A Matrix of Material Representation

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Abstract

The sensory properties of materials such as colour, texture, sound, smell, etc and people's perceptual responses to them are very important information for designers to consider when selecting or combining materials for a manufactured product. Based on theoretical, experimental and computer programming methods, this research has established a framework of a database referred to as 'Matrix of Material Representation'. The Matrix is a visual narrative model that systematically contains the holistic information about the factors involved in the human perception of materials and illustrates the interrelationship between these factors. Currently, the detailed information about material texture perception has been integrated into the Matrix, which includes a series of material texture perception maps. The Matrix is expected to provide guidance and a reference point to enable design practitioners to make intelligent judgements in selecting and combining different materials in order to match human sensory adaptation, aesthetical and perceptual expectation. The Matrix is seen as evolutionary and therefore has been designed to allow further research data to be integrated at future points. The paper presented here will give a detailed introduction to the Matrix and its dynamic development.

Key words: Matrix/database, materials selection, sensory properties, product design.

1 Introduction

Selecting or combining materials for a manufactured product is one of the key aspects involved in design process. It can affect the overall perceived image of the artefact, either from the physical and functional side ('hard' elements) or from the aesthetical and perceptual side ('soft' elements). The material selection process can be quite complex and will be based on a range of considerations such as functional requirements, manufacturing constraints, economics and life cycle, ecological sustainability, material's aesthetic and sensory properties, and their cultural and representative meanings etc. With this complex interaction of factors, some general guidelines are necessary for designers in order to make a suitable selection of materials. Some very useful information databases do exist regarding material selection, but these are mainly focused on the 'hard' elements of materials. Such examples include the Cambridge Materials Selector built by Professor F M Ashby [1, 2], a software programme which helps to identify and select materials based on various engineering properties. However, no software or database exists to help in the selection of materials based on the 'soft' elements of materials, particularly for matching human sensory adaptation, aesthetical and perceptual expectation. This information is equally and significantly important in today's technology-saturated market, as understanding of how people respond to the sensory properties of materials will help designers and engineers to select materials with more positive user-experience embedded into the product and increase the aesthetic appeal and perceived value of the product. This research is trying to develop such a database of material sensory properties called the 'Matrix of Material Representation' by using theoretical, controlled experimental and computer programming methods.

2 Sensory properties of materials

Sensory properties of materials are defined as: the properties that can be perceived by humans via sensory organs and can evoke physiological and psychological responses. These properties include colour, texture, sound, smell and taste etc. Unlike engineering properties or physical properties of materials which are completely objective (this is due to the fact that these properties are specified by instrument and have wide-accepted standards of formulation and have good test accuracy and repeatability), the sensory properties of materials, on the other hand, have objective-subjective dual attributes. The objective side is referred to as the content of the sensory properties, either a green colour or a rough texture, which exists physically. The subjective side is referred to as the interpretation of such an existing property, which results from the sensory perception initiating from the peripheral organs (eyes, skin, ears, etc.) and then being processed via corresponding areas within the brain. This makes a perceived sensory property of a material not only differ with human individuals, but also differ with particular environmental contexts. A sensory property of a material is actually a combination of a physical property and the human subjective response to it. But such a physical property will at first have to be within the human sensory thresholds; otherwise it cannot be called a sensory property.
So, a sensory property of a material has the following attributes:

- It is objective as it is a particular physical or chemical property
- It is subjective as it is described and assessed by human via sensory perception
- It is within human sensory thresholds
- It can evoke physiological or psychological responses

It is necessary to explore the relationship between the objective content of a sensory property of a material and the subjective interpretation to it, and to see what kind of physiological or psychological responses can also be evoked.

3 Material Representation Matrix

The Material Representation Matrix is a visual narrative database that contains the holistic information about the sensory properties of materials. In other words, the information includes the factors involved in the human perception of materials and illustrates the interrelationship between these factors. It presents a direct, easy-to-understand picture of the subjective-objective dialogue between materials and humans' perception and response to them.

