A NEW SEMANTIC TEXT-IMAGE SEARCH ENGINE FOR CAR DESIGNERS

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ABSTRACT

The Trends Research ENabler for Design Specifications (TRENDS) system integrates flexible content-based image retrieval facilities with database management and other useful functionalities that aim at improving the inspirational information gathering process in the early design stages. TRENDS is a 6th Framework Programme IST project, funded by the EC that started 01/01/2006 and will end 31/12/2008. It aims at elaborating the design trend boards dedicated to product designers in business to consumer markets such as for the automotive and original equipment manufacturers. The main innovation is related to the content based image and semantic text information search engines and to the integration of the elements under a cutting edge user interface specially designed to fulfill the designers’ requirements.

1. INTRODUCTION

Designers use a large variety of types of sources coming from different areas as comparable designs, other types of design, images of art, beings, objects and phenomena from nature and everyday life. Sources of inspiration are an essential base in design thinking. In favorable contexts, designers built trend boards in order to structure their inspiration sources. Trend boards offer a visual and sensorial channel of inspiration and communication for design research and development. They are usually a collection of images compiled with the intention of communicating or provoking a trend or ambience during the product design process.

As a routine part of the creative process product designers search for and collect materials that they find inspirational. They get their inspiration in their personal life and through a more focused way in their professional life, in various sources like specialized magazines, bibliography, material from exhibitions and the web. They deal with this visual information individually and/or collectively through complex cognitive processes. Traditional manual approaches showed some shortcomings, they are very time consuming and do not provide exhaustive results. Sometimes they use commercialized image search engines but the results provided are still not adequate because of the semantic gap inherent to this kind of tools. This problem is particularly of great importance. Indeed a core activity of a designer when selecting inspirational materials is the use of high level information like semantic adjectives in order to link words with images and vice-versa. When they are searching for inspiration sources, pictures they select explicitly or mentally often have a high emotional impact. In this way, the keywords used by the designers are mainly semantic adjectives.

In this paper we propose a new system which enables to partly support the informational and inspirational process, especially where the computer can provide an added value and in some way the web. This interface is aimed to improve designers’ access to web-based resources, helping them to find appropriate material, to structure this material in ways that support their design activities and identify design trends. The Trends Research ENabler for Design Specifications (TRENDS) integrates flexible content-based image retrieval facilities that utilize ontological referencing, and software able to realize main procedures relating to Conjoint Trends Analysis, i.e. the ambience identification and formalization and the pallets generation. The developed interface is being built after the formalization of the cognitive processes of the car designers, end users of this project.

2. THE CONJOINT TRENDS ANALYSIS METHOD

Few issues until now in the discipline of design science were specifically centered on the design information phase. The information phase of cognitive design activity was studied and formalized in order to define the Conjoint Trends Analysis (CTA) method [1][2]. The Conjoint Trends
Analysis method was created after a study of the designer’s cognitive activity. CTA makes it possible to enrich and to inspire the designers when designing a new product. It takes place in the early phases of the design process following the steps shown in next figure.

CTA enables the identification of attributes linked to particular datasets (e.g., common properties of images in a database) so that they can be used to inspire the early design of new products. CTA results are trend boards that represent sociological, chromatic, textural, and shape related trends. The trend boards communicate identified homogeneity in terms of style and consumers’ sociological values. They are mainly based on visual information, and result from the frequent occurrence of certain properties within a dataset. From this analysis, images and relevant words are selected and formalized under the form of ambiences. Ambiences are typical representations where the emotional impact is intended to be high. Global and discrete design elements are then extracted from these ambiences under the form of pallets. These design elements are used for the generation of new design solutions. Trend boards offer a relatively exhaustive representation of the references usually used by the designers for their composition and play an important role in stimulating idea generation while anchoring contextual matter [3].

Another purpose of the trends analysis is to define user-convenient principles and solutions that can be integrated in future products. Indeed designers often have to provide new designs using insufficient information about consumers. Trend boards show ambiences including people in context. Contexts are decisive in the attribution of a signification to the object. The fact that the concept is in harmony with its context adds not only to its merely semantic contribution but also to its aesthetic contribution.

