MODELLING LAYOUT FOR INTEGRATING SIMULATION, OPTIMIZATION AND VIRTUAL REALITY

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ABSTRACT

The aim of this research is the development of an innovative approach to support company upgrades, reorganization and new facility establishment. This approach is focused on combining layout engineering with the use of simulation and optimization; this combination is very important because allows to reorganize the whole layout and production processes and flows and to measure the results in the virtual world before making real changes. The proposed methodology is applied to a real case study: the reengineering of the production plant layout in an aerospace company moving to a new site.

INTRODUCTION

The Layout analysis is a well know application area for both simulation and optimization; in fact the necessity to consider the interactions among many different variable, often affected by stochastic behaviors, support the use of complex models and the application of simulation methodologies; in this area often the problems are becoming pretty complex in term of size of the problem or type of the components. In these cases the optimization techniques are often dynamically interacting with the simulator in order to proper estimate the performances of the new proposed layout.

In this paper the authors are presenting a methodology derived from these cases that combines different models: simulation models related to production flows, intelligent optimizers based on Genetic Algorithms (GAs) and Virtual Environments for presenting the dynamic nature of the phenomena and their evaluation along the whole production site construction.

In fact in this case the final goal it concentrates not only on optimizing the layout, but much more in obtaining a robust solution that could face the market evolution and that could support the whole factory transitory: from the dismissing of the old one to the completion of the new facility. In this inter reign it is critical to guarantee the production levels by a proper planning and a proper layout organization as well a proper factory movement schedule. The authors developed a solution for considering all these aspects defined as LEXIS (Layout Excellence & Integrated Solutions) which is implemented in C++ while VEGA™ is the commercial solution for 3D. Therefore LEXIS project integrates Layout Optimization based on Genetic Algorithms, Modeling & Simulation and Virtual Reality for supporting the development of a new large Production Facility for an Aerospace Industry. In fact Lexis aims to create a model that maximizes the layout of an aerospace production.

This paper provides the description of the model used for constructing the simulator to be integrated with the optimizations paper.

THE PROJECT MOTIVATION

The project motivation is related to the aerospace company reorganization; currently the company includes two main production facility: the first one devoted to planes manufacturing and engine components, and the second one focused on the whole aircraft assembly.

In fact it has established the transfer of the manufacturing plant in a new area; in fact the old facility was developed during WWII and the layout was strongly affected by related considerations. Today market evolution proposes new opportunities for setting up the production site and it was making sense to evaluate alternatives.

The Company production facilities cover 120,000 square meters (1.3million square feet) in the northwest of Italy. Nowadays the company is building a new state-of-the-art facility , designed to implement the latest lean manufacturing technology that substitute one of the existing production site. This lean philosophy will increase production capacity, efficiency and optimize workflow, building this facility in response to the rapid expansion of its business. The new production facility, called in the following figures “site N”, will better position the company to successfully meet the challenges of the market. Final aircraft assembly, flight-

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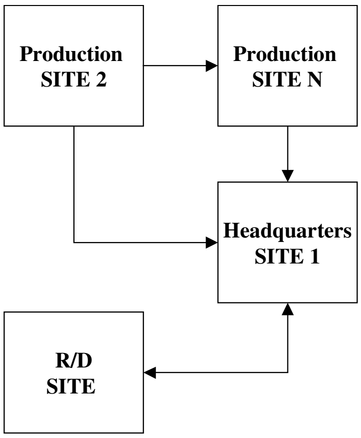
testing and aircraft overhaul operations are located at the corporate headquarters (site 1). The company service center offers full service support to its aircraft and aircraft under Jar 145 certification.
Aircraft and engine components, manufacturing, general engineering, engine maintenance and overhaul are based on production site 2. Operations include a maintenance center and two production areas, one for engines and sheet metal parts, another for major aircraft sub-assemblies.



Figures 1: Production Flows

The object of this work is to optimize the layout of the production flows and to guarantee the transitory during the change from the old facility to the new one.
The project is divided into different main phases:

- Data Collection and Certification
- Production Flow Definition
- Simulation Development
- Synthetic Environment Integration
- Layout Optimization