3.1 The preliminary matrix

Human perception of materials including their responses to material sensory properties is a complex process with many variables. Firstly, what essentially needs to be established is a general frame in which the perception of materials can be described. This is the preliminary matrix of material representation, which was established in an empirical way, and shown in Fig.1.

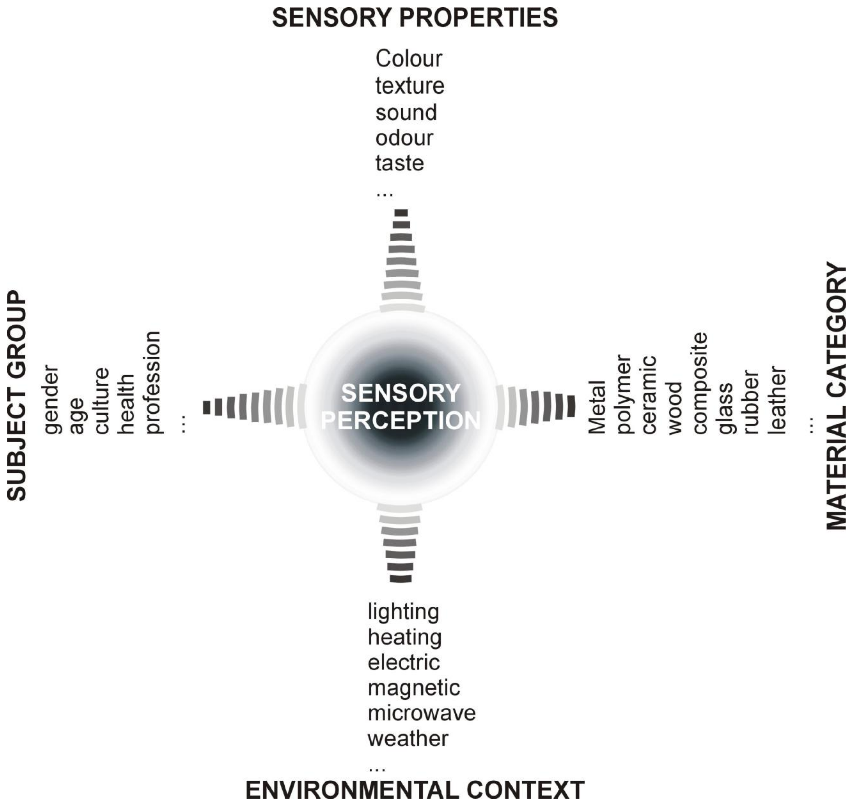

Fig. 1 The preliminary matrix of material representation

The possible elements, which are involved in the perception of materials, can be broken down into the following dimensions.

Dimension I – **human perception activity** (central dimension) – this dimension looks into what sensory modalities such as visual, tactual, auditory, olfactory or gustatory sensation will be evolved in the perception process in the material-human interface.

Dimension II – material categories (right dimension) – this dimension looks at which particular materials with which particular manufacturing and surface treatment are presented as the stimuli to be perceived by the user groups.

Dimension III – material sensory properties (upper dimension) – this dimension looks into what properties of materials such as colour, texture, sound, smell or taste, or combination of these, are to be perceived by the user groups.

Dimension IV – subject group (left dimension) – this dimension looks into what factors influence the perception of a particular subject group, such as their age, gender, cultural background, professional background etc.

Dimension V – **environmental context** (lower dimension) – this dimension looks at the effect and control of particular environmental conditions during the materials-human interaction process. This includes the natural environment (such as weather, temperature etc.), artificial environment (such as mechanical force, electrical field, chemical media etc.) and the particular product context.

It should be pointed out that it is possible to add new dimensions or add new elements within one dimension into the preliminary matrix. For example, an additional dimension, **Dimension VI – physical parameters** (a branch dimension linked with dimension I), was later integrated into the developed matrix. Some new materials may also be added into **Dimension II**.

In developing the matrix, it is necessary to specify clearly the functions of the matrix, the sources of the detailed information to be put into the matrix and the tools used to construct the matrix.