The trend boards constitute a visual synthesis of many sources of inspiration, enriching the generation of design solutions. This synthesis plays a major role in design, especially for the innovative side of the to-be-designed products. The information that is integrated in the trend boards encompasses images and keywords.

In the Conjoint Trends Analysis, current activity of information research integrates routine tasks which are manually and intuitively done. Some of them are laborious, time consuming, and provide incomplete results. The design watch activity, as it is done for the technological watch, is never exhaustive. However the aid of computerized tools from the Web resource could allow a significant optimization of certain phases in the Conjoint Trends Analysis.

3. TRENDS SYSTEM

TRENDS system aims at being an inspirational tool for the designers that can carry out in an automatic mode the functionalities they require in daily work, as they have been described in previous sections and that are mostly gathered in Conjoint Trends Analysis method.

The key and innovative function of the system is the mixed semantic text and image search component, as element that will provide with the inspirational images according to a content based retrieval process where image processing descriptors (color, shape and texture), text indexing and ontologies are combined. The retrieved images are possible to be shared, moved to the desired collections, displayed in 4 different available ways, zoomed in or out and reused for further fine tuning. Another unique feature in TRENDS is the possibility of selecting the sectors where the images come from. The specific database will be later described.

The relevance feedback functionality is also an important added value of TRENDS tool. This is, once the user has received the first batch of retrieved images, he can indicate the system which results fulfill his expectancies, i.e. which ones are more suitable to his preliminary idea. It is possible to select those ones not fitting at all with the idea. With this information about the feeling of the users, the system carries out a tuned search. It is possible to carry out as many tuned searches as wanted.

Other interesting functionalities are the pallets (for colors and textures) and ambience boards’ automatic generation, performing much faster a traditionally manual task. Clustering of images in different groups is also possible, as well as the obtaining of statistical data, such as the number of images containing a certain feature related to their origin sector. All these functionalities are wrapped under a cutting edge user interface that provides, together with the advanced solution, the user oriented pleasant elements. Both the design and development have followed a careful iterative process supported by the end users.

4. SYSTEM ARCHITECTURE AND COMPONENTS

In order to achieve this ambitious software tool, it is necessary to think of a proper architecture. It seems clear that there will be several servers that will perform the heavier computing tasks and a client side. With such a
graphically advanced user interface, it was not possible to design a web-based system. Other requirements for the application were the light client side, the fast interaction with the interface, the advanced graphical elements, and the scalability of the system. All these requirements led to a client–server architecture that is shown next.

![Fig. 2. TRENDS system architecture](image)

All the communications between TRENDS servers and client-side Human Machine Interface (HMI) will go through the Request Management Server (RMS) via HTTP request. This RMS distributes the queries between the text and image servers. Every server accesses to its proper indexes generated from the database automatic indexing separate processes. The text indexes are also ranked according to an ontology tagger. This RMS acts as a Fusion Search Engine, able not only to distribute the query between the servers but to act as a fusion element able to joint together and to provide the new ranked results coming from the two search engines. Specific algorithms have been developed for this fusion purposes.

At the moment, the first interactive version of TRENDS system is available, and referred as prototype 2. This prototype 2 has been tested by the end users and these first tests results will be shown in section 7. The functionalities available in this prototype are:

- Search: query by text (semantic adjectives are possible to be inserted), query by image (descriptors color, shape and texture), query by both text and image, relevance feedback.
- Display options: mosaic, one by one, big and small.
- General handling: drag and drop, access to properties of images, storage in personal collections.

During the last third year of the project, the final version of the interface (containing the feedback obtained from the end users in the tests sessions) is being developed and it will also include the advanced remaining functionalities.

A permanent work is conducted to improve the protocols, to reduce the weight of the exchanges, and to make them more efficient and less bandwidth consuming.

### 5. CONTENT BASED MIXED TEXT AND IMAGE SEARCH ENGINE

The core of the system is the content based mixed text and image search engine. The Request Management Server distributes the queries between the image search engine and the text search engine. At the same time, it is capable of merging the results retrieved by any of them and to rank them according to a specific fusion algorithm. The system is able to perform queries by text, queries by image, and mixed queries with both text and image. The image descriptors are color, shape and texture.

