Simulation of the production chain by use of an XML-based Job Definition Format

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ABSTRACT

Based on the XML- standard a vendor and platform independent exchange format has been defined in order to manage the integration of the complete production chain. This Job Definition Format (JDF) has been initiated by the four companies Adobe, Agfa, Heidelberger Druckmaschinen and MAN Roland and is focused on the workflow of the printing and publishing industries. The further development and maintenance has been given to the CIP4 Consortium. At the University of Wuppertal in cooperation with the Heidelberger Druckmaschinen a JAVA class library for writing and parsing JDF has been implemented, which is published within the CIP 4 Consortium as an open source library. On top of this library a JAVA based simulation tool for modeling JDF Workflow is developed at the University of Wuppertal. This simulation shall enable to test new JDF agents, controllers and devices in an early stage without the requirement of a real existing production environment.

INTRODUCTION

Industrial production in the area of print and media production has been changed rapidly over the last years. In this production fields a long time most of the production had been mainly manual. Then the thirst step was the mechanization, which opened the way for automation. In modern production systems modular automated systems with high efficiency are used nowadays. However in most of the production environments the communication between the devices is not sufficient and the process is not fluid. In today's age due to changes of the market industrial production in the field of print and media production is facing to the following trends:

- Decrease of run length of jobs
- Increase of job complexity
- Requirements for flexible response

The increase of automation requires making processes more productive, more flexible and more transparent. Once efficient automation is in place, a job ticket is a next logical step. With this information provided by the job ticket, the production can run more efficiently.

The integration of the complete supply and production chain inside and outside the entire company can be realized based on a job definition format and using a job messaging mechanism. Integration based on modern Internet and database technologies shall offer better productivity at lower costs. This integration shall improve an efficient data acquisition, a reduction of make ready times and production cycles, and an increase of production flexibility. The integration offers advantages for vendors, production companies, and customers as well.

PRODUCTION IN PRINT AND MEDIA INDUSTIRIES

Modern production facilities can attend to each individual element of a print job and can even link some of those processes. However an information flow has been missing to handle a job from the moment a customer places the order to the moment the final product is delivered. A significant reason that this continues to be a problem is that multi-vendor cooperation is still possible only on a very limited basis. It still takes significant effort to get machines manufactured by different companies to work together. The encoding capabilities of versatile languages such as XML have been recognized, but so far not fully used.

An important lack in the printing production is that progress has so far had the least success in connecting. Management Information Systems (MIS), generally responsible for the planning and controlling of a job, and production services, responsible for the operation of a job, still remain in relative isolation from view of communication. There is no means for consistent, automatic, and effective bi-directional communication between the two indispensable facets of every printing business. All data enumerating planning and scheduling, process results, job status and job tracking must travel from production to MIS so hat the latter can process the information and provide instructions on how to continue. This still continues to be mostly a manual procedure. Today there is an entire process that is comprised of multiple machines and functions, all necessary for the completion of a job, but incapable working as a coherent unit. In today's age of digital unification this kind of fragmentation is inefficient and at a long run not acceptable in the business world.

In order to initiate a step towards the required production integration a vendor and platform independent Job Definition Format (JDF) based on the XML- standard has been initiated by the four companies Adobe, Agfa, Heidelberger Druckmaschinen, and MAN Roland and is focused on the printing and media industries. These companies brought their experience and knowledge into the development of JDF. The further development and maintenance has been given to the CIP4 Consortium.

JOB DEFINITION FORMAT (JDF)

A Job Definition Format (JDF) and a Job Messaging Format (JMF) have been developed for advanced interfacing of production based on the XML- standard. The JDF Format shall offer a product independent communication between various production areas and management information systems (MIS). JDF is a very comprehensive and flexible exchange format. It is independent from the system architecture, the operation system and the software product in use. The Definition includes also a Job Messaging Format (JMF) for advanced interfacing of production devices.

