Consumer Mechatronics: a challenging playground for Transducing Materials and Devices

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1. BACKGROUND

The authors of this article are characterised by having a background within robotics technology, and have within the last 2-3 years moved into a material & process dominated environment.

The authors are among other things responsible within LEGO Company; an internationally known toy developer and producer, for identification, prioritisation and procurement of new technological opportunities within materials, processes and devices providing new functionalities for the LEGO product.

2. LEGO COMPANY'S SITUATION
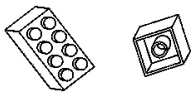
The traditional core product of LEGO Company consists purely of mechanical elements characterised by modularity, simplicity, high precision, and made of polymer materials providing kids over the most of the world with a tool to stimulate creativity, fun and learning.
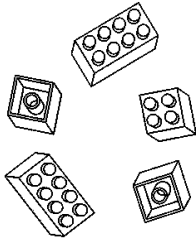
In the late 90's LEGO Company took advantage of a co-operation with MIT's Media Lab and developed and marketed the first robotic toys instantiated by a so-called intelligent Brick. This Brick had the size of a package of cigarettes containing batteries, a programmable computer, a IR communication, a display, some buttons and a number of I/O's by which the Brick could interact with and control motors and sensors.

This robotic tool set combined with mechanical LEGO Bricks enables kids to build cars and robots and download self made programs from a PC to define the toys behaviour. The product was later extended by a software based camera vision sensing system.
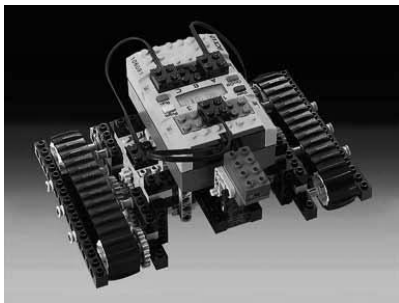
Since LEGO Company demonstrated that an advanced robotic system could be sold at toy cost levels, numerous more or less intelligent robotic toys have entered the marked. This lead to a despaired fight of the toy makers to compete with the successful play consoles, which over the recent years have captivated the kids attention, time and pocket money.
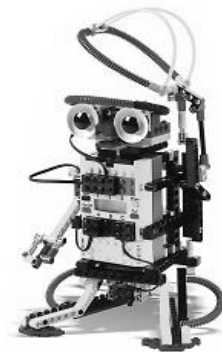
One of the more famous robotic toys, which very much exemplifies the mechatronic version of house hold pet, the SONY AIBO, even more opened up the worlds eyes for what could be expected from house hold robotic.

One could wish that it could be stated, that these kind of toys exemplified the front edge technological development, but sad to say real break through here deals with the integration and engineering of existing

technology into cheap and ingenuous fitness for purpose solutions. And one could ask one self, why new functional technologies like new actuators, sensors, displays etc. did not appear in these products.

Video & PC

The most likely answer could very well be that new functional technologies beyond a miniaturisation of what was used in the mechatronics business actually did not exist. Even if single products desired new functional technologies, they on their own could not and can not pull sufficient R&D to break the existing limits.

LEGO Company now has the ambition to regain the position as driver within the robotic and interactive play materials by introducing to this business the classical values of the LEGO play. This means that we are exploring technologies, which can provide functionality in modular systems at low costs and at adequate level of intuitivity.

But why wasn't any pro-active R&D been done within new functional technologies?

3. Did IT R&D jeopardise the conditions for the transducing materials boom?

For one or two decades we have witnessed how huge attention was drawn to the technological break through and the wide spread use of information technology, and every once in a while it is claimed that Moore's law on how the computing capacity per volume will develop is still valid. No one could have foreseen the speed by which the information and communication technology developed and was integrated in our society, and the immense effect it has had on the globalisation.

In spite of the present crisis in the information technology field, extrapolations from the history combined with imagination predicts still a glorious future for the information and communication technology. In the future the concept of a PC evaporates and the pervasive computing provides us with intelligent houses and environments where computing power and information is dragged right out the air.

As hardcore robotics and materials developers, it has been tough to experience the attention the information technology has caught. Not to mention the amount of funding which has been allocated at the expense of other R&D topics and how simple software production has been interpreted by politicians as "Research" activities in the societies.

Thus after many years of envy should we really hate and dislike the information technology? On the contrary the global information infrastructure has provided us with splendid tool for global research co-operation and a splendid information platform for distributed intelligence, which will come in handy when introducing new devices using new functional technologies.