3.2 Functions of the matrix

The functional features of the matrix include the following aspects:

- **Visualisation**. All data or information where possible are displayed in the form of symbols, charts, graphics, pictures, with minimum necessary text-introduction and explanation. This will make the representation more direct and immediate.
- **Systematisation**. Information of the relationship between all the possible factors/elements within the dimensions, which influence the material representation, can be accessed level by level. The systematic structure is like a multi-layered network.
- **Interaction**. Here the meaning of 'interaction' includes two aspects. Firstly, the data within the matrix is interactive. For example, whenever there is a change in selecting the element in any dimension in the matrix or sub-matrices, the final output of the representation information is likely to be different. Secondly, the interface with the users of the matrix will also be made interactive. For example, when you enter a particular need of your sensory/perceptual expectation in terms of one material, the outcome will result in one or several recommended textures to match this expectation. This will be a bit more complex to achieve, as it will probably include special software programming.
- **Flexibility**. This means the matrix is intended to be dynamic. It has the flexibility to be up-graded and have new data added from future research.
- **Practicality**. The matrix will provide practical guidance and evidence for designers, artists and craftsmen to make intelligent judgements in the selection of different materials with certain sensory properties. The matrix should be easy to use.

3.3 Information within the matrix

The information within the matrix addresses the following:

- What are the basic theories and information of sensory perception (the perception by vision, touch, audition, olfaction and gustation)?
- How do people verbally describe the sensory properties of materials, e.g., a material's surface texture via touch?
- What inter-relationships exist between various responses to the sensory properties? For example, how do people's descriptions of texture influence their emotion?
- How will the perception of materials vary due to different product and/or environmental contexts?
- What relationship exists between subjective perception of materials and objective physical parameters?

- § What technical methods are required to realise an expected sensory property for a particular material?

There are three basic constituent elements in constructing the matrix.

- § **Data sheets**. All the information within the matrix takes the form of data sheets. Each data sheet explains one subject, which can be short or long, from one page to several pages. A data sheet always begins with one or more 3-dimensional sphere(s), each symbolically represents the dimension(s) addressed in the data sheet. An example of a data sheet is shown in Fig.4. Producing the data sheets was the first important part in developing the matrix. There will be hundreds of data sheets within the matrix. The number of data sheets will increase overtime as further research is conducted.
- § **Sub-matrices**. A sub-matrix means the internal relationship-frame within a part of the matrix. For example, Fig.5 shows a sub-matrix about the relationship between dimension I (sensory perception), dimension III (sensory properties), and dimension VI (physical parameters, an added dimension). Other smaller sub-matrices might be included within some data sheets.
- § **Links**. Within the matrix or sub-matrices, data sheets are well organized and mutually linked. It is possible that a certain data sheet can be reached through different routes. Designing the symbols and routes for linking the data sheets was the second main part of developing the matrix.

The sources of detailed information to be integrated into the matrix include theoretical research results, experimental research results, empirical research results, results from previous research, and provision for including results from any future research. This will include results from the author's research and from other scholars' research within design, psychology, material science, cognitive science, computer science, or other related areas. However, at the current stage, the matrix has been enriched with information on the perception of texture, by integrating the results from controlled experimental research by the author.

3.4 Tools of developing the matrix

The following three aspects are to be considered when developing the matrix into a practical resource of information for designers to access, whether it takes the form of a website or the form of a particular software package.

- § **Collecting the data**. Methods include controlled experimental research, survey, interview etc. Controlled experimental research is for obtaining first-hand information. For example, in terms of texture perception, the controlled experimental research includes subjective tests (sensory evaluation) and objective tests (parameter measurement), and should be carried out in two conditions. One is where the materials are evaluated in isolation and secondly, when they are evaluated within a particular product context. Survey, interview, and questionnaire are used to test the findings from controlled experimental research, as well as evaluating secondary sources of information such as other theories or findings which have been justified or widely accepted.
- § **Designing and editing the database**. Microsoft Access, or more powerful programming software such as Microsoft SQL Server (SQL stands for Structured Query language) or Oracle will be used to store, manage and edit the large amount of data. These data can be texts, charts, and images etc.