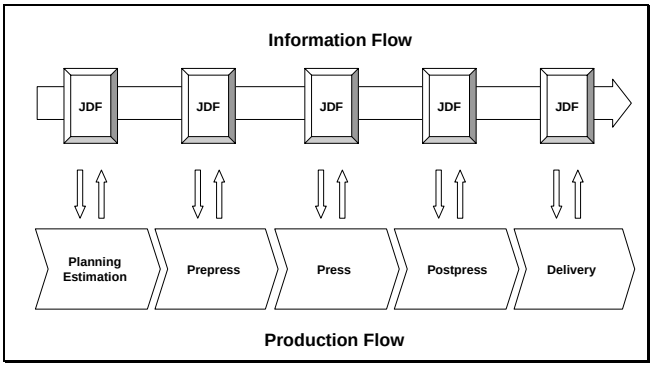

Figure 1: Print Production and Information Flow

The Job Definition Format (JDF) provides a mechanism to control all of the processes in production. The task of JDF is to handle the information flow for every part of a job from start to finish and to link the Management Information Systems (MIS) with the production equipment. Important is the ability of the JDF to perform both of these tasks no matter what tools are used. Unlike other job ticket formats, JDF allows the description of all the processes needed to complete a product, from job submission through the complete production processes. Each process step in a job is translated into a node and a tree of these nodes represents the entire job. All of the nodes taken together describe the desired product and the each individual node is defined in terms of inputs and outputs.

JDF is an open standard for integration of all computer aided business and production processes. It is designed to streamline information exchange between different applications and systems. JDF is intended to enable the entire print and media industry, including on demand and e-commerce companies to implement and work with individual workflow solutions. Advantages of JDF are the ability to carry a print job from creation through completion of a job, the ability to bridge the communication gap between production and Management Information Services and the ability to bridge the gap between the customer's view of product and manufacturing process. Integration gives the possibility to do so under nearly any precondition.

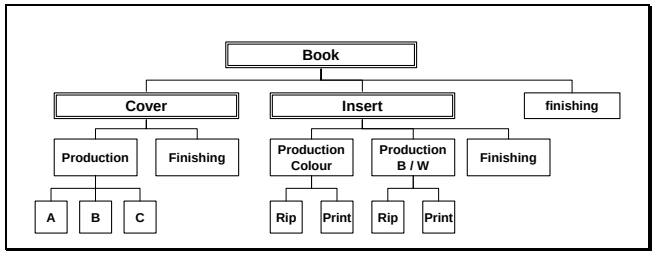

Figure 2: A subsection of the larger tree of nodes, depicting inputs and outputs [CIP4]

JDF defines the entire job as a hierarchical network of processes that are linked through the consumption of inputs and production of outputs, which in turn become the inputs for further processing. The end result is the combination of outputs that produce the desired finished product. JDF provides the ability to place individual actions into a greater context, so that each element is regarded by the structure as a part of the whole.

JDF can be used by business of any size, from a small size business with only a few jobs up to big size companies with a lot of jobs to handle. JDF provides possibilities to set up communication between systems from different vendors with minimum configuration efforts. It also facilitates the execution of every aspect of any print job, from creation through shipping.

PROCESS HIERACHIE

JDF jobs consist of a set of nodes that specify the production steps needed to create the desired end product. The nodes, in addition to being connected through inputs and outputs, are arranged in a hierarchical tree structure. The nodes describe the end product and the components of that product, which, in case of the example are the cover and the content pages. As the tree branches, the information contained within the nodes gets more specific. Each sub-node defines a component of the product that has a unique set of characteristic, such as different media, different physical size, or different color requirements. The nodes that occur in the middle of the tree represent the groups of processes needed to produce each component of the product. The nodes that occur closest to the bottom of the tree each represent individual processes. In the example there are two

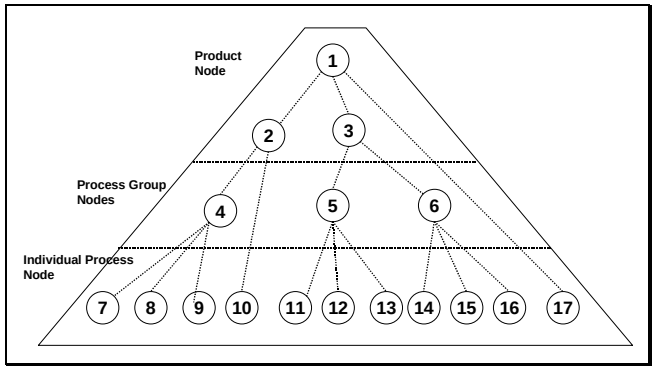

Figure 3.: JDF tree structure [CIP4]

sub-components of the job, the cover and the contents, each with distinct requirements. Therefore, two nodes are required to describe the elements of the job in broad terms. Within the content pages there might be some black & white pages, and some color pages. Since fabricating of each requires a different set of processes, further branching is necessary.

