surprisingly, Toyota had the dominant patent portfolio. Toyota was assigned a relative dominance index of 100, and the other patent owners were assessed in comparison to this. Of note, Honda has a dominance score of 71, or more than two thirds of Toyota's dominance score, despite having less than half the number of patents. Nissan had a lower dominance score than Honda despite having more patents, and only just ahead of the dominance score of Ford despite having twice as many patents as Ford. For Ford to achieve a dominance score of 60% of that of Toyota despite having less than one quarter of the patents suggest that Ford may be filing patents that may be relatively stronger than the patents filed by Toyota.

Table 7. Relative ranking of patent applicants according to NPA analysis

Rank	Patent owner	NPA Relative dominance index*	Number of patents in NPA data set	NPA ranking of 3 leading patents	Summary of highest rated patented invention
1	Toyota	100	3635	6, 12, 16	US 5,428,274 (1995) Control system for electric motor powered by internal combustion motor or battery
2	Honda	71	1435	10, 23, 26	US 6,943,460 (2002) Control system for a hybrid car including cylinder deactivation
3	Nissan	62	1644	31, 60, 67	US 6,732,526 (2004) Hybrid automatic transmission
4	Ford	60	809	3, 36, 58	US 5,264,764 (1993) Controls the engine used to recharge the battery for parallel hybrid vehicles
5	General Motors	23	428	46, 65, 78	US 5,935,035 (1999) Electric motor combined with gears
6	Peugeot-Citroen	22	255	107, 1146, 1206	US 4,187,436 (1980) Controls generator on hybrid vehicle
7	Hitachi	21	393	8, 138, 174	US 6,470,983 (1999) Controls battery level on hybrid drive according to navigation plans of drive
8	Volkswagen-Audi	20	127	28, 78, 145	US 4,533,011 (1985) Uses electric motor as flywheel for engine
9	Paice Corporation	18	28	1, 2, 4	US 6,209,672 (2001) Hybrid car with two electric motors, one connected to engine and one connected to car wheels
10	Renault	16	209	230, 288, 342	US 6,751,960 (2004) Controls engine speed to reduce overheating of hybrid transmission

There is a big jump back to the remainder of the patent applicants. Of note is Paice Corporation, with a dominance score of 18 despite having just 28 patents in this analysis. This shows the effect of having four out of the ten top patents in the entire patent list.

Section summary – Toyota had the strongest patent portfolio, followed by Honda and Nissan. However the comparative dominance of the patent portfolios did not always reflect the comparative size of the patent portfolios, with both Ford and Paice Corporations having spatent portfolios stronger than their relative size would suggest.

Acknowledgements

The hybrid patent data analysed in this white paper was supplied by the Information Services Group of Griffith Hack, who have worked closely with Ambercite to help develop the NPA process. Griffith Hack sourced the hybrid car patent data from the core patent collections available through Thomson Innovation which is provided by Thomson Reuters.

References

[1] Hybrid car patents were searched by looking for all patents in which the words 'hybrid' and 'car' were within three words of each other in the body of the patent.
[2] Figures 1 to 3 were sourced from the earlier Griffith Hack report on hybrid car filings, Lloyd, M and Blows, J.; 'Who holds the power? Lessons from hybrid car innovation for clean technologies'; Griffith Hack White Paper October 2009, found at www.griffithhack.com.au and www.ambercite.com
[3] Ambercite™, Network Patent Analytics™, NPA™ and Next Generation Patent mapping™ are trade marks of Patent Analytics Holding Pty Ltd. Components of the processes used to perform Network Patent Analytics are the subject of patent applications filed in the United States and elsewhere.
[4] The final NPA ranking is the combination of two separate proprietary ranking algorithms, which look at different aspects of the connection of the patent to the patent network. Because of this, it is possible to have an equal ranking for two patents. Alternatively, the two different rankings can be considered separately for specific applications, i.e. infringement analysis. Please contact us directly for more information on these advanced applications.
[5] At time of the 2009 NPA analysis – this number may have increased since this study. However we will list the 2009 figure to show that the NPA ranking of a given patent does not depend entirely on the forward citation count.
[6] At time of the 2009 NPA analysis – this number may have increased since this study. However we will list the 2009 figure to show that the NPA ranking of a given patent does not depend entirely on the forward citation count.
[7] At time of the 2009 NPA analysis – this number may have increased since this study. However we will list the 2009 figure to show that the NPA ranking of a given patent does not depend entirely on the forward citation count.
[8] Case 5:10-cv-00092-DF Document 1 Filed 05/07/10, found at http://greenpatentblog.com/__oneclick_uploads/2010/06/paice-ford_complaint.pdf on 26 November 2010.
[9] http://www.prnewswire.com/news-releases/paice-and-ford-reach-settlement-in-hybrid-vehicle-patent-infringement-disputes-98646969.html, found at 26 November 2010.
[10] http://www.allbusiness.com/professional-scientific/scientific-research-development/775458-1.html, accessed at 26 November 2011.