The retrieved images will come from the TRENDS database, not from internet. A detailed description of the single elements constituting the content based mixed text and image search engine is given next.

#### 5.1. The database

The database for the system has been specifically designed and generated for the end users of the project, i.e. the cars designers. The aim of this database is to group together the inspirational material that the designers may use. In order to achieve this, the different sources of inspiration of the designers have been identified, such as magazines, websites, etc. These links have been classified into different sectors of influence, such as fashion, automotive, sport, etc. The database has been widely improved by grabbing fifteen sectors. The evolution of the statistics for the database is presented in the following table. The grabbing for the last version of the database has begun and will be completed by the end of the third year.

<table>
<thead>
<tr>
<th>Sector</th>
<th>grabbed during the second year</th>
<th>last version grabing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fashion</td>
<td>5 sectors</td>
<td>15 sectors</td>
</tr>
<tr>
<td>Automotive</td>
<td>5 sectors</td>
<td>10 sectors</td>
</tr>
<tr>
<td>Sport</td>
<td>5 sectors</td>
<td>10 sectors</td>
</tr>
<tr>
<td>Reviews</td>
<td>5 sectors</td>
<td>10 sectors</td>
</tr>
<tr>
<td>Magazines</td>
<td>5 sectors</td>
<td>10 sectors</td>
</tr>
<tr>
<td>Websites</td>
<td>5 sectors</td>
<td>10 sectors</td>
</tr>
<tr>
<td>Total</td>
<td>30 sectors</td>
<td>50 sectors</td>
</tr>
</tbody>
</table>
The table shows that the filtering process removed 87% of the text and only 26% of the images resulting in a more efficient index. In the last months major improvements have been realized to automate the grabbing and filtering processes. New tools have been implemented thus improving the robustness, the error recovery, and providing statistics. Moreover, the last version of the grabber is able to process flash websites which was missing in the previous versions.

5.1. The text search engine

By using web pages, we can get a lot of information from the textual content linked to the images. For each image, the textual indexer abstracts the text surrounding the image. The system semantically expands the words to enlarge the search possibilities. It also tags with an ontology dictionary named ONtoROXML and a list of semantic concepts defined by semantic adjectives.

5.1.1. Adapted semantic indexation

The text search engine is a semantic search engine that includes a semantic module in the indexation process. When indexing, the system uses the parent page of the image. In order to improve the accuracy of the search, the system tests led to this evolution only the text surrounding the image is indexed. For the same reason, the name of the image is indexed with a specific weight that has been tuned to match the users’ needs. The indexation phase includes pertimmizers (see below) from semantic adjectives, ontology tags (see below), metadata from the images and the user comments with the usage of the system.

5.1.2. Ontology tags

The Ontology tagger analyses the Web documents in the collection and assigns ontology tags to them. The ontology tagger first parses the web documents from the collection and extracts text from the HTML code. It then calculates statistics such as word frequency, frequencies of occurrence of ontology categories that the words belong to, and compares these statistics with the statistics for the whole collection, and then it assigns ontology tags to these documents. Finally, the result is transferred to an XML file to be used as an input to the Pertimm Indexer. The ontology tags are used at search stage.

5.1.3. Pertimmizers

“Pertimmizers” are a set of words or phrases which may be linked by topological relations but generally are not. These words and phrases are simply what a computer can “know” as of today and it must be obvious that, when time comes, “Pertimmizers” will contain whole descriptive sentences that would be “understood” by the computer.

Of course, the system will not look for documents containing all of these words, as this is doomed to fail, it looks for paragraphs which contain the largest number of corresponding terms (corresponding meaning, lemmas, synonyms, translations, etc.). Pertimmizers can also be seen as a way of classifying documents.

In this project, semantic adjectives are interpreted as pertimmizers and compiled to enhance the semantic value at the indexation stage. It improves the results at search stage.

5.1.4. Semantic search

The search process benefits from all the data gathered at indexation time. It also provides the user complements to refine its request. These complements can be provided before the search, when the user types the words of the request or after the search being then filtered/oriented by the results. The following schema illustrates this.

