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ABSTRACT

In the current milieu of ISO 9000 certification, just-in-time engineering (JIT), demand flow technology (DFT), and total quality management (TQM), industry is attempting to implement available technology for the creation, control, and delivery of documentation. In most cases, their efforts are in need of outside resources to analyze, develop, propose and implement usable solutions. This paper addresses the need for a graphic engineering system to distribute graphic products of computer-aided drafting (CAD); it reveals a single solution by outside contracted resources, to quantify, justify, create, and deliver three- dimensional modeling-based graphics into a systematic communication environment. Software and hardware delivery systems in graphic engineering are presented in support of communication instruments required for manufacturing and assembly processes. Examples are presented, with supporting data, as evidence of the value that a simplified graphics system approach has on visual literacy in industry. (Author/AEF)

Attaining Visual Literacy Using Simplified Graphics in Industry

by Terry Burton

Abstract

Under the current ISO 9000 certification, just-in-time engineering (JIT), demand flow technology (DFT), and total quality management (TQM) demands, industry is attempting to implement available technology to solve their documentation creation, control and delivery needs. In most cases, their efforts are in need of outside resources to analyze, develop, propose and implement usable solutions. This paper reveals a single solution, by outside contracted resources, to quantify, justify (ROI), create and deliver 3-D modeling based graphics into a systematic communication environment. Software and hardware delivery systems are presented in support of communication instruments required for manufacturing and assembly processes. Electronic examples are presented, with supporting data, as evidence of the value that a simplified graphics system approach has on visual literacy in industry.

Introduction

American industry is embracing computer generated 3-D geometric modeling as a means to facilitate quality improvements in engineering design and manufacturing. Previous to the current movement to modeling, industry employed groups of skilled graphic production people to develop, distribute, revise and store graphic information. These groups would spend countless hours creating and recreating graphics for a variety of documentation. Engineering drawings, assembly graphics, catalogs, production documents, service manuals, advertising, training information and many other types of graphics were produced to meet their needs. It is significant to note that a graphic is being defined as an iconic or digital (digital in this instance means alpha and/or numeric information) image or document that is used to accomplish communication (Burton, 1989). This paper is an attempt to quantify some of the variables affecting graphics in industry and to qualify a strategy for implementing a visual based graphic system, delivered just-in-time (JIT), in an intense industrial training environment.

Industry observations

Over the past two years, an analysis of industry graphic production and distribution processes of over seventy-five moderate to large American corporations located in nine states and Mexico, has revealed tremendous under utilization and duplication of creation tasks of graphic products within companies. It was discovered that images developed for use in one department were being recreated in other departments, frequently at exactly the same time. Most departments were operating independent of knowledge and resources of other areas. This revelation indicates clearly a need for better communication and coordination of graphic production. Possibly there could be a graphic database of information that could be distributed corporate wide.

Along with the discovery of inefficient graphic operations, it was also observed that the revision and updating process for documentation was not timely or accurate. Numerous engineering and management document changes were not being posted in a usable timely fashion to the departments. JIT was not a reality. This lack of dynamic updating creates potential for errors and waste within a corporation.

The corporate documentation processes, when analyzed holistically, indicates a need to develop a system of distributed information that is dynamic (addressing the needs of concurrent engineering), quantifiable (relates to the issues of ISO 9000) and usable (providing an atmosphere for JIT and Total Quality Management TQM environments) within the current corporate structure.

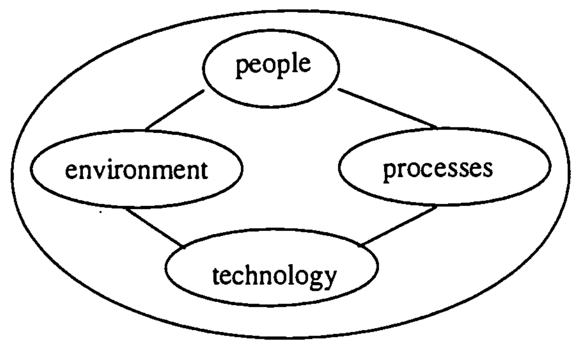
Electronic corporate information delivery systems have been in use for several years. Most often they are referred to as MRP (Manufacturing Resource Planning), PDM (Product Data Management) and EDM (Electronic Data Management) systems. MRP was also the acronym for Material Resource Planning. It has recently evolved into Enterprise Resource Planning (ERP). To confuse the "acronym soup" of our language even further, EDM has also been referred to as Enterprise Data Management and Engineering Document Management systems.