But will there be a need for a revolution within materials technology?

4. How long will consumers be satisfied with just being provided with information?

In accordance with LEGO Company's fundamental believes and studies we have made, the consumer fascination of having access to information of various kinds and in various forms even at any given time and place, will rapidly fade out and become a "necessary but not sufficient" functionality.

The modern person whether it be a kid, a teenager, an employee, a middle aged or an elderly or even disabled person although in different forms desires all of following and expects it to be conveniently available in the future:

- **service** – tools, which offers the owner practical conveniences, assistance and ease of life
- **learning** – tools, which increases the level of competence of the owner within a field of relevance and which provides the owner with potential for self realisation
- **health** – tools which monitors, maintains or increases the owners physical condition or even tools which repairs or compensates for physical damage
- **entertainment** – tools by which the owner is amused or challenged and enabled to spend time in a fun way adjusted to the individuals desires
- **social interaction** – tools or maybe even creatures (pals and pets) which fulfils emotional demands and provides social and cosy atmospheres

The information and communication technology available and emerging today provides the user with glimpse of above, but only in a very narrow sense, and our believe is that not until a "hands-on/minds-on" experience is provided, true appreciation will be experienced.

The sub functionalities required to fulfil above desires are: controlled dynamic motion, multiple fused sensing, integrated optics and sound based on a platform providing a mechanical, electrical, digital infrastructure.

Each application will put forward particular requirements to how the above desire is fulfilled: Say, within service Autonomy is expected to be the dominating challenge, within health reliability whereas within entertainment interactivity is the key challenge.

5. Innovation process

The traditional technological problem is the lack of synchronisation between the technological availability, the capitalisation of development and marketing and not least the lacking or unpredictable adoption of a new technological opportunity in the society.

Product development has been a matter of combining existing "components" and putting them together to form new products. The product developers doesn't have to be technical people, since understanding the needs of the consumers is often more important than understanding the newest development in technical abilities. Most of LEGO Company's product developers are non-technical people with a lot of knowledge about marketing, design, and children's play.

Meanwhile fundamental research has been making new components, without really worrying about whether they would end up in a product. Sometimes fundamental researchers where lucky and found something which had an obvious use, but it was not the goal of the research, just a side effect.

Applied research has been struggling to fill the space between these camps, by doing fundamental research in areas, where there were believed to be a documented need for knowledge. Fundamental researchers have often seen the applied researchers as not really doing research, but merely product development, and product developers have seen the applied researchers as partly competitors and partly as partners. Meanwhile politicians have seen these researchers as the modern innovators, although most applied research has staid at the level of research and not been used in real applications.

But really: Innovation is a matter of abilities meeting needs.

Usually new abilities are sought in the direction of the known needs, although the abilities actually reached are not always the ones sought for, funding sources are often promoting research which leads towards covering a need. The innovation process is often slowed down, because people searching for new abilities are not usually up to date with the development in needs. This is only natural as they are often placed in other organisations than the people researching the development in needs.

On the other side, the current needs are of course controlled by the current abilities, but are also developed in the direction given by the abilities. As an example, before the PC was sent on the market nobody had guessed how big a need there would be for PC's. Just as the innovation process is often slowed down by lack of knowledge about the needs, so is it slowed down by the fact that the people working with marketing activities, and therefore needs, are seldom aware of the latest development in abilities. They cannot know the difference between a need, which can be fulfilled by the latest abilities, and a utopian dream.

So, the development in needs and the development in abilities are mutually dependent.

Speeding up innovation can be done by either adding more resources to or by increasing the effectiveness of the total research and development process. Having common goals and visions, shared by researchers and product developers, is an obvious way of increasing the effectiveness of the process. This is why LEGO Company works with formulating visions of how the technology will progress.

These visions are not just created by looking at general trends; that would thigh it to technology development founded in current needs. That in turn would thigh the development in needs to a slower cycle that what can otherwise be achieved.

To really create a vision that speed up innovation, it must be understood that both the needs and the abilities will change as a function of the vision!

Therefore we must combine the general trends in technology, with the characteristics that make up great inventions. Thereby we can create a new need in parallel with the development of the ability to fulfil this need.