5.2. The image search engine

An important part of the TRENDS system is the Image Search Engine (ISE) that can index and keep up to date a list of web sites and other related visual material specific to the automotive industry in particular, but also to other sectors of influence for the designers, such as architecture, aeronautics, fashion and art in general. The main objective is entirely visual, i.e. the purpose of a search session is to find images illustrating a query subject. From this perspective, the system registers itself into the mainstream
The Image Search Engine is the software component that addresses issues linked to the extraction of information from the raw images (visual indexing) and querying of the image descriptors (visual search). Using the database implies two distinct operations: indexing and querying. The indexing module extracts all relevant visual information from the images and generates the “image signatures” (also called “feature vectors” or “visual descriptors”). This operation is done only once and can be performed offline. After the indexing, the resulting descriptors can be employed to perform queries and return the results. The user composes his/her query and the query module searches the database and returns a selection of results. This is an online operation and long query times are penalizing since the user will not wait more than a few seconds to have the results.

The indexing module takes all images, one at a time, and compute from them several descriptors based on the global visual characteristics, i.e. color, texture and shape. The descriptor is a fixed sized vector in the \( n \)-dimensional Euclidian space. Thus, indexing is an operation that associates to each image an \( n \)-dimensional vector that represents the visual content of the image from a given perspective (i.e. color, texture and shape).

More involved image descriptors, such as local descriptors based on characterization of image region or a different category of points of interest, are reported in the literature to offer good results on some database, but because they require intensive resources and computing time, their use are restricted to small databases [5]. The size of the TRENDS database will grow to more than 1,000,000 images, thus the constraints imposed are very difficult: visual descriptors should have a low memory/space impact and should be very fast to compute and to use.

The descriptors we extract are as follows: (1) colour histogram in the HSV space (color); (2) histogram weighted by the Laplacian (emphasizes regions in an image that are likely to contain edges and contours) and histogram weighted by color probability (emphasizes regions that are more likely to contain interesting objects and entities); (3) Hough histogram (shape): this descriptor projects the local flow of pixels on a referential quantized by angle and by distance - it is based on the Hough Transform and it gives an overall description of the shape structures in the image; (4) Fourier histogram (texture): the descriptor projects the power spectral density of the image to several partitions of the complex plane such as to give an overall view of the spectral distribution of the energy with different frequencies. Texture is a visual property rarely sufficient to use alone for searches, but combined with colour and/or shape descriptors it can greatly improve de relevance of the results [5][7]. A thorough description of the descriptors can be found in [8][9][10].

The query module produces a re-ranking of the database according to the degree of visual similarity of each image (feature vector) to the query target. This is usually done by employing a distance function, such as visually similar images are situated at small distances from the target. What type of distance functions to use is still subject to debate, but most systems use with good results \( L_p \) distances (usually \( L_1 \) or \( L_2 \)). For speed reasons, the query module uses \( L_1 \) distance. Results obtained with \( L_2 \) distance are similar but involve additional operations that slow down the system for large databases. The system also implements a state of the art relevance feedback machine [11] based on one-class (positive examples only) and two-class (both positive and negative examples) Support Vector Machines. More details on are given in [8][9][12].

The interface module implements the communication protocol with the rest of the TRENDS system. It takes the form of a server that listens to a fixed port and accepts HTTP POST messages. This is standard practice for implementing remote procedure calls for distributed systems and guarantees compatibility with existing software and easiness of future developments.

The Image Search Engine is implemented in C++ for speed reasons. The query time is linear with number of images. For the present database (~500,000) images cost time is less than 1 second on a standard 3GHz PC for both, query by example and relevance feedback queries.

5.3. The mixed image and text search component

While queries by text and queries by image content may provide satisfactory results in many situations, they
nevertheless cannot completely satisfy the complex semantic targets expected by the users.

User scenarios for the TRENDS system include searching for semantic categories that are difficult to describe by using keywords alone (i.e. categories describing emotional states or impact) or by using combinations of visual features.

In these situations, hybrid search by using a combination of text and visual features to describe the images, may provide better results, compared to using each modality (description) alone. Indeed, if we regard the information provided concerning the target concepts or the possibilities of interaction between the user and the system, keywords and visual content are complementary to each other and it is important to rely on both of them for the retrieval of images.