MRP systems are typically corporate level wide information networks that integrate manufacturing, financing, maintenance, distribution and data transfer functions. These systems are very limited in their ability to archive and distribute graphic information. This technology was developed in the late 1970s and tends to carry the "technical baggage" of such systems.

However, PDM and EDM systems are an emerging technology. These acronyms reflect a subtle difference in functionality between systems, but often they are used interchangeably. They are attempting to provide updated information, restrict access to sensitive information, and control revisions to a variety of production and manufacturing documentation. Unfortunately, the vision of these products and their reality are still far apart. As with most new technologies, the promise of PDM and EDM have grown faster than both available products and the available experience to understand and utilize it effectively.

The success of a corporate level implementation is often restricted or prevented by the weight of bureaucracy, technology or personnel ability limitations. It is the opinion of the author that corporations tend to lose their effectiveness in implementing change when they abandon involvement of user level personnel. Admittedly, the ultimate success of the development and implementation of a new technology and/or system must be consistent with the existing corporate systems. However, it is more important that the end users have input into and realize direct benefits from the creation and implementation of such systems. In short, people (Figure 1) are the most important component of any system and deserve the largest commitment of resources.

System Model
Figure 1



Corporate graphic production

The arrival of computer-aided drafting (CAD) has added another component necessary for changes in how industry can create and distribute its graphics. Though CAD solved some of the problems of storage and revision, departments continued to create graphics for their own needs independently. Industry merely changed the tool for creating graphics and did not immediately see a need to change the process.

With the emergence of CAD, industry began to recognize the need to incorporate a PDM or EDM system for distribution of their graphic products. Communication infrastructures have emerged as a necessary entity in the development of efficiency strategies in the creation, revision and distribution of graphic data. However, in this instance, the focus of effort was on the interpretation of engineering design to engineering documentation. Typically, little or no effort was expended at the corporate level to find and apply potentially significant uses of these engineering graphic products in other departments. Sometimes, individuals in aftermarket parts, service or marketing would see the benefit of having such information available. But, due to limitations of the available technology, pressure of current work loads (relative to the issue of corporate control on head count, etc.) and corporate structure exploration and development of the necessary linkage to acquire the information was frequently prevented. Like most technology, CAD solved some problems, created some problems and provided opportunities.

The next generation of graphic technology has seen corporations embrace the geometric 3-D modeling processes. Several technology companies have created and marketed powerful modeling tools. These tools have allowed industry to push technology farther into their engineering design processes. Now the engineer can use a computer to electronically design and create new products, jigs and fixtures in a modeling prototype environment. This helps to reduce the product design to production time previously required. A large database of modeling information that has the potential to provide graphic products for many uses is being developed.

It seems logical to assume that if an engineer creates a 3-D model of a new part that is archived, besides the obvious benefits to the production and computer integrated manufacturing environments, another potentially tremendous opportunity exists. Other departments and entities within the corporation could benefit from having access to a 3-D model database. For example, the aftermarket parts department personnel could use a snap-shot of the model, oriented in a pre-determined position, as a line illustration in one of the electronic or static parts catalogs.

The opportunities for the utilization of such 3-D information are almost limitless. However, there are two issues that arise from this opportunity. First, there is the issue of modeling standards. With current technology, for interested parties to be able to utilize 3-D models, the model must be created to a pre-determined standard. The process of sequence of model creation, coordinate locations and other modeling practices must be defined so the model is usable in other departments. A model created with standard parent-child relationships, built from the inside-out, would be of little use to a marketing department that only needs external detail for their graphic product. Typically, there would be no need for the internal components of a product that were not visible from the outside. Therefore, it would predictably destroy the internals of such a product. Obviously and unfortunately, if the model was constructed from the inside-out, linking one part to another with the parent being the inner most part, the model would be destroyed. To prevent this from occurring, a set of standards for creating and developing 3-D models must be created.