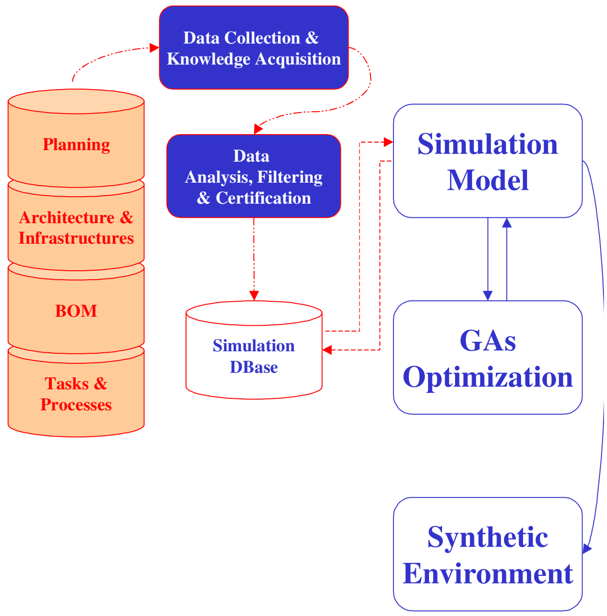
Before to activate the modeling research it was requested by the company to evaluate different implementation solutions in order to guarantee the users with the capability to maintain the simulation implementation. Different COTS (Commercial Off-the-Shelves) have been evaluated in term of their technical and functional aspects:

- Layout Optimization Capabilities
- Graphics Capabilities
- Compatibility with other Software
- Maintainability & Stability
- Acquisition, Service and Training Procedures

In the proposed case the company is composed by a production machinery set over passing 400 entities; in addition to these elements it becomes necessary to define all the warehouses and the areas for work in progress (WIP); in addition architectural elements, and ancillary entities have to be consider as part of the whole layout.

LEXIS ARCHITECTURE

The proposed architecture expect to integrate three different modules: the simulation model, the Optimizer and the Synthetic environment.
In fact the simulation represent the core to be interrogated by the Optimization system; the authors are currently presenting the simulation model, while the following step will be the integration of the optimizer; this module is based on genetic algorithms considering the number of variables that need to be optimized and the benefit of this approach in using user proposal as seeds for the optimization process.



Figures 2: LEXIS Architecture

CONCEPTUAL MODEL

The proposed methodology is based completing the creation of a simulation model based on OODA (Object Oriented Design and Analysis).
In fact the following objects was defined for representing the elements of the layout problem:

- Layout Object
  - Id_{LO} Layout Object (LO) ID
  - S_{LO} LO Status
  - α_{LO} Orientation
  - Dx_{LO}, Dy_{LO}, Dz_{LO} Delta Position from
    i) Department Reference Point
  - Fnx_{LO}, Fny_{LO}, Fnz_{LO} Foundation Size (X,Y,Z)
  - Fnm_{LO} Foundation Mass
  - FnS_{LO} Foundation Surface
  - Lx_{LO}, Ly_{LO}, Lz_{LO} LO Size (X,Y,Z)
  - La_{LO} LO Area
  - PDI/ACI_{LO}Production Department Id
    i) and Activity Cost ID
  - $Description_{LO}$ LO Description
  - $Code_{LO}$ LO Code
  - $Constructor_{LO}$ LO Constructor
  - $Model_{LO}$ LO Model
  - $Type_{LO}$ LO Type
  - $Department_{LO}$ LO Department

- Smoke$_{LO}$ Smoke Evacuation Requirements
- Pr$_{LO}$ Productivity
- Mob$_{LO}$ Mobility
- Noise$_{LO}$ Noise Generation Level
- Sens$_{LO}$ Sensibility Grade respect Noise
- SO$_{LO}$ Operating Status
- Disp$_{LO}$ Availability starting date (new devices)
- Line$_{LO}$ Production Line
- Time$_{LO}$ Expected Time required for
- moving from old to new facility

- Service Box
  - id$_{SB}$ Service Box(SB) Code
  - lo$_{SB}$ Associated Layout Object
  - dx$_{SB}$,dy$_{SB}$,dz$_{SB}$ Distances from LO Reference Point
  - lx$_{SB}$,ly$_{SB}$,lz$_{SB}$ SB Size
  - β SB Orientation

- Flows
  - id$_f$ Flow Code
  - Type$_f$ Flow Type
  - S$_f$ Description
  - From_Where$_f$ SB Origin
  - To_Where$_f$SB Destination
  - MainProductID$_f$ Main Product ID
  - Items/MainProduct$_f$ Production Ratio
  - ItemID$_f$ Item ID
  - Code$_f$ Item Code
  - T$_{f1}$ Set Up Time
  - T$_{f2}$ Unit Production Time
  - LT$_f$ Production Lot

- Products
  - id$_p$ Final Product ID
  - Q$_p$ Planned Quantity
  - Code$_p$ Final Product Code

- Items
  - id$_i$ Item ID
  - S$_i$ Item Description
  - Sx$_i$, Sx$_i$, Sx$_i$, Item Size (X,Y,Z)
  - N$_i$ Number in Packaging Unit
  - MM$_i$ Movement Mode
  - Code$_i$ Item Code