Some hybrid combination methods rely on early fusion of different modalities, such as distance queries and machine learning on product spaces [5]. However, in the TRENDS system, the text and image search technologies are proposed by different partners and come in the form of closed source modules. As such, the access to internal data structures of each module is difficult.

The method that has been envisaged for hybrid retrieval relies on late merging with re-ranking. The query target is described by a set of words and expressions complemented by one or several example images. The system performs a text search retrieving a list of relevant results and an image search (by visual similarity or by relevance feedback) retrieving a second set of relevant results corresponding to the image part. These sets of results are further integrated using their rank and their relevance score where it is available. The method envisaged is a linear combination of ranks/scores:

\[ R = \alpha T + (1 - \alpha) I \]

where \( T \) is the text score, \( I \) is the image score and \( \alpha \) is a weighting parameter that the user can set. In practice, since the database is very large we cannot afford to re-rank the whole database, but we only keep the first 500 hundred results on each modality.

The choice is motivated by the fact that if an image is not present in the first few hundreds results it is likely that it is not relevant for the query.

Also, the user is unlikely to browse more than a few hundreds results. In the case where the similarity score is not available to the system, i.e. text retrieval, we use several score functions dependent on the rank, such as the Gaussian model which favors images that have good ranking or the linear model that computes a score proportional to the rank. The results obtained so far are very promising. We are in the process of testing different scoring functions to the relevance of the results.

6. THE USER INTERFACE

Creativity session enabled TRENDS end-users and project members to integrate their needs and opinions into the definition of the TRENDS-tool interface. Through these work sessions, the graphical interface and the functional sequences behind were progressively defined. This result comes from a specific methodological approach including both a highly user centred approach and creative collaborative thinking. Thus a list of around hundred functions coming from the needs analysis and from the Conjoint Trends Analysis was transferred into design solutions. The proposed ideas were refined before the development of the initial version of the non-interactive Human Machine Interface HMI.

The HMI is the interface of TRENDS system that allows the user to interact in an easy and fast way with the information retrieval server. The HMI executes in the client and communicates with the servers. This HMI consists of a Graphical User Interface (GUI) for the user and several functions that allow the transference of the data inserted by the user towards the servers. These are the keywords and images for the search. In the same way, the HMI will receive the data from the servers and will show it in a friendly way to the users.

At this moment, the interface of prototype 2 has been developed. This interface constitutes the interactive software that allows the user to request and receive information from the text and image search engines. In comparison with the interfaces usually used, it can be appreciated that it is graphically advanced, and it manages a big amount of data every time, however, it is capable of maintaining a very good response time, totally satisfactory for the user, as it has been confirmed in the tests.

The user interface of prototype 2 has been developed in C#. C# is an object-oriented programming language developed and standardised by Microsoft as part of its platform .NET. It syntaxes results from C/C++ and uses the model of objects of platform .NET. The integration of the different servers under the user interface being executed in the client’s side has been carried out and validated in prototype 2. This prototype 2 proves the feasibility of the integration of the different modules which constitutes one of the main achievements of this prototype, and key issue in the final TRENDS software.

Moreover, the user interface of prototype 3, that gathers all the prototype 2 limitations detected during the end users’ tests and includes the proper improvements, is even more cutting edge. Its wide functionality, careful aesthetic and fast interaction with the users turn it into a useful and nice tool that manages to automate successfully manual actions in first design stages.
7. TESTS RESULTS

The end-users participate directly in the design process thanks to the design and use of early prototypes. Continuous test sessions had been carried out with the end-users. These included: the initial needs analysis, the validation of TRENDS functions, the early evaluation of the Graphical User Interface (GUI) concept and of the non interactive prototype, and finally the evaluation of the second prototype which is interactive.