Many output resources of JDF nodes are the input resources for other JDF nodes. Many nodes cannot begin executing until all of their resources are complete and ready, which means that the nodes execute in a well defined sequence. One process follows the next. For example, a process for making plates will produce, as output resources, press plates that are required by a printing process. In the hierarchical organization of a JDF job, nodes that occur higher in the tree represent higher-level, more abstract operations, while lower nodes represent more detailed, specific process operations. More specifically, nodes near the top of the tree may represent only intent regarding the components or assemblies that comprise the product, while the leaf nodes provide specific, detailed instructions to a device to perform some operation.

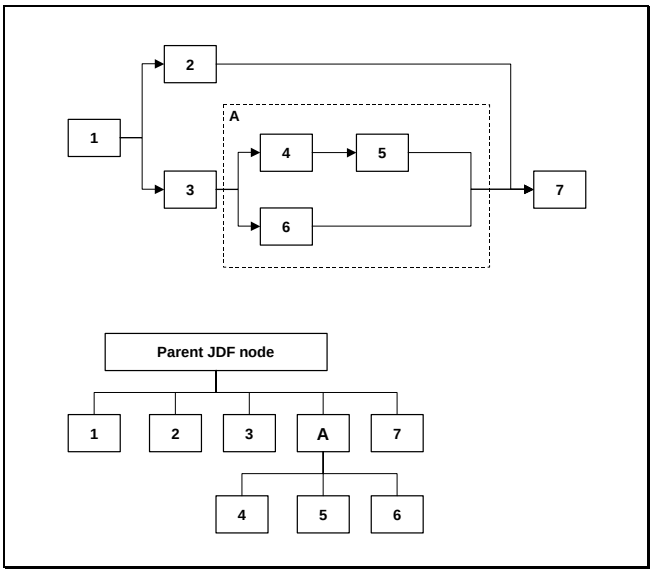

Figure 4: JDF Tree / Network Structure [CIP4]

In addition to the hierarchical structure of the node tree, nodes are linked in a process chain by their respective resources. An output resource of one node ends up representing the input resource of the following node. This interrelationship is known as resource linking. With resource linking, complex networks of processes can be formed.

```
    ...
- <JDF DescriptiveName="Buch1"
      ID="Link3d2:-7ffe"
      Status="Unknown"
      Type="Product">
    <NodeInfo />
  - <ResourcePool>
      <Component Class="Quantity"
          DescriptiveName="Umschlag"
          ID="Link3d2:-7ffb"
          Status="Unavailable" />
```

```
    - <SizeIntent Class="Parameter"
          ID="Link3d2:-7ffa"
          Status="Draft">
        <NumberIntent Name="Width"
            Preferred="615.0" />
        <NumberIntent Name="Height"
            Preferred="850.0" />
      </SizeIntent>
      <Component Class="Quantity"
          DescriptiveName="Inhalt"
          ID="Link3d2:-7ff5"
          Status="Unavailable" />
    - <SizeIntent Class="Parameter"
          ID="Link3d2:-7ff4"
          Status="Draft">
        <NumberIntent Name="Width"
            Preferred="615.0" />
        <NumberIntent Name="Height"
            Preferred="850.0" />

    ...
    ...

  - <JDF DescriptiveName="Umschlag"
        ID="236" JobPartID="236.0"
        Status="Unknown"
        Type="ProcessGroup">
      <NodeInfo />

    ...
    ...

      </JDF>
    - <JDF ID="1243"
          JobPartID="237.9"
          Status="Unknown"
          Type="ConventionalPrinting">
        <NodeInfo End="20.01.2001 19:36:00"
            LastStart="20.01.2001 11:13:00"
            SetupDuration="63.0"
            TotalDuration="503.0" />
        <ResourcePool />
        <ResourceLinkPool />
        <AuditPool />
      </JDF>
    - <JDF ID="1244" JobPartID="237.10"
          Status="Unknown"
          Type="ConventionalPrinting">
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            LastStart="20.01.2001 19:36:00"
            TotalDuration="24.0" />
        <ResourcePool />
        <ResourceLinkPool />
        <AuditPool />
      </JDF>
    </JDF>
  </JDF>
</JDF>
```

