Ergonomic analysis in manufacturing process.
A real time approach
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Abstract
The actual main target for manufacturing systems is the constant research of new technologies and solutions to implement lean processes gaining flexibility along assembly lines. An important approach to correctly investigate in this direction is the analysis of the human interaction with the workplace and the assigned activities or, in other words, the ergonomic aspects. In the past a lot of efforts have been already spent to increase comfort and safety of human operations. Nowadays also the ageing factor of blue collars, especially in Western Europe, is not at all a negligible problem. Requirements as “more flexibility” and “reduced time to market” imply a faster and easy capacity to analyze impacts of new products and processes on workers healthy condition already before the first production trial. Electrolux is participating in the EU funded project INTERACT to develop and adopt a user friendly tool simulating the manufacturing process and getting a precise ergonomic analysis before having at disposal any physical prototypes to perform the assessment. For the ergonomic analysis the specific case is the material handling operations, starting from the supplier delivery till the refurbishment of assembly stations. The target is to identified and prevent, using standard methods (NIOSH) and index (OCRA), eventual ergonomic hazards in pre-assigned movements (picking, handling, loading, etc…) also comparing alternative solutions. Operating in advance in a “fully virtual world” using only 3D drawings, it will be possible to simulate in few minutes any working operation and to get the relevant ergonomic evaluation. It also will be possible to get real time analyses of already existing activities, simply using standard cameras and without any impact on the workers privacy. Such an innovative way of analysis will allow an immediate understanding of any work-related physical disease and selecting a better solution for both random and mass working operations.

1. Introduction
Electrolux and Electrolux Professional
Electrolux is a global leader in home appliances, based on deep consumer insight and developed in close collaboration with professional users. Electrolux produces thoughtfully designed, innovative solutions for households and businesses, with products such as refrigerators, dishwashers, washing machines, cookers, vacuum cleaners, air conditioners and small domestic appliances. Under several brands besides Electrolux, AEG, Zanussi, Frigidaire and Electrolux Grand Cuisine, the Group sells more than 50 million products to customers in more than 150 markets every year. In 2013 Electrolux had sales of $15.1 billion. The global number of employees is over 60,000. Through profitable growth, innovative products, operational excellence and dedicated employees, Electrolux creates the conditions to reach its vision to become the best appliance company in the world. The values in the Electrolux Company are:
- Passion for innovation
- Customer obsession
- Drive for results
A very living part of the Electrolux Company, is the Electrolux Professional which is the only supplier worldwide offering a complete range of high-performance products for professional kitchens and
laundry systems under the same brand. Our 2,000 service partners in 140 countries ensure that our resource-efficient equipment, leading in innovation and design, improve our customer’s everyday business. In 2013, Electrolux Professional had sales of EUR 640 million, 2,600 employees and 7 factories all over the world.

**Work organization: LEAN concept**

The production and management system used by Electrolux Professional is called EPS (Electrolux Production System) and have been established to improve the competitiveness on the market. Since its foundation in 2005, EPS has focused on continuous improvement and on involving all company employees in order to reduce or eliminate non-value activities (“muda”). Electrolux Professional has redefined its production organization based on the principles already adopted by other companies especially in Japan. In accordance with this style, EPS is represented by a temple; the roof contains the objectives, the columns and base list the techniques and requirements necessary to reach the objectives. More than a specific technique to be applied literally, this is a philosophy (Kaizen). It uses Kaizen workshops to spread its concepts in order to teach its techniques and to facilitate a change in the mindset of the people. Moreover, the company is obliged to reorganize its production system if it wants to be competitive.

**Workers involved in the Vallenoncello (PN) plant**

The present project started in the plant of VALLENONCELLO (Pordenone – Italy) where Electrolux Professional produces ovens, refrigerators, horizontal cooking devices and dishwashers for professional customers.

In the plant the blue collars involved in the manufacturing process are about 350, out of them 50 are employed for warehouse activity (incoming-stocking-line feeding).

Mandatory for Electrolux is “SAFETY FIRST”, so any activity must be analysed in order to avoid any accident or injury and also any potentially dangerous activity or situation. In fact in the plant the quantity of injury dropped down, putting in more evidence the professional diseases.

Such in an environment Electrolux tries always to get the best methodologies in order to prevent any disease, also making a lot of analyses of the workplaces in terms of efficiency but never forgetting the safety of the worker throughout a good ergonomic study.

**Age of manufacturing blue collars: an important factor**

Also the aging of the workers is important and it is increasing. The following graph shows the distribution of the age in the manpower: the actual average is about 48.