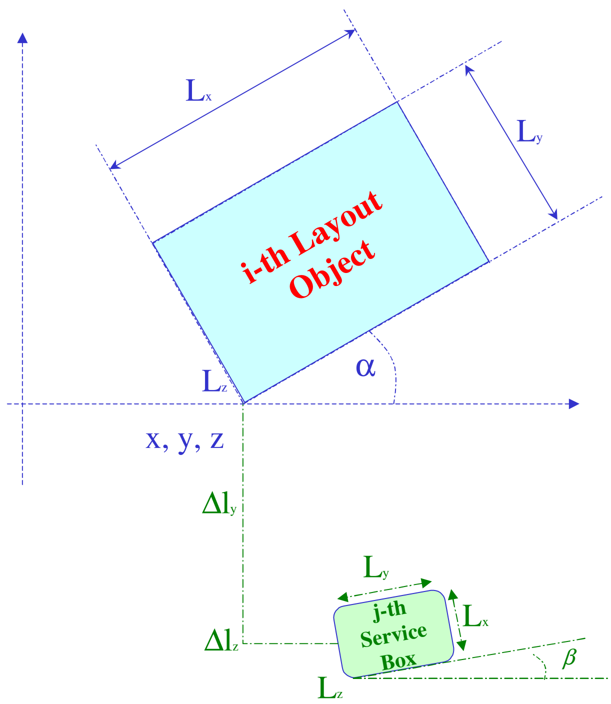
- Corridor
  - id$_c$ Corridor ID
  - Type$_c$ Corridor Type
  - Description$_c$ Corridor Description
  - From_Where$_c$ Starting Node
  - To_Where$_c$ Ending Node
  - Size$_c$ Corridor Size

- Corridor Node
  - id$_{cn}$ Corridor Node ID
  - Type$_{cn}$ Corridor Node Type
  - Description$_{cn}$ Corridor Node Description
  - X$_{cn}$, Y$_{cn}$, Z$_{cn}$ Corridor Node Location

- Handling Device
  - Id$_{hd}$ Handling Device ID
  - Type$_{hd}$ Handling Device Type
  - Description$_{hd}$ Handling Device Description
  - Cap$_{hd}$ Handling Device Capability
  - Cos$_{hd}$ Handling Device Cost
  - Speed$_{hd}$ Handling Device Speed
  - N$_{hd}$ Handling Device Number

- Production Department
  - ID $_{Dp}$ LO Department
  - S$_{Dp}$ Department Description
  - Dpη_{Dp} Department Orientation
  - Dpx $_{Dp}$,Dpy $_{Dp}$,Dpz $_{Dp}$ Department Location (X,Y,Z)

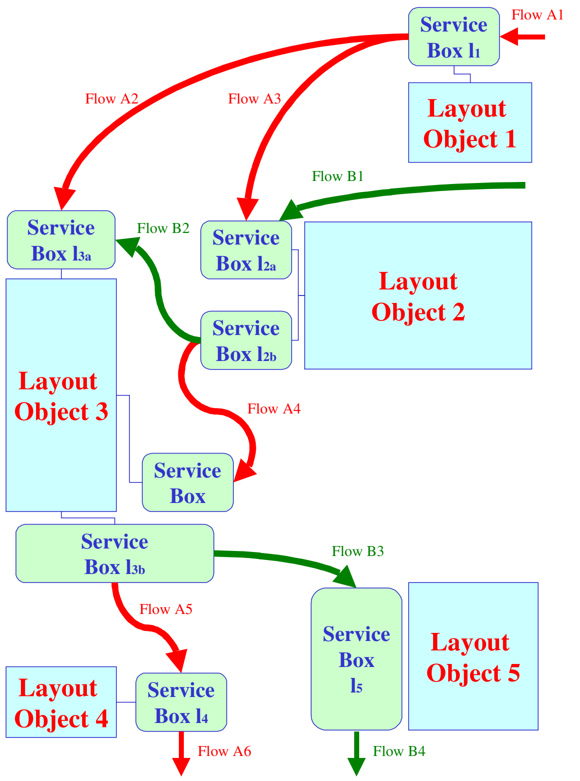
Layout Objects represent both machinery components, architecture elements, offices, warehouses, testing areas etc.; each Layout Object (LO) can be associated with one or more Service Boxes; each Service Box (SB) is in charge of being the connecting point for the Flows and can serve as input, output or input/output point for a machinery or a warehouse; the system is defined in 3D even if most of the optimization is expected to work on 2D. The basic structure of the LO and SB in term of space occupation is proposed in the following picture.