- § **Designing the interface**. Java, or C++, or Java Script will be used to design the interface, assisted by using some 2D and 3D software such as Coreldraw, 3D Studio Max for creating the basic visual narrative elements such as 3D ball symbols etc.

In the case that the matrix takes the form of a website database, an application software such as ASP (Microsoft Active Server Pages) will be needed to connect the database to the web. In addition, some web site design software will also be used when necessary.

3.5 Application of the matrix in design

One of the main purposes of developing the matrix is to provide guidelines for designers when specifying a particular material and surface finish for components within their designed product where sensory perception and aesthetics play a key role.

Taking material texture as an example, the information for selecting a material with a particular texture will be available from two aspects. One is the general information about texture perception of a particular material without product context; the other is the texture perception of the same material category related to a particular product context. In the former case, a series of results about the general information of texture perception in terms of steel, ABS plastic and thermoplastic elastomer (TPE) have been obtained by controlled experimental research. It is supposed from controlled experimental research that the subjective description of texture perception can be summarised with four dimensions: geometrical dimension, physical-chemical dimension, emotional dimension and associative dimension [3]. The correlation between different responses within the four dimensions has also been experimentally explored and results of this have also been integrated into the matrix. For example, a '*smooth*' surface corresponds to the feeling of '*shiny*', '*sticky*', '*moist*' and '*cold*' [4]. However, The subjective responses within the geometrical dimension and the physical-chemical dimension generally can be regarded as 'neutral'. For example, it is hard to say whether '*smooth*' or '*rough*' is either a good or bad attribute. To decide which particular surface attribute is preferred (e.g., '*smooth*' or '*rough'*) will depend upon a number of considerations, one of which is the functional consideration. How will it influence the user's performance or operation with the product (e.g., grip, push, sit, or walk etc.)? Another one is the affective consideration. Will the surface texture stimulate a positive emotional response? Both functional consideration and affective consideration will probably relate to a particular application context, which is the above-mentioned second aspect of information.

There are three routes to access this information within the matrix from the first level or called homepage of the matrix. By clicking the 'texture' button in Dimension III (Sensory properties), you can access the general introduction about texture, texture definition, classification, identification and description. By choosing options from all of these dimensions, for example shown in Fig.2, you can obtain particular information about metallic texture perception by people with different ages through tactual sensation under normal interior environmental conditions. You can also access a particular sub-matrix from the bottom of the first level of the matrix. For example shown in Fig.3, you can enter the sub-matrix I-III-VI, the relationship between Dimension I (sensory perception activity), Dimension III (sensory properties) and Dimension VI (Physical parameter, another added dimension).