It is also important to take note that Electrolux moves the blue collars from one position to another quite frequently, in order to avoid an excess of repetitivity.

In the following graph you can see that up to 24% of the workers changed operation and product line within the last year.
interaction with auxiliary equipment and transport vehicles (trains-trolleys) require also the development and adoption of appropriate simulation tools and services, based on human experience, shop-floor data and available layout, in order to optimize the allocation operations and the warehouse management strategies to fulfill assembly lines requests.

Pilot case description

The pilot case is built up around the Dishwashing plant (DW) of Electrolux Vallenoncello plant (Italy), into the picking warehouse which deals with the storage and handling of all the components used for professional dishwasher’s assemblies. Before illustrating the pilot’s details, hereinafter a brief introduction to the current material handling flow is reported. The incoming components and materials are delivered from various suppliers in different packaging modalities, accordingly to their dimension, shape, weight, etc… When an item (or more than one) enters into the warehouse for the first time, due to a new product/module introduction, it is physically analysed by the Material Management Team (MMT), which is responsible for the definition of its future way of handling, positioning and transport within the entire area. The following pictures give just an idea of how the different types of items are stored along the warehouse shelves depending on their dimension, volumes, defined packaging and picking frequency.

Even though the material handling flow appears rather functional in terms of operability, as they have been implemented over the years, it is a common perception of the MMT and the plant management that it cannot be considered optimized and neither flexible when sudden and specific modifications are needed. Moreover the
efforts required for the activities definition and application are highly time-consuming and too affected by the human operability and experience. In order to be more productive and efficient in logistic human operations, ELECTROLUX intends to introduce the use of computer aided technology to support definition and optimization of these kinds of processes. Starting from the observation of a realistic situation (pilot) based on human work tasks and related knowledge, these data are used to simulate and analyze the best-fit operative conditions for the operators and for the entire process. The simulation will have to cover several aspects related to the material handling, from the simple picking of the item to the suitable design of the trolley to allow a correct uploading of the same item. Moreover, the simulation and the related tools should be capable of covering human-related aspects as: ergonomics, safety and efficiency. Also all the possible environmental constraints as spaces, auxiliary equipment and infrastructures that affected the human operability must be taken into account.

The pilot idea is therefore to limit the analysis to a specific case: Line 2 of Dishwashing product line in Electrolux Professional of Vallenoncello

In particular the aim is to analyze the manual activity of picking form the storage and uploading on the proper trolley. Tracking of current human tasks and their operative sequence will be the first step of the analysis. The simulation of the proposed scenario, adopting the platform developed tools together with the data collected from the field, will provide a series of solutions and suggestions for getting the optimization of the same tracked tasks. Finally the MMT will be in charge of compare, evaluate, modify and select among the two scenarios (real vs simulated) the best configuration and sequence of tasks for the operators (i.e. respecting the ergonomic principles) and for the warehouse operations (i.e. respecting the efficiency of the activities).

2. Current state in Electrolux Professional

In Italy the issues about health and safety in workplaces are covered by the Decreto Legislativo n. 81 issued on April 9, 2008, (D.lgs 81/2008).

D.lgs 81/2008 proposes a management system of safety and health in the workplace, through:
- full compliance to safety codes;
- evaluation of residual risks;
- reduction and management of residual risks acting on technical and organizational factors;

Risk assessment analysis is the fundamental tool that allows the employer to identify prevention and protection measures and schedule their implementation, improvement and control in order to verify the effectiveness and efficiency of the actions done.

Among the main risks to be assessed in assembly-related workplaces, there is the risk of not-ergonomic postures and movements.

The official reference to evaluate this kind of risk is ISO 11228: “Ergonomics – Manual handling” that is split in 3 parts:
- Part 1: Lifting and carrying: using NIOSH Lifting Equation
- Part 2: Pushing and pulling: using SNOOK e CRIELLO method
- Part 3: handling of low loads at high frequency: using OCRA score.

These kinds of assessments are very important as, in Italy, WMSD (Work-related Musculo-Skeletal Diseases) are an emerging problem due to the aging of the working population and the spread of incorrect styles of life (physical inactivity, inadequate diet, uncertainty of the work). The issue is evident as the requests for work-related diseases outweigh work-related injuries, though control Authority (INAIL) confirms only 30% or less.

Also the blue collars continuously increasing retiring age is another important fact that encourages employers to have an accurate ergonomic analysis and to design ergonomic risk-free workplaces.

In Electrolux Professional Pordenone Plant, knowledge on ergonomic assessment is owned by Process Engineering Department and Health&Safety Department.