Figure 5. Part of an JDF Example

In JDF, the linking of processes is not explicitly specified. Nodes are not arranged in an abstract chronology, dictating, for example, that the trapping node must come before the Ripping node. The links are implicitly defined in the exchange of inputs and outputs. Resource dependencies form a network of processes, and the sequence of process execution can be derived from these dependencies. One resource dependency might have multiple possible process routing scenarios, and it is up to MIS to define what will be a

proper solution with respect to the local constraints. The agent or set of agents employed by MIS to write the JDF job must therefore be familiar with these local constraints. These must take into account factors such as the control abilities of the applications that complete the pre-press processes, the transport distance between the pre-press facility and the press itself, the load capabilities of the press, and the time requirements for the job. All of the factors taken together construct a process network representing the workflow of production. To aid agents in defining the workflow, JDF provides the following four different and fundamental types of process routing mechanisms, which may be combined in any way:

- Serial processing (subsequent production and consumption of resources as a whole, represented by a simple process chain)
- Overlapping processing (simultaneous production and consumption of resources by pipes)
- Parallel processing (involves the splitting and sharing of resources)
- Iterative processing (circular or back and forward processing for developing resources by iteration)

INTEGRATION OF MANANGEMENT INFORMATION SYSTEMS

It takes significant effort to get equipment manufactured by different companies to work together. The encoding capabilities of versatile languages such as XML have been recognized, but so far not really used. Furthermore, two of the biggest and most important islands in the printing workflow are the ones that progress has so far had the least success in connecting. Management Information Systems (MIS), generally responsible for the planning and controlling of a job, and production services, responsible for the operation of a job, still are not sufficient integrated. All data enumerating planning and scheduling, process results, job status and job tracking must travel from production to MIS so that the latter can process the information and provide instructions on how to continue.

JDF provides a mechanism to allow production automation systems (MIS) to control and track jobs. JDF supplies a messenger service to run between MIS and production. As each process in a job executes, the results are recorded into the job to facilitate tracking each aspect. The architecture defines a standard set of messages, a format for all messages, and a set of protocols, which devices can implement. Furthermore, a range of messaging capabilities is provided. The minimum available capability is no messaging. When no messaging is selected, the controller must examine the JDF to determine the results of processing. Independent of messaging capabilities, JDF includes different audit records for each process that provide details of the planned and actual results of the process. Most devices, however, will choose to support some level of messaging capability. Devices may support commands. If command capability is selected, the controller can issue a directive to interrupt the current job, to restart a job, or to change the priority of jobs in the queue. Besides messaging, another option JDF provides to controllers is the ability to collect performance data for each process and pass that information to a job-tracking system for use by the job accounting system.

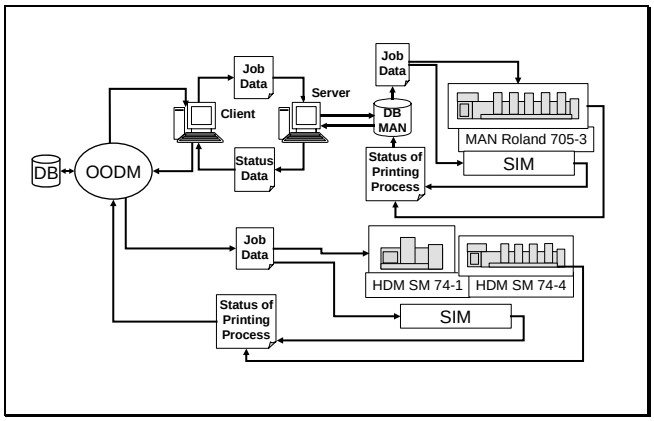

Figure 6: Integration of virtual printing facilities into the production environment

Alternatively, the completed job may be passed to the job accounting system, which examines the audit records for itself to determine the costs of all the processes in the job. Each individual project manager selects the option or set of options for each individual job. JDF is a vendor-independent standard. While the first version of JDF is being developed, the four companies involved intend to pass control of the specification to a cross-industry consortium. This ensures that all vendors can develop systems that use JDF, and that no vendor is disadvantaged with respect to any of its competitors.

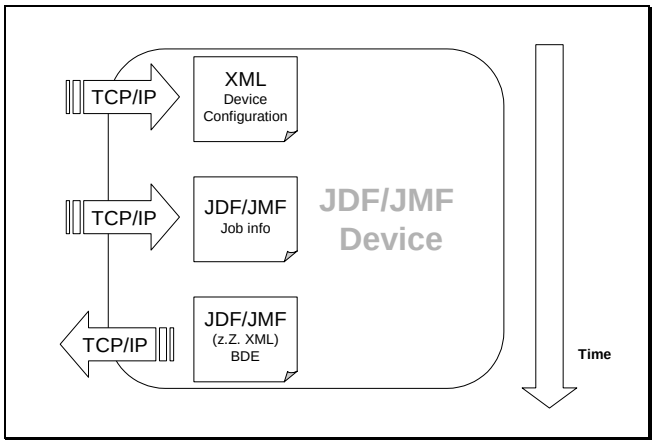

Figure 8: JDF/JMF Device

JDF defines a messaging architecture, which includes message formats, semantics, and message protocols. JDF devices use this architecture to communicate with systems that control production facilities. System vendors therefore are given a great deal of flexibility in terms of how they choose to use the messaging architecture, and whether they provide both notification and control facilities. JDF offers a good opportunity for the integration of MIS.