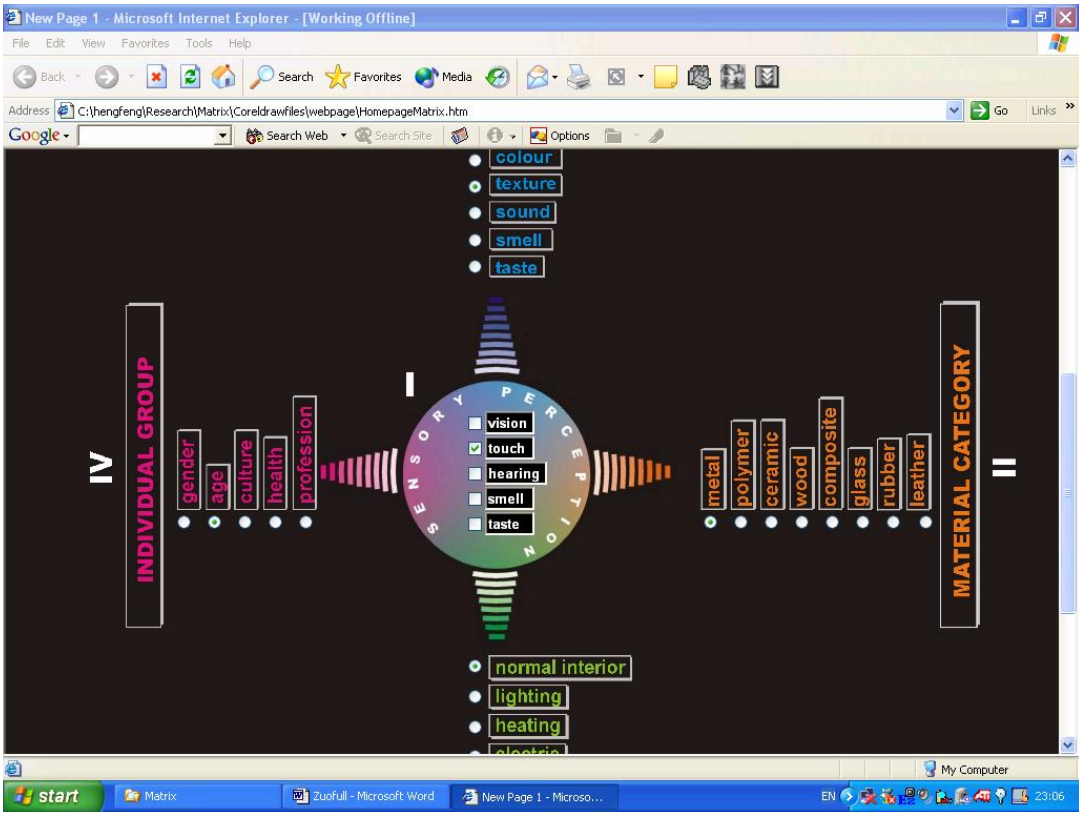

Fig. 2 The first level of the developed matrix

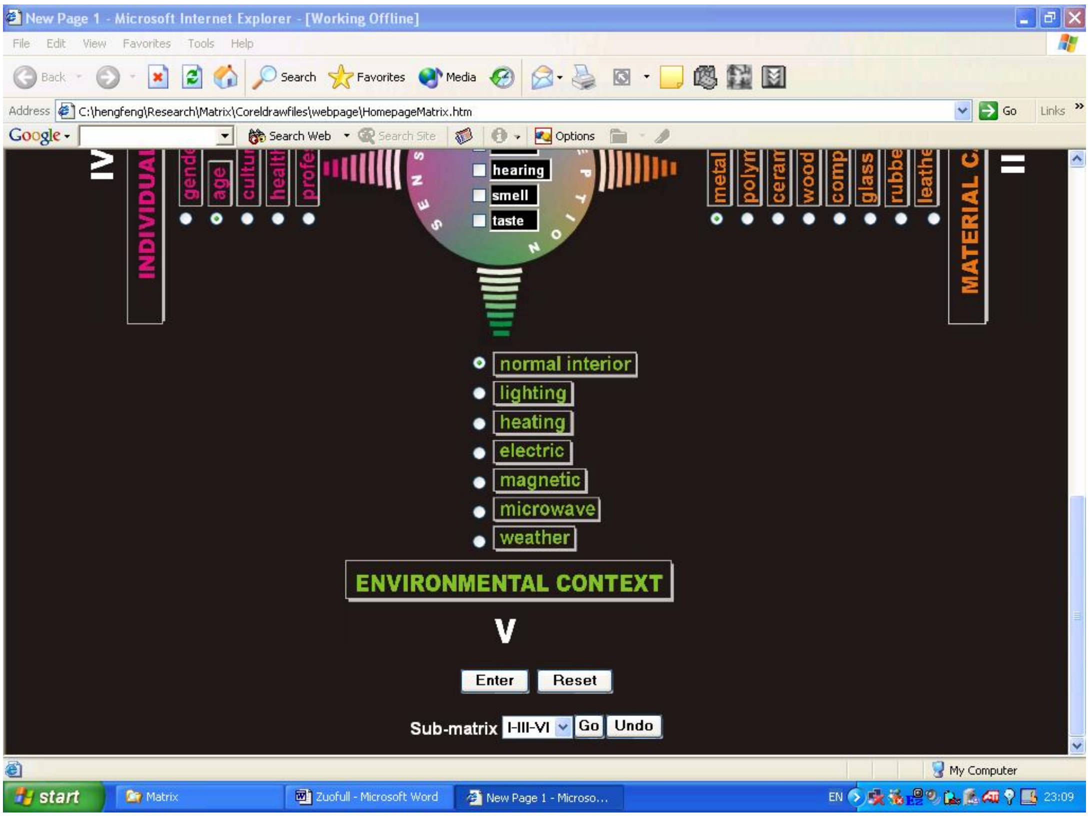

Fig. 3 The first level of the developed matrix (continued)