There are some facts, though, that make necessary the use of qualified external consultants. Mainly application of OCRA index is difficult due to long work cycles (more than 10 minutes average) and high-variance in mix-model production.
The context is so different from the factories of Domestic Business Unit where the cycle time is <1 minute and the mix model variance is not so high.

Actually we are working with a consultant that is used also by local Safety Authorities (INAIL, SPSAL) as a reference.

### 4. Problems coming from the field

The main moments to accomplish this analysis are:
- Design of a new assembly-workplace;
- Modification of assembly process due to product change;
- Kaizen experiences on an assembly-workplace;
- Risk Assessments updating.

### 3. Current State Weaknesses

Main problems of current situation are:

1) workplaces inspection and following analysis to define proper risk index need high investment in terms of man’s hours;

2) a complete mapping of workplaces is unattainable, as there are frequent changes in phases balancing that cause daily variations in the work contents assigned to line workers.

3) the analysis should be carried out by analyzing real people and physical objects: so, or it is carried in the final balance once the production process has been developed, or it needs to be replicated in workshops that reproduce the working area

4) the analysis is often conducted on the operator holding the workstation: this implies that the assessment may be influenced by anthropometry of the person who is being analyzed (eg: tall vs. short people, etc.)

5) the result of the evaluation is affected by the experience of the person who conducts the analysis.

### 5. Targets

In front of the “week points” above mentioned of the actual situation, it is worth to realize a tool / automatic procedure which could guarantee the following performances

a. Fast output

In fact is very important to get results directly on the field and to be able in comparing different solution without wasting too much time. If possible it should happen in the same “session”.

b. High coverage

The concept “SAFETY FIRST” pushes the whole company to extend the analyses not only in “urgent” situations, but in each work place.

c. Cost efficiency

If the request is to increase and extend the quantity of analysis to be made, obviously it is also mandatory to reduce the cost of each session, in order to maintain and increase the global system efficiency.

d. Analysis possible also with “virtual” objects

The target for Electrolux is to prevent any problem before the start in production, and if possible to find out a global optimisation. Part of this process is also the analysis of the workplace and of the material handling, including the design of the specific container and the location into the warehouse.

e. Standard and objective output data

Due to a wide knowledge existing in our consultant, all the analyses are coherent and repetitive, but in any case it is always necessary a lot of experience to get the right results from any analyses. It is clear that in the future the target of Electrolux Professional is to have these analyses internally made and, if possible, already in the design phase and with granted and repetitive results. This will be possible only with a standard automatized tool, like the one which will be the output of the DHM project.

### 6. Digital Human Model - DHM

The project aim is to fulfil all the above mentioned targets.

For this predicting activity is employed in the Digital Human Model (DHM) simulations, which transfer the semantic handling operations tasks into human motion building blocks. The human movement trajectories, derived by the building blocks, will then simulate the manufacturing and handling tasks.

The output should be a software and hardware tool fast and performing, able in giving precise evaluation of potentially all the real situations of the plant. Two more features are really very important:

To be able to compare different proposals giving to the process engineer all the relevant information in order to make the final choice (or eventually to make and evaluate a new proposal).

To work in a completely virtual environment, that is to work before releasing any product or process.

And this is a great advantage in terms of “TIME TO MARKET”, and a hard reduction of it is one of the most important goals for Electrolux Professional for the next years.

### 7. Problems of an automatic proposal

Similar automatic solutions are already available on the market, and the only existing problems are the resources (big and fast computers) and the new competencies
necessary to run them (for simulations and managing complex tools). Also the time necessary to get results is usually quite long (days for any simulation). Also for the INTERACT project similar problems could arise, but at this stage it seems they are not realistic.

8. Conclusions

Since the beginning of the project, the main targets were clearly defined. By the same time was also clear that they were highly demanding and a big effort was required.

At now, that is in the middle of the project, the first goals are available and a first step has been achieved.

In fact, with the aid of low cost optical sensors (video cameras) a SW tool has been developed (till in a preliminary release) in order to get the ergonomic analysis and “score” of an existing situation. It is also possible to compare similar situation.

More difficult is the complete approach.

The core of the solution is starting from a “natural language” to simulate a whole a “picking and placing” operation in complete a virtual world, with the guarantee that movements are “natural” and also “collision avoiding”.

Many tests have been done ad a lot of new solution/algorithms have been put in place, but till now the results are acceptable only if limited to some specific cases. During the next months a big effort will be done by the specialists in order to universalize the solutions.

It is important to point out also that part of the complexity of the work is the fact that the human body will be simulated with a lot of joints, including a well detailed description of the hands. In fact the “grasping technique” is quite relevant for a definition of the effort dome in picking and it ergonomic evaluation.