SIMULATION OF THE PRODUCTION CHAIN

A JAVA class library for writing and parsing JDF has been implemented at the University of Wuppertal in cooperation with the Heidelberger Druckmaschinen. This library is published within the CIP 4 Consortium as an open source library for members of CIP 4. Based of this open source library software for agents, controllers and devices can be developed efficiently.

On top of this JDF library a JAVA based simulation tool for modeling the JDF Workflow has been developed at the University of Wuppertal. This simulator is using the same JDF communiction structure as the real JDF system. The resources in the simulator are discrete event simulation modules, which simulate the production on a requested level of detail. For testing the communication this might be a model with a very low level of detail for the production processes, however a very high level modeling of communication issues.

Through a web interface the user can put a JDF in a hot folder as input information for the simulation. The required process information is send via JDF towards various production resources. These simulated resources can be run either on one single computer or as separate processes on distributed systems connected via TCP/IP. In a future stage for testing purposes even 'real' JDF-machine controller may be integrated into the simulation environment.

During the simulation run discrete events such as state of the production, error messages etc. are generated by the simulator and are send by use of job messaging towards the controller

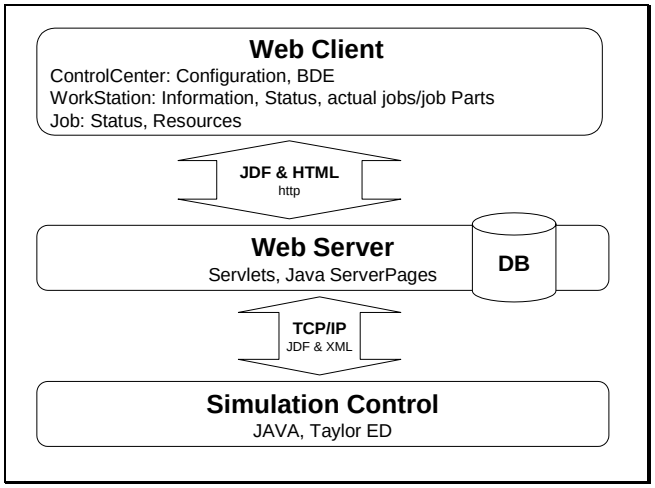

Figure 7: Concept of JDF/JMF Simulation

With this concept an advanced approach to test new JDF agents, controllers and devices already in an early stage nearly under production conditions can be realized. This has advantages for a simultaneous engineering and development process. The test can take place in an early stage without the requirement of any real existing production environment.

SUMMARY

With the Job Definition Format a very comprehensive vendor and platform independent exchange format based on the XML-Standard has been developed for the printing and publishing industry. JDF provides a flexible and comprehensive solution. It is capable of creating a bridge between each separate production area, from the time a customer places an order to the time the finished product is delivered to the customer, regardless of how many manufacturers contributed resources, or how complex the task is.

However the industrial use will depend on how fast many companies will realize the JDF in their control applications soon. Production can be controlled more transparent so that production facilities can accurately estimate and fairly assess the costs of producing work for customers. A generalized version of the Job Definition Format and the Job Messaging Format might be a challenging opportunity even for other production industries.

The simulation of the producition chain by use of the JDF developed at the University of Wuppertal offers an efficient investigations and tests of the required communication between various JDF agents, controllers and devices. The simulation allows to test the communication in detail before real machinches with those commication features are available in the market.

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BIOGRAPHY

WOLFGANG KUEHN studied mechanical engineering at the University of Brunswik, Germany. Afterwards he worked two years with Blaupunkt. At the University of Bremen he got 1991 his PHD in production engineering and 1997 his habilitation in the area of simulation of production systems. From 1993 to 1995 he worked as Associated Professor at the Asian Institute of Technology in Bangkok. 1996 he founded the SIPOC Simulation based Planning, Optimization and Control GmbH in Bremen and since 1997 he has a professorship at the University of Wuppertal in the filed of production planning and control.