Secondly, although it is ideal to believe that an engineering 3-D geometric model is usable to the majority of graphic users, the technical reality is different. Although PDM and EDM vendors claim that the distribution of models is simple, it is not. The unacceptable nature of the access of modeling data can generally be attributed to an ability shortcoming of the hardware and software. This technical problem manifests itself by causing large amounts of computer time to retrieve and manipulate graphic information. It is not uncommon for the movement of a model from a corporate graphic vault to a requesting terminal to take twenty minutes. In most instances, this is a totally unacceptable amount of time. Graphic data is difficult enough to retrieve and manipulate in a non-modeling 2-D environment, much less adding the amount of data memory necessary to access an engineering model. Storage needed for models and the overhead of graphically inadequate corporate data delivery systems make it difficult to use 3-D geometric models. There is a need to reduce the amount of data that a typical engineering model requires. It is suggested that a simplified version of the model be created for access by those corporate entities that require it. This would also require the development of a standard for simplified models.

Simplified models

The full potential of engineering 3-D geometric models within a corporation can be realized by utilizing a simplified modeling approach to development. The development of simplified models logically unites the simplified graphics strategy, similar to the one proposed by the aerospace industry, and 3-D geometric models.

The simplified graphics strategy permits the creation of a completely electronic documentation environment without the data magnitude associated with typical graphics files. A set of standards for reducing the amount of data contained within graphic files was developed. In short, stripping unneeded graphic information from document files enables the significant reduction of the amount of electronic storage space required. It is interesting to note that by performing a rigorous graphic analysis of the minimum needed graphic information or cue, it was discovered that the ability of graphic information to communicate predetermined specific information was effectively enhanced.

Extending this simplified graphic logic to the 3-D geometric model provides a means to create simplified models that are usable in a variety of industrial applications. Simplified modeling database development, with current available technology, is a logical solution to providing corporations with usable graphics for a variety of needs. Each department has access to the simplified model database. Unlike the legal and ethical issues that arise from the distribution of 3-D geometric models outside the corporation, a simplified model could be used for this purpose.

The potential benefits of developing and maintaining a simplified model database are extensive. Product design engineers could begin creating the geometric model, according to a predetermined sequence, and at some point the model could be defined as being simplified. When it reaches this stage of development, it could then be saved as a new file. Just like the subsequent high level engineering geometric model, the simplified model can be accessed, rotated in space, exploded, rendered, and messaged to a usable form using a fraction of the computing power and storage required for the high level model. This customized graphic entity, extracted from the simplified model, could then be saved in a graphic vault, be owned by the developing department and made available to the rest of the corporation. The resulting small graphic files and subsequent graphic database can be more easily distributed over current corporate electronic systems than the high level 3-D geometric model.

Graphic engineering

Graphic engineering, the process of designing, creating, evaluating, archiving and distributing graphic information utilizing a systems approach, could be thought of as the emergence of a discipline that is the direct result of current and developing graphic technologies.

Graphic engineering allows the creation and distribution of electronic graphic information that contains all of the data necessary to produce a product. As corporations develop in their understanding and implementation of graphic based solution strategies, there will be an emergence of a new discipline that will utilize *graphic engineers and graphic engineer technologists*.

A graphic engineer would be responsible for the standards and practices relative to the development, storage and distribution of graphic products. Having a strong background in the visual sciences (Bertoline, 1993), this profession would emerge with personnel who could create good graphics, consult and set standards for graphic production. Finally, they would be managers with the ability to design, develop and distribute graphic systems cooperatively within an organization. ISO 9000, TQM and JIT movements that require analysis and review of corporate document systems would tend to support the emergence of such a profession.

Realistically, the selling of graphic engineering as a discipline is a non-commodity based issue at this time. Individuals possessing all of the required attributes to be graphic engineers are not yet aware of their potential to be a part of the emerging graphic engineering.

It is possible that a person could someday attend a university and major within its School of Engineering in Graphic Engineering, or within its School of Technology in Graphic Engineering Technology. It is apparent to the author that within industry there is a need to provide this type of opportunity. Further more, it seems logical that this profession would become the developer and guardian of the utilization of graphical information as a means to provide non-language dependent communication environments capable of spanning across cultures. Thus, we may be able to provide a technical visual solution to the language barriers that many cultures must cope with when entering a global industrial setting.

The power of graphics

Hypothetically, the appeal of a highly effective real image based visual communication system utilizing 3-D geometric modeling and simplified modeling databases, along with an efficient delivery system, would have a significant impact on current manufacturing processes.