Figures 3: LO and SB Structure

The Flows represent a logical connection between two Service Boxes; Flows can be associated with different Items; Items usually represent raw materials, components, intermediate products, finished goods, however it is possible to use Items for defining flows of resources, people, data. The Handling Devices are used in order to define the effort required to transport the related items over a Flow based on their capabilities (i.e. unit time, capability, unit cost), while the Item quantities are attributed to each Flow in relation to the final product quantities, by this approach all the quantities and costs are easily updated based on production mix expectations.

A general scheme of the Flows in the Layout is proposed for an example involving two different final products (A & B) is provided in the following picture.



Figures 4: Flows Scheme

DATA COLLECTION METHODOLOGY

In order to proceed in the analysis it is critical to acquire all the information and data required by the model; in this phase it is critical to collect data, to acquire knowledge and to proceed in information certification.
In relation to the production machinery components it is important to acquire: technical details (i.e. foundations, productivity, size, service required), technical drawing (layout element shape) and process definition (bordering areas for WIP). These things allow to define the machines into the simulator, and it can be possible to evaluate the volumes for the related buffers and to define the optimum layout to facilitate the loading and unloading of materials. It was defined as an active LO each element that is hosting a task or production process, while as passive elements it was defined the entities representing architecture component, infrastructures or ancillary objects.

Scenario definition

A critical step in simulation projects it is the scenario definition; in the layout optimization it is necessary to consider different components defining the scenario to assess the effects that different hypotheses can generate.
In particular it is critical to define alternative market evolution scenarios; in fact in the near future it is usual to expect changes over time in demand of the different finished products; the layout obviously need to be robust to face the changes in the flows in term of volumes.

Production elements

As anticipated the proposed methodology was applied to a real Case Study; in this case the data collection required strong liaisons with company experts of the different division (industrial engineering, processes, production, maintenance, etc.); in this case the solution was developed also in order to support the production process re-engineering based on the opportunity to set up the new production facility.
During the data collection it was evident the missing interconnection among the data in fact the available information resulting in this case was including, as usually:

- Bill of Material (BOM)
- Machine Parameters & Drawings
- Production Process Definition & Task List

However the very important information related to the processes not directly connected with machines was not structured: i.e. the testing activities and the necessary devices and equipment as well as the acceptance areas and checking procedures.
In addition the production in this reality involved different general products: engines and aircraft and all the data structures was divided and with different format.
So it was necessary to combine the Production Processes with the BOM in order to define the sequential procedures for production of the finished goods as well as the structure of the initial, intermediate and final warehouses.
However the production processes include tasks to be carried out in the production facility in examination, outsourcing as well as other production plant activities; so it is necessary to extract the items related to the layout based on task list definition; obviously the model requires to be flexible in order to compare solution where tasks are moved inside the layout or outside (by outsourcing for example).

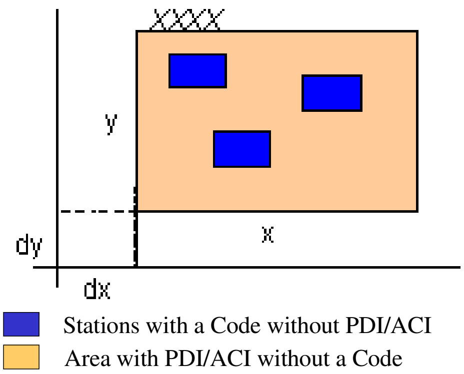
Bill of materials

The Decomposition of the main products in term of elements is a fundamental element for extracting the items to be attributed to the production flows. The BOM is usually structured as a tree, with the final product at the top, and then the different levels exploding down it in components, sub-components, etc. In the proposed case study the BOM was characterized by 14 different levels.

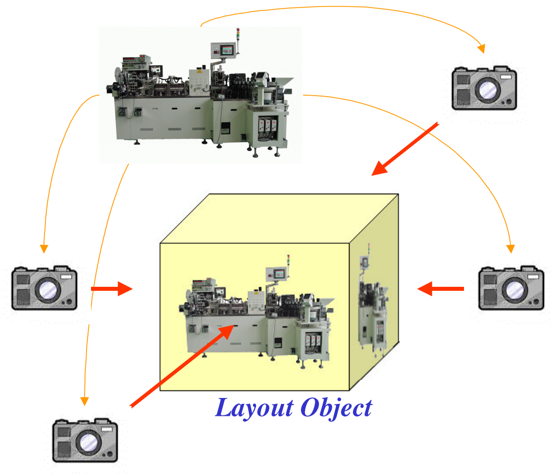
Task & Machinery Lists

For each element required by the Task List it was defined a set of two different Identifiers: Production