There are several characteristics of great inventions for instance:
- A great invention will supplement rather than replace existing technologies.
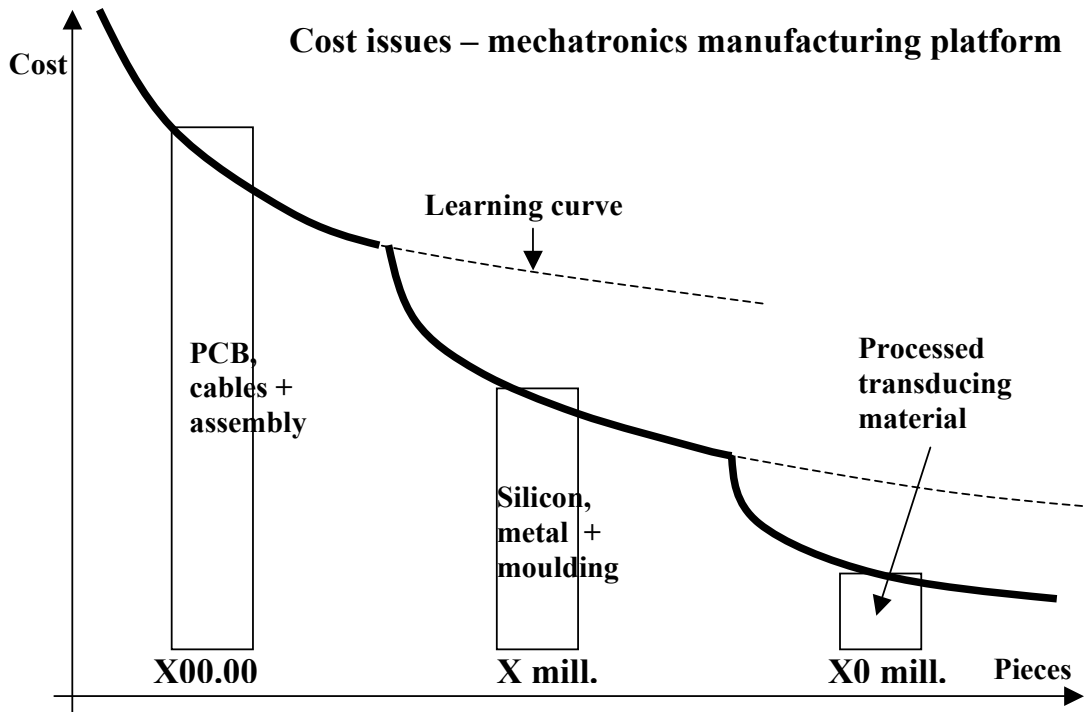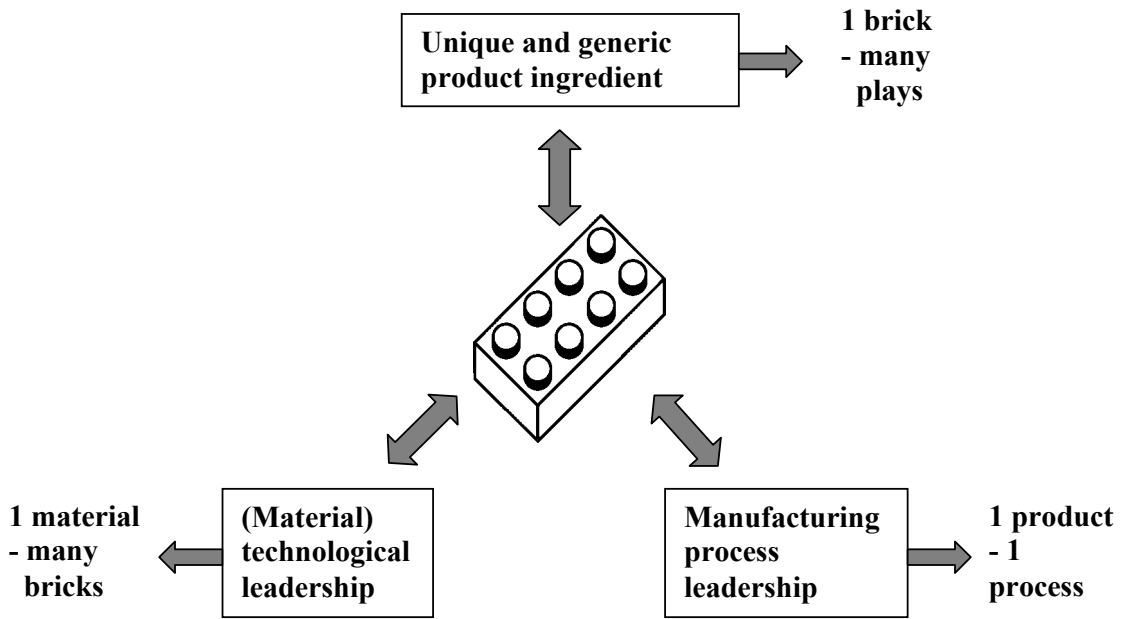- A great invention is available to everybody.