Considering an analysis of current industrial work forces, and the realization of the global marketplace, it seems the application of a graphic based system would be beneficial when applied to a company or manufacturing environment with a:

- large training overhead due to multi-lingual environments
- large variation of jobs.
- low formal education
- poor attitude
- and have a high rate of turnover.

The type of graphic system proposed for implementation into a typical industry production environment would consist of a/an:

- electronic database distribution system.
- 3-D simplified modeling strategy.
- graphic database development and maintenance environment.
- custom graphic distribution software that is non-intrusive on existing systems or databases.
- dynamic real-time revision and updating of graphic information.

The success of such a simplified modeling based graphic system exists in its ability to effect change and improvement within the workforce by:

- meeting specific needs of its users.
- preventing excessive duplication of graphic tasks.
- positively effecting communication.
- providing predictable consistent responses to graphic stimulus.
- effecting total quality.
- providing a positive return on investment (ROI).

The following preliminary Pilot Case Study is presented as evidence of an attempt to substantiate the previous discourse and proposed graphic based simplified model system by implementing it into a real industrial setting.

Preliminary pilot study

Preliminary evaluation

The Whirlpool Corporation (Corporation) facility in the Purdue Research Park in West Lafayette, Indiana was experiencing what it defined as "excessive training investments" required to maintain the current production quality and quantity. This facility's main function is the packaging of aftermarket parts.

At the request of the plant manager, a systems analysis of the current work environment was performed. The purpose of the analysis was to determine if the potential existed to apply the previously presented system solution and graphic products in an attempt to alleviate some of their training overhead.

Many of the employee characteristics deemed necessary for a graphic based solution strategy were in evidence within the packaging facility. They included but were not limited to low motivation, high rate of turnover, large number of parts and a variety of complex procedures.

Demographics

The management staff at this plant consists of ten full time employees. Their average age is thirty-two years. They average approximately fifteen years of formal education.

The production workers consist of four-hundred fifty part-time student employees between eighteen and twenty-five years old at varying levels of completion toward their undergraduate degrees. The average worker turnover is approximately eighty percent per year and has been as high as one-hundred thirty percent. This employee turnover is a significant contributor to quality, assembly, part verification and excessive training overhead problems. Production employees are required to work a minimum of twenty hours and no more than thirty-eight hours per week.

Production

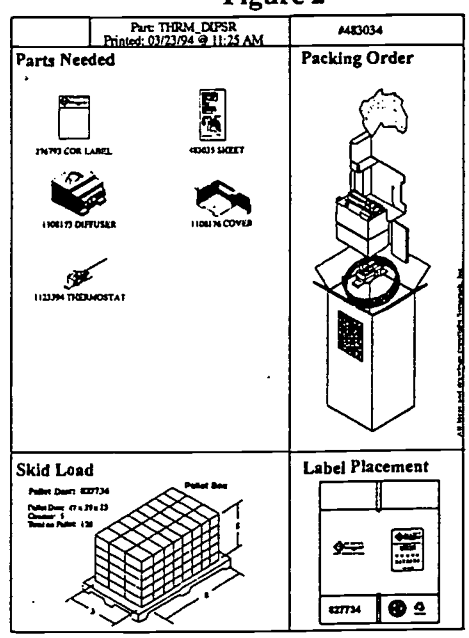
Currently, the Corporation processes over seventeen million parts per year. There are over two thousand five hundred stock keeping units (SKU) and kits derived from a total of six thousand eight hundred different components. The two thousand five hundred SKUs, are cycled to produce over fifteen thousand different jobs requiring training and retraining each year. These jobs are divided into three different production areas Combi (automated packaging machine), Manual Pack and Polybag.

Proposed system

After analyzing current documents and processes, it was determined that the development and implementation of a graphic based system to make and deliver visual operation sheets would be beneficial and cost justifiable. The new system must:

- provide the ability to be updated quickly and easily as there are a large number of changes that occur on each packaging job.
- not intrude on the existing systems or database information currently in use because job scheduling and process information exists in a management level MRP system inaccessible to the Corporation.
- be serviceable and deliverable within house.
- be capable of providing part verification, pallet configuration, label placement and assembly procedures.
- reduce mispacks and reworks while increasing employee productivity.
- be deliverable on the current PC technology computers.