Department Id (PDI) and Activity Cost ID (ACI); by this approach it is possible to support planning and to estimate the added value of each operation in the production process. As input data it was used the database issued by the maintenance department including description of the machines, this list was extended including all the areas required by the tasks and processes based on review of production process definition and task list with subject matter experts.
In fact it is critical to complete as soon as possible the full list of all required active LOs in the plant; obviously the support from company experts is fundamental.
However the Machine database, developed by maintenance department, was mostly driven by the necessity to support the factory movement in the new facility; so it was structured based on new machine acquisitions and existing element listing for the movement; it is evident however that by this approach, the machine tables could result inconsistent respect the PDI/ACI list. In fact it is interesting to outline the presence of "exceptions" that have to be "normalized" to be included in the model; in fact there are machines that are defined in term of PDI and ACI, but are still missing a single code, being in fact an entity resulting from the merging of many different elements and small machines; at the same time it is possible to have areas that was identified as an element in the task lists but that still miss the Id code for the factory movement
The following picture propose an example of the current situation and the relative definition of elements respect its production department; in order to combine the two data set in a single consistent element it was necessary to avoid duplications and to identify connection; the authors was working with Subject Matter Experts (SME) in order to define proper level of detail for modeling the active elements representing Layout Objects



As result of this phase it was possible to add to the LOs to be moved in the new facility or to be acquired, also the elements that aren't "real machines", but that represent critical Layout Objects: for instance testing areas and working banks.
By this approach the list of entities was representing all the "active" Layout Objects.
The authors decided to collect also four pictures for each machine, one of each side; the aim of this activity was to insert them on the cubicles that was expected to be used in the 3D representation of the Layout Objects.



Figures 5: Collecting images for 3D representation

Current Layout

Using the company CAD files, it was possible to measured the current position of each machine in relative coordinates respect its production department, as well as the position and size of each department; obviously it was necessary to extract also all the positions for warehouses and buffers in each department.
These data was collected in order to being able to estimate current layout effectiveness as reference value for comparison with the new plant solution; in addition the relative coordinates of LOs could represent a proposal for the new plant layout with a simple relocation of the departments; this solution is obviously a very limited optimization, however represent an interesting reference value for comparing new solutions and new production planning strategies.

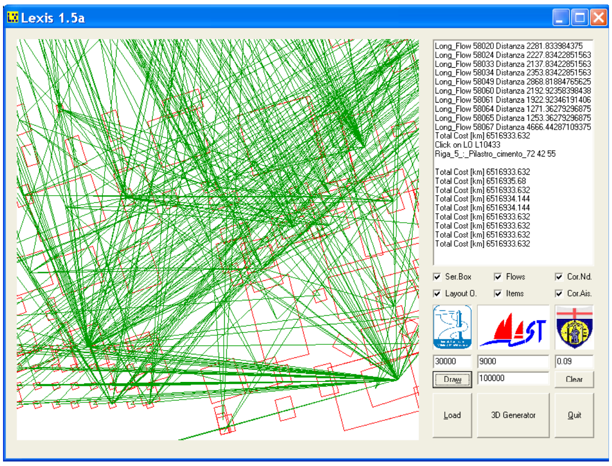
Architectural Elements

Therefore it is necessary to collect the information about the infrastructure of the new facility such as its size, narrowness of the wall, material structure, position of the columns, position of the toilets, the offices, foundations, special plants and the emergency exits.
So the next step was to complete the LOs by extracting all the architectural elements from the future factory blueprints; these elements was including both fixed (i.e. pillars, underground escape routes) and mobile (i.e. offices or element not yet finalized in term of position and characterized by degree of freedoms in locations) items; the related characteristics was introduced in the LO definition.

EXPERIMENTAL ANALYSIS

As anticipated the first phase was to apply the proposed model in order to reproduce the actual layout of the

production under reorganization and the related flows of the material and information.
Currently the authors are working in carrying out the experimental analysis on the current and new layout. The verification and validation of the model was strongly based on joint review with SME and final users, as well as statistical analysis of the simulator results.
In the following picture is presented a synthesis of the simulator GUI (Graphic User Interface) presenting overall flows and LO for a case study.



Figures 6: Flows and GUI

CONCLUSION

The paper proposes an approach for modeling industrial facility in order to face layout optimization by an integrated approach; the proposed methodology, LEXIS, demonstrates it consistence with Lean Simulation approach and was successfully applied to the real case study of a large production facility in aerospace industries.
The authors are currently finalizing the optimizer integration in the LEXIS architecture and in completing the simulator fine tuning.

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