The Principles of the Virtual Machine-Building Factory of the Future

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Abstract. Currently remote and digital services are significantly expanding, replacing entire departments of industrial enterprises. In the near future, it is possible that fabless-companies will conduct large-scale development, but carry out only intellectual research and development tasks, carrying out organizational and entrepreneurial activities.

This paper discusses the methods and foundations of a prospective organization, which can achieve an increase in profits using automated manufacturing of the entire production, marketing and logistic functions by cross-industry third-party interconnected companies. Resulting methods and algorithms are applicable primarily to such industries as the production of electronic devices, modules and devices, electrical engineering, instrumentation and mechanical engineering in general.

The algorithm of such digital factory is described.

1. Introduction

Any new industrial product begins its story from ideas, but then it goes through a large number of stages to the final product, and then, to a consumer.

At the moment, there are companies that offer the full-cycle assembly of devices. Some of these companies are significantly supplied with robotic systems and support various software interfaces for automation via the Internet.

In particular, semi-automatic ordering services for the manufacture of printed circuit boards, film and metal panels of devices, and mechanical parts are available to a wide range of consumers. Larger companies can manufacture special components from suppliers with a large circulation. The difference between modern digital manufacturing services is that industrial manufacturing companies sometimes provide users with an access to a software interface (API) to automate purchases, payment, tracking and closing an order.

Most of companies providing APIs for users are concentrated in the field of procurements. Some companies provide consumers with software interfaces for tracking order statuses, and some even provide users with the ability to order products automatically.

Services that implement the task of delivering goods are electronic automated sales services, logistic solutions that allow automated reception of goods for dispatch, courier delivery services, unified goods tracking systems, chat bots.
The presence of all these opportunities for doing business leads to the concept of partial or, to the extent, full automation of the enterprise, except for development. The feasibility of these studies is to increase the creative potential of companies, increase the amount of headwork rather than mechanical work. It must be pointed out that mechanical work performed in this case by large manufacturing enterprises is often already largely automated and robotic [4] [5].

A potential problem from an increase in the number of such enterprises is a decrease in the number of jobs in positions related to physical work - soldering, machining, assembly from individual units and components. In general, the emergence of intelligent digital factories is unlikely to change the situation on the labor market in many other industries except military engineering. This is due to the fact that in the factory of the future a large number of technologies are implemented in a transparent manner, open to third parties at many stages, which is unacceptable in the case of work with a high level of clearance. In particular, the rise of factories of the future is promoted by the development of projects under open licenses - GNU GPL, BSD, MIT. For hardware development, the CERN Open Hardware License V2 [1] is relevant.

One of the main trends in the development of industry is the shift of the "center of gravity" to the research, design and development stage - which is a key aspect of the factory of the future [7].

Figure 1 shows the algorithm of the virtual factory, in general, similar to the work of a conventional factory.

![Figure 1. Virtual fabric working algorithm.](image)

The design stage is excluded from consideration, since it is the main one in the work of any engineering organization.

2. Procurement stage

The procurement phase is significantly different in enterprises in the private and public sectors, in small, medium and large businesses. The private sector can often easily purchase any products for production both on the local market and abroad. In addition, often the decision on specific purchases is made quickly enough, and immediately purchased goods can immediately be paid.

The main tasks of the conceptual factory of the future, if it does not belong to the government sector, is the automation of the tasks of generating accounting data, payment orders and other documents related to the payment process. The ideal way to conduct procurements is to switch to operations that will be similar to working with individuals, but in this case, all reporting documents must be generated.

Many companies supplying components already provide the opportunity to create procurement positions on the basis of a list drawn up in an arbitrary way. Built-in algorithms automatically recognize the text position of names and quantities. This is a way companies supplying electronic components, hardware, industrial electrics (e.g. Mouser, Digikey, RS Components, Farnell, etc.) operate. In the near future, we should expect the appearance of such tools for procurement in the field of various structural materials, which is more applicable to the engineering industry.

The procurement process in companies where the state has a significant share, as well as in large companies in the private sector, has a significant drawback in the form of extremely long procurement lead times. This is due to the fact that more documents are required to conduct these operations. For example, tendering is required for large purchases, and even orders for small components must be accompanied by a procurement statement documents. Moreover, all operations are carried out by the procurement department, which is almost completely separate from others, including accounting.
Thus, these companies must solve these problems through the implementation of special document software. Most often, such documents in organizations have an established form, which means that it can be filled in according to this model when purchasing a large number of small positions. Procurement departments for private and state-owned companies basically require the same package of documents for procurement, so these concepts for private companies are also valid for state-owned companies.

3. Automatic manufacturing stage

At the end of product design, CAD systems and their CAM utilities (Computer-aided design and computer-aided manufacturing) allow to generate output data for the machine manufacturing of products. In general, modern web infrastructure allows to upload this data to the manufacturer in an automatic manner, if the API was provided.