The initial needs analysis enabled to identify the main functions expected by the designers in their day to day activity for specific tasks like trends analysis and idea generation. The functions of storing, searching/interacting, collaborating and using relevant contents in databases were considered as crucial. Following also the fundamentals of the Conjoint Trends Analysis, the final requirements towards the TRENDS system were the system shall (1) correlate high-level dimensions like concepts, semantics and affective reactions with low level image features, (2) use semantic adjectives for retrieving images, (3) used keywords structured according to a purpose built domain ontology dedicated to design expertise, (4) the domain ontology shall be linked to the established sectors of influence following the CTA methodology. For detailed specifications, it was also investigated how designers search for information. Results showed that the search capabilities must go from open (with serendipity) to focused. The design cognitive structures and the domain specific knowledge were formalized in order to build pertimizers. The categorization processes carried out in CTA were investigated and clustering algorithms working with similarities and harmony rules were definitely recommended.

A creativity session enabled to integrate the main requirements into the interface. The proposed ideas were refined before the development of the initial version of the non-interactive GUI, which was used as support for the expression of the design and ergonomics specifications. After a first testing session of this GUI by the end-users, the main improvements were the addition of personalization capabilities, the visual integration of the technologies of text and image retrieval on the GUI, the lightening of menus visualization, the differentiation of spheres types by color, and the integration and the illustration of multiple functionalities in the search module. The TRENDS GUI was finally composed of the following main functions: search, statistics, pallets, workspace... The interface of the interactive prototype 2 has been developed from this version.

Prototype 2 was tested by 12 car designers from CENTRO RICERCHE FIAT and STILE BERTONE according to the following dimensions: database content and retrieval algorithms, interface usability and system functionality performance. Results suggest that the current value of the TRENDS system may lie in the quality of the database rather than the quality of the keyword search algorithm. In addition, content-based search using colour matching was valuable, adding incremental value to keyword search results. The same was not true for texture-based or shape-based searching. It was not clear whether this is due to intrinsic properties of colour or the quality of the specific search algorithm. The results linked to the performance of the prototype in terms of speed of response were satisfying. Relating the usability, the outputs were favourable, even if some difficulties were discovered when using relevance feedback and zoom in/out. A number of improvements were identified, and were used as design specifications for next prototype.

8. UPCOMING WORK

During the third and final year of the project, there is still a big effort to do. The new version of the software, prototype 3, will lead to the final software. The big difference of this prototype 3 with prototype 2 lies on the new user interface, that contains now the feedback of the end users that arose from the different tests sessions in order to make it a useful and appealing tool they could use in their daily work.

Apart from the user interface, this last version contains all the advanced functionalities described that support the end users, such as the pallets and ambience generation boards, the clustering and statistical functions or mapping.

In fact, TRENDS system should provide the categorization of images collected by expert designers in order to help them have a global view of categories related to several concepts. For instance, all chairs could be
gathered together according either to photometric attributes, shape or texture depending on image descriptors. The clustering algorithm is a fuzzy partitional competitive agglomeration algorithm [13] that has several benefits: 1) the algorithm automatically determines the optimal number of final categories; 2) the distribution of data and granularity of clusters is taken into account during clustering by means of the Mahalanobis distance.

Another novelty of TRENDS system is the pallet generation where a pallet stands for groups of pairs of coherent colors or textures according to harmony rules. Thus, TRENDS system will suggest to designers (end-users) a new way to arrange images (categorization process) and also extract the relevant information presented in a smart way (pallet generation process).

There is still another test session planned by the end of the year that will allow evaluating the prototype 3. The feedback of these tests will be included in the final software of TRENDS system.

9. CONCLUSIONS

TRENDS system is a software tool that will improve the early stages of the design process. It aims at making easier the inspirational process of designers, which usually implies the investment of lots of hours looking for information in magazines or in the website. The core of TRENDS system is content based information retrieval system, which allows performing different types of queries: queries by text, by image, or mixed queries with both text and image. Moreover, it allows tuning the query by means of a relevance feedback functionality that let the user indicate the system which results fulfill their expectancies, and which ones are not suitable at all. Moreover, the software presents other useful functionalities for this design process.

Up to now, the prototype 2 client has been developed. The advanced interface permits connection and queries to the servers. The tests carried out till the moment are encouraging and the designers are confident of the tool. The final software will include all the feedbacks provided by the end users regarding the graphical appearance, the final mixed text and image search component and all the auxiliary utilities. This will make TRENDS useful and promising software that will improve the early design process.

10. REFERENCES