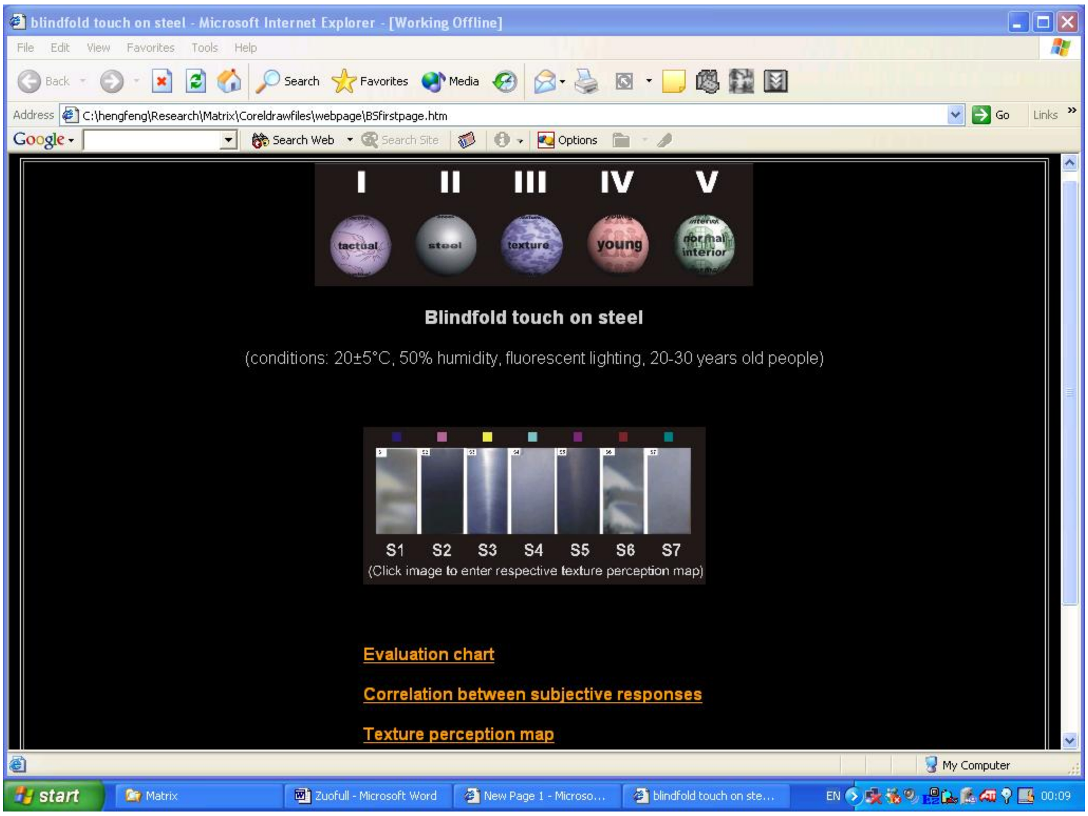

Fig. 4 A data sheet of steel texture perception by touch

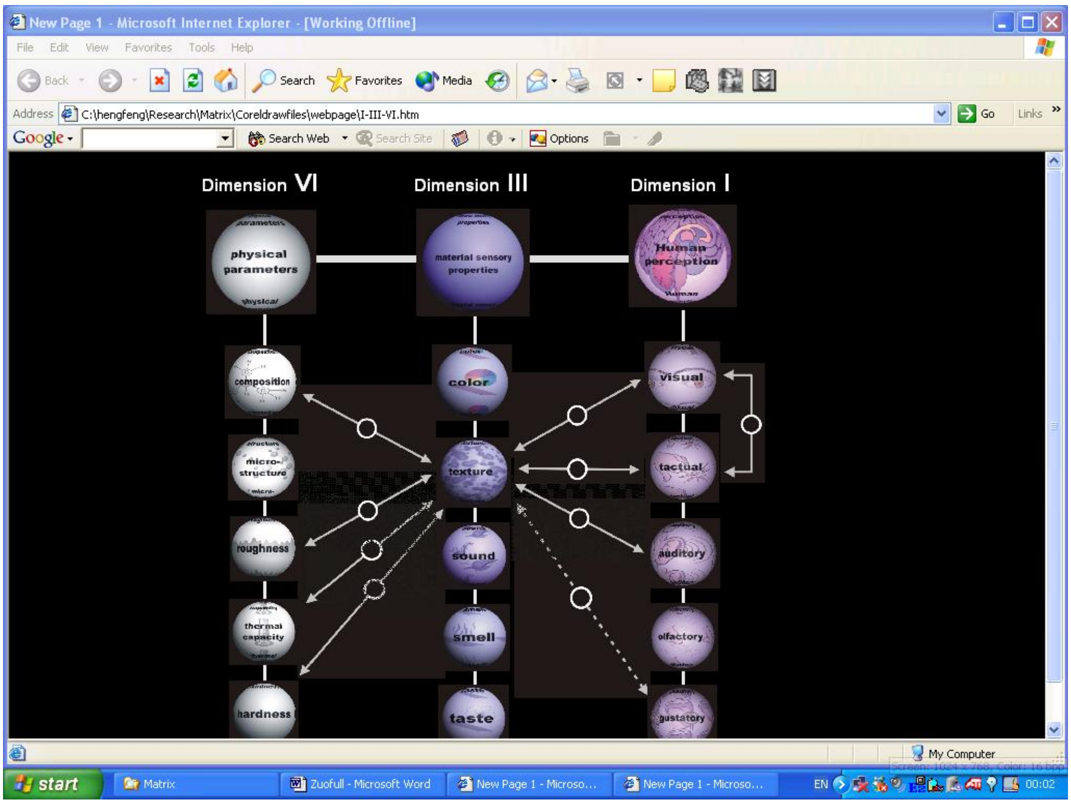

Fig. 5 A sub-matrix between Dimensions I, III and VI

The next phase of our research is to obtain data of texture perception within particular product contexts, and then integrating this data back into the matrix. For example, the context can be a series of products according to different types of grip, such as a static, precision grip (e.g. pens, remote controls), dynamic grip (e.g., steering wheels, power tools, tennis rackets), grip in wet environmental conditions (e.g. using a tooth brush, a bathroom shower handle etc).

4 Conclusions

§ Sensory properties of materials and human perceptual responses to them are equally important as the engineering properties, and therefore should both be considered during any material selection process.

§ The matrix of material representation is a new database embodying the information of material sensory properties and human responses to them.

§ The matrix database will hopefully provide significant guidance for design practitioners in selecting and combining materials with suitable sensory properties to match human sensory adaptation and aesthetic and perceptual expectation.

References

1. M. F. Ashby, (1999), *Materials Selection in Mechanical Design*, 2th edition, pergamon Press Ltd.
2. http://www.grantadesign.com/products/ces/components/selector.htm
3. H. Zuo, T. Hope, P. Castle, and M. Jones, (2001), An investigation into the sensory properties of materials. In *Proceedings of the International Conference on Affective Human Factors Design*, edited by Martin G. Helander, Halimahtun M. Khalid, and Tham Ming Po, London: Asean Academic Press, pp. 500-507.
4. H. Zuo, T. Hope, M. Jones, and P. Castle, (2004), Sensory interaction with materials, in *Design and Emotion*, Edited by D McDonagh, P Hekkert et al, Taylor & Francis, pp.223-227.