   For engineering parts and assemblies, such data is:
   - Assembly drawings and detail drawings
   - Drawings for bending parts
   - DXF files that are applicable for milling, engraving, or cutting operations
   - STL files for the manufacture of castings, 3D printing parts, powder metallurgy [3]
   - STEP files with a detailed product model

For printed circuit boards, this data is:
   - Gerber files for PCB layer information
   - Excellon Drilling Operations File
   - Pick and place files for robotic circuit board manufacturing
   - Sheet of electronic elements, or BOM file

The following information is generated for integrated circuit topologies:
   - Description of the functioning of the system in Verilog / VHDL
   - System tests based on similar languages
   - GDS II graphics file format, the de facto industry standard for IC design
   - CIF file format (Caltech Intermediate Form)
   - SDF, SDEF files
   - MEBES electron beam lithography files

Files issued for production can be either very simple or, on the contrary, extremely complex. Typically, tariffing in automated production is more dependent not on the real complexity of the part, but on the complexity of the technologies involved. In machine-building industries manufacturing is sometimes heavily dependent on the part complexity, while the manufacturing of printed circuit boards, tariffing depends on the technological process for the production of the board itself, and on the number of mounted radio elements, as well as their various options. In the manufacture of ICs, the cost is determined for the most part only by the technological process used, although it depends on the number of IC outputs and the package used. In turn, CAD systems make it possible to control the observance of production rules (Design Rule Check routines) on all stages. At the moment, these checks make it possible to predict the price of a future product with a high accuracy.

For harnesses, the data is currently only assembly drawings, and assembling electric harnesses is still an extremely time-consuming task, often all electrical harnesses are made by hand. If the harness is made using machines, 40% of the cost of it is compared to the cost of machine equipment [2].

The automatic batch data generation can be implemented using specialized software, which is compiled for the needs of a particular organization. In particular, almost all CAD systems have a built-in programming language or the ability to use add-ons. Using these built-in tools allows automatic preparation of parts of new products for production.

The leader in automated production are Chinese companies, as well as several large German manufacturers (for example, Shaeffer AG).
In addition, the market for distributed production technologies is developing, e.g. Shapeways platform, which allows to use the production capacities of private manufacturers.

The most relevant virtual factories, of course, are in the field of prototyping and small-scale production.

4. Shipping and logistics stage
At the logistics stage, there are tracking APIs for standard domestic and international tracked shipments that are processed by federal mail. Almost all private logistics companies also have these software interfaces.

The control of the shipping process is most conveniently carried out using massive tracking systems with tracking number support for most logistics companies.

It is possible to create an automatic tracking system using scripting programming languages and, for example, Google Spreadsheet tables. A good source of parcel data is 17track.net, which provides users with universal tracking services. The software developed by them as a whole does not satisfy the needs of even small businesses, although the results they provide, on the contrary, is excellent for tracking and analyzing shipments. This project is lacking a correct API system.

Regular monitoring of the logistics of consignments allows you to reduce the time to receive the developed products to a minimum, and therefore increase the chances of their quick market entry and good sale indicators.

5. Marketing and sale of goods
In general, at the moment marketing is already sufficiently automated, there are a large number of e-commerce, marketing, advertising sites and other functions. Trade consolidation in the near future will focus on aggregator sites which offer sellers and buyers opportunities to place goods and purchase. The popularity of these types of services is increasing due to the lower price of goods sold than in the case of the purchase of similar products at retail (both for B2C and B2B segment).

It is worth to point out that many of these carriers support the formation of consignment notes for goods and the consignments themselves through web services.

The table lists a number of marketing platforms that will be relevant in the near future, their market sector, as well as the reasons for their popularity and localization of their markets.

| Platform name | Market sector | Country segment |
|---------------|---------------|-----------------|
| Amazon        | B2C/B2B       | Europe/USA      |
| Alibaba       | B2B           | Worldwide       |
| Aliexpress    | B2C/B2B       | Worldwide       |
| Ebay          | B2C/B2B       | Worldwide       |
| Walmart       | B2C           | USA             |

These platforms are the same for buyers and sellers, and, in addition, are connected with payment systems and with tax systems.

The goods produced are sold on these resources, documents for shipments are automatically generated, and thus the goods reach their final consumer in a reasonable time. The question of storage of goods remains open, which is partially solved by the method of forecasting the production amount of items that will be sold in a certain period (equal to the period of production and delivery).

6. Conclusion
The increase in the number of virtual factories is mainly due to the increasingly significant role of the design stage. The stratification of “intellectual” and “physical” professions is growing. These trends
are due to the desire of manufacturers and entrepreneurs to reduce costs, to load workers with one type of activity that is fully consistent with their skills.

The provided algorithm of the virtual factory is more suitable for small and medium-sized businesses. At the moment, it is difficult to predict whether it is possible to carry out large-scale production in this way, since most of the open e-commerce platforms are designed for the B2C segment for private customers. The process of creating cross-industry platforms for business helps to close this gap, and this means that in the near future large business can be fully distributed.

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