Visual Op Sheet
Figure 2



To satisfy the needs of the new system, it was proposed to the Corporation that a simplified model graphic database of all components be created, a new visual operation sheet (Figure 2) be designed and implemented to augment and eventually replace the existing paper bill-of-materials type operation sheet

(Figure 3), and a new software capable of existing within the current technical envelope of the Corporation to generate the new operation sheets (op-sheet) be developed and implemented.

Old Op-Sheet
Figure 3

PACKAGING VENDOR OPERATIONS SHEET 1
Part numberPart name Pr cl pkg qty schd pcs/man people hours code
483034 thrm-dfsr re 01 h7 43.0 1 942302
Seq qty unit component #name note loc qty loc qty
1.00 276793 cor label 310201 79500
1.00 283241 kraft paper stuff 12x12 910101 45600
2.00 283267 kraft tape 9in. 254461 600
1.00 48300 sheet 361501 643
1.00 827734 carton 730341 55
1.00 1108173 diffuser 371501 136
1.00 1108176 cover
1.00 1123394 thermostat 371701 18
* *
K245 datecoding required
K250 part no. on rear of thermostat 1123394 is 1123393
K999 s 29 000144

The project would serve both internal and external customers. Internally, production schedulers, small parts personnel, selectors and production workers would benefit directly. The packaging process would become clearer and employees would have a better understanding as to what is expected of them, significantly reducing the potential for reworks and other errors. Consequently, other agencies within the Whirlpool organization would have access to the graphic database as needed. Externally, the consumer would be less likely to receive wrong or incorrectly packaged parts.

Along with the immediate benefits of the proposed system, one of the significant features is that it would allow expansion for future graphic products to be developed. The 3-D graphic database permits the development of animations and other graphic products to support the training required to perform an assembly process. Also, the new software permits the electronic distribution of visual operations sheet data (op-sheet) to the assembly workers. The infrastructure exists to accomplish these and other future tasks.

Project justification

To justify the funding of this project a simple return on investment (ROI) was used. It was discovered that fifteen percent of all jobs (2250) were being performed in the Combi area and the rest in the Manual Pack and Polybag areas of the plant. It was determined that the difference between the set-up and training required for Manual Pack and Polybag production areas was consistent but differed by the number of people at each job station.

A First Part Inspection (FPI) used for checking initial quality of each job at its start, as the end of the training component in the job setup, determined that it took each employee approximately fifteen minutes per job to reach the FPI.

The total training time expenditure for Combi jobs is 15% of 15,000 for a total of 2250 jobs. Combi has approximately 5 employees per job. Therefore, the total Combi jobs equivalent is 11,250 jobs. If it takes 15 minutes to reach FPI, then 15 x 11,250 equals 168,750 minutes or 2812.5 hours of training time per year. At a base wage rate of $8.00 per hour, including benefits, this works out to $22,500 spent each year for job training.The total training time for Manual Pack and Polybag areas is calculated by taking 85% of 15,000 for a total of 12,750 jobs times 15 minutes to reach FPI for a total of 191,250 minutes or 3187.5 hours expended on training per year. Using $8.00 per hour, this totals $25,500 per year for job training.

As a goal, an initial savings of 10 minutes per job in training was predicted. This would result in a combined total direct labor savings for a year of 66% or $31,680.

Residual or indirect benefits could be calculated by applying the above time savings to a projected increase in production. The 6000 hours saved in reduced training time could result in 409,960 additional parts per year. The dollar amount of savings is not known. However, the production employee time saved would in effect add the equivalent of 2 weeks of full production to the plants capabilities. This information and some preliminary testing persuaded management to initiate the proposed project.

Project team

Selection of team members for this project was based on management and leadership skills, planning and project coordination, total quality management knowledge, extensive production and packaging knowledge, packaging engineering services, technical services and project design and implementation. The Corporation team was composed of 8 people, which included the plant manager, production supervisor, quality control personnel, packaging engineers and technical manager. The external team consisted of a graphic engineer, a computer programmer, a computer technician, a project manager and 10 computer graphics modelers.