Here we will focus in the availability, since it is what consumer electronics is all about. If a good innovation is one that is available to everybody, then it must be cheap! And cheap means ten times cheaper than you think!

If a technical functionality, which covers a need, is cheap, then it must be created in the triangle of process, materials, and function. A good example of this is the traditional LEGO Brick. To mass-produce LEGO Bricks, it takes excellence in injection moulding (process), fundamental knowledge of polymers (materials), and knowledge of role of the brick in children's plays (functionality).

LEGO Company knows that the area of smart materials will give many new technical abilities build on the same triangle of process, materials, and function. More over LEGO Company will combine these with the needs to make great innovative products.

This is not just a dream! This is something we know. We work from the assumption that it will happen, and thereby we are part of making it happen!

But what is it we believe will happen?

Unique and generic product ingredient → 1 brick - many plays

1 material - many bricks ← **(Material) technological leadership**

Manufacturing process leadership → 1 product - 1 process

Cost issues – mechatronics manufacturing platform

Cost

Learning curve

PCB, cables + assembly

Silicon, metal + moulding

Processed transducing material

X00.00   X mill.   X0 mill.   Pieces

6. We Imagine

Functional materials technological progress will change our lives, to an extent, which we cannot yet imagine. It will change how we view the world, and how we interact with each other.

We believe that issues of today's political world disappear, for instance environmental friendliness will not be an issue; it will be taken for granted. If a company does not comply with these trends, it will be out of business.

Functionality will be available everywhere. Even in throwaway items there will be functionality, which today belongs to expensive consumer electronics. The basic functions will be processed directly into the product:
- Printing can be used for making electronics, sensors, light emission and colour change.
- Sound and motion will be created using bulk materials properties.
- Small local power sources will be embedded everywhere.

To achieve this only a few process steps will be used for making a product. These process steps will be very general, therefor the same manufacturing set-up can be used for making a great variety of products, and mass-customisation will be taken for granted.

Another important attribute of the manufacturing system is that it is scaleable. Goods used locally must be produced locally, otherwise delivery time will be too great, or there will be too many depreciated products adding to the total cost of goods.

We can only guess at the consequences of this development, but we do know that humans have fundamental values and needs. Therefore we can imagine some of the applications which the technology will lead to.

7. Just Imagine...

If we had...
- cheap robots cleaning our house, there would be no need for ever worry about that again.
- cheap actuators, we could have our furniture adjust to fit our bodies perfectly and rearrange without braking our backs.
- active carpets, telling the house where we where, so the house could adjust to this.
- display wallpaper, able to display 3D, then your house could have a view from everywhere in the world, and your .
- robots in the home for entertainment and socialising.
- cheap temperature sensors, every throwaway plastic cup could tell you the temperature of it's content.
- cheap chemical sensors, we could have throw a way food containers which could tell you when the food it contains is bad, dippers which could tell you when it's time for a change, and ...
- cheap robots for our assembly lines.
- cheap and simple manufacturing, we could have one of a kind products manufactured at your local supermarket!
- cheap id-tags, then everything would have an identity and remember it's history. You would never have to search for anything again.
- cheap access to producing chemicals on demand, then every doctor (even in the 3rd world) could have access to all the medical products ever invented.
- cheap sensors for diagnosing illnesses, we could save millions of lives across the world.
- cheap electronic pills which only released their drugs if it detected the illness it medicated against. The pill could even send out a signal, to tell you whether it had found the illness.

Now imaging how much longer elderly people can stay active, when they don't need other humans to help them with every detail of their life. From being a challenging problem of the next decades, they will become active participants in the society.

Maybe we will have a future, where humans primary interact for social reasons...

8. Conclusion

We are at the forefront of a new wave of technologies, most of which will supplement rather than replace existing technologies. These technologies will be available everywhere, because they combine smart materials, simple processes, and added functionality. Don't ask yourself whether this will happen, it will happen, ask yourself where and how you can contribute!

At LEGO Company we actively pursuits the exploitation of these technologies, by giving information about needs to researches, and information about abilities to our product developers. Furthermore we actively work at getting common visions formulated for the different communities involved in the innovation process.