Implementation

The completion of models and software products took 6 months. Implementation and system testing took 2 months. Another 2 months was needed to bring the system to 90 percent efficiency. It is currently running at about 98 percent complete. The other 2 percent is due to the dynamic nature of the parts updating and op-sheet changes that occur daily. The current level of operation is considered by the Corporation to be optimal in nature.

Preliminary data

Data collected from production documents and observations is presented as preliminary evidence to indicate the potential for conducting a formal study to verify the perceived significance of the simplified modeling and graphics (Simgraph) project. The success of the project was measured through quantitative, qualitative and intangible benefits. The introduction of Simgraph to the production process reduced the time it takes to perform initial job setup by an average eleven minutes per job. Time savings were realized by reducing job setup time that includes reading the op-sheet, performing part verification, completing FPI and assembling the sample first part.

Setup time was reduced from nine minutes to four minutes for a 56% reduction. However, the most significant procedural time reduction came about in the skid pattern identification and label placement verification process. The time necessary to perform these operations went from five minutes to mere seconds.

Another benefit of the Simgraph system was a greater than expected reduction in training process time for new employees. A 20% reduction was projected, however, an average time saving of 62% per trainee was achieved. This includes a reduction of op-sheet learning time, pre-assembly parts verification and quality certification FPI time.

Rework reduction produced by Simgraph has not yet been reflected in the Corporation quality parts per million. This data will be revealed when the system has been in operation for a one year period. However, not a single rework has been attributed to the Simgraph system. Also, component verification errors and part assembly errors during the initial stage of implementation have been visibly reduced.

The total yearly projected savings, at this time, directly attributed to the Simgraph project, is $42,500. This number does not include the significant residual savings as stated earlier in the Project Justification.

Internal customer satisfaction has become evident through the actual time procedures reduction affected by Simgraph. The quality certification process that measures new employees' comprehension of the op-sheet and shipping procedures has shown a reduction of testing time. This is an obvious increase in the efficiency of comprehension within the training process. The training staff reported that, "Simgraph is an excellent work-simplification tool."

Conclusions

Technology provides the opportunity to develop electronic tools for industry that are capable of solving a number of visual communication and comprehension problems. Previously, most of these problems were impossible to solve. This paper introduces a huge opportunity for those who wish to pursue the realm of synthesizing graphics, engineering and technology to create visual environments that promote visual literacy.

Although some would say that the environment created at Whirlpool could have been solved with multi-media, other off-the-shelf authoring packages or a visual database product like Microsoft's Access or Borland's Paradox, let it suffice that during the testing and evaluation of the proposed graphic system solution, those products were tested and proved to be severely lacking when confronted with the magnitude of this project. Custom software for specific solutions is infinitely more adaptable in needs based environments.

It is the belief of the author that the solutions to many industry visual literacy training problems can be solved by designing and implementing discrete systems that perform specific visual information tasks. These systems must be compatible with, and a part of, the corporate data and technical envelope. They must also be non-intrusive on current systems. Top-down approval and bottom-up utilization scripts these type of systems for success.

The emergence of a graphic engineering discipline is inevitable. It may not be called graphic engineering, but a discipline that has as its roots in the fundamentals of communication, graphic creation, archiving, distribution and visual literacy while in a technical environment, will emerge. Unlike technical systems people, programmers, drafters and designers, although drawing from parts of all of them, when opened for closer scrutiny these individuals will know graphics, communication and technology. They will be able to apply graphics and its products to create environments that are visually far more powerful than those currently being used.

Other industries have used systems similar to the Simgraph system. One Fortune 500 company had a math and reading assessment survey performed on their union employee population that revealed that math and reading levels, according to a standardized test, were at fourth and fifth grade levels. Further testing revealed the workers had very high math and reading ability levels.

When they were offered the possibility of providing visual graphic tools and a system to distribute them within their company, they immediately realized that the creation of an environment that was not formal knowledge dependent would allow them to enable the workers to succeed in spite of their deficiencies. A system that provided comprehension, through visual literacy, using graphic images of products and procedures worked. Although success stories are too numerous to list, this example is typical.

The time appears to be approaching when graphic engineers will and must be able to design and distribute systems that are not language dependent. The need for such systems has existed before the development of formal language. Communication was based on grunts, gestures and of course, pictures. Is the reality of turning to a basic instinctive need to communicate with "pictures" the solution that frees us from the communication barriers that currently exist?

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