INTERNATIONAL DESIGN CONFERENCE - DESIGN 2004
Dubrovnik, May 18 - 21, 2004.

TOWARD A DATA MATURITY EVALUATION IN COLLABORATIVE DESIGN PROCESSES

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Keywords: evaluation, data maturity, collaborative design process

1. Introduction

Aircrafts are complex systems to define and assemble. Their development requires association of several thousand engineers and technicians that work together in a common process called concurrent engineering. In concurrent engineering, complex design activities currently require the collaboration between multidisciplinary actors working in geographically distant companies (i.e.: Extended Enterprise). Management of these activities is mainly based on the concept of collaborative spaces [Girard & al., 2003] where engineering data should be shared in real-time. The literature proposes solutions based on a common design framework defining a system reference architecture and a generic data structure [Hubel & al., 2001], both are generally supported by software [Chung & al., 2002].

2. Problematic and context

Due to the complexity of the aircraft and the important workload, several different design teams are created in order to define the main parts of aircraft to assemble (i.e.: wings, landing gear, fuselage nose, propulsion, etc.). This is the classic example of the engineering breakdown structure developed in Airbus. Also, they work together, the progress of each design team is not equal. So, fourteen milestones cover the design process from the first idea up to end of the development phase of the new aircraft. These milestones help designers to define a controllable concurrent engineering design process. For each milestone, designers implement and conduct program reviews to evaluate their progress as well as to solve problems and to freeze the different solutions, ratify the development of the aircraft.

Between two milestones, teams and designers exchange information among them in order to progress correctly. They also exchange information with their partners (engine manufacturers for example) or subcontractors that are usually located in distant engineering offices. So during the design process, some designers need a way to appreciate the data they produce compared with fixed objectives; the other have to compare the data they want to use compared with their needs.

The purpose of this research concerns the engineering data exchange control, in order to control the design collaboration. It proposes to define a data evaluation system based on the concept of “data maturity”. The generated indicators measure the data satisfaction level for each designer. Instead of noticing delay, information is provided on the data information level and so allows the designers to anticipate on difficulties. Like this, those indicators will help actors decision making to perform their own activities.

In this context, Airbus decided to launch research activities. The Engineering and Information Technologies department of the EADS Corporate Research Centre has been in charge of the analysis including the development of methods and tools. We defined this level as the “maturity” of data. More generally, the notion of data maturity can be generalized to all collaborative activities that exchange evolving data.

3. Data evaluation to control design processes

Along design, actors perform activities using and creating information (Figure 1). Created information is made in accordance to objectives. Objectives are fixed either at strategic level [Girard & Doumeingts 03], or during collaboration initialisation phase (objective definition is not developed in this paper). Some actors need to evaluate received information, in order to use it. Other actors need to evaluate the accordance level of the produced information in comparison with objectives. Exchanges between actors generally occur from one actor to several actors (1 to N).

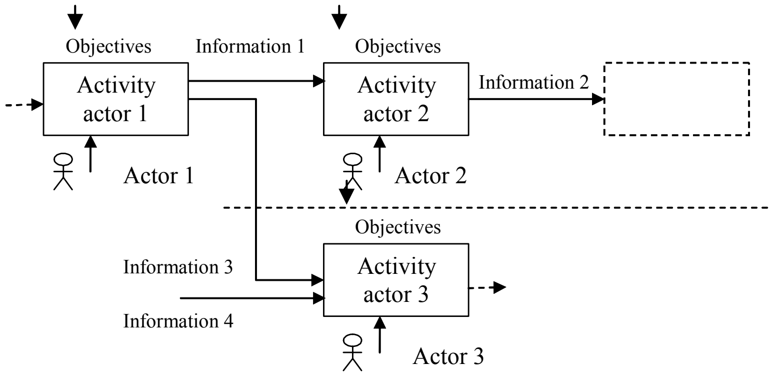

Figure 1. Information exchanges between actors

The next paragraphs analyses the different actor's points of view that could have along design activities, and describe the kinds of exchanged information. Data will be evaluated in order to facilitate actors activities as well as to pilot decision making in design.

3.1 Actor analysis

In the collaboration activities, the actors (the designers) that exchange information could have two points of view during the design.

- The "**provider**" of the information. A designer is sharing his information to the others designers who need it. During the exchange, he provides data with several states of maturity (see next chapter).
- The "**receiver**" of the information (the designers who need information), has a point of view of evaluator and compares work in progress to objectives (his/her needs). He defines the objectives that the provider will comply with.
- The "**coordinator**" is played by an actor different of "receiver" or "provider". His aim is to manage the convergence in order to realise the product.

3.2 Data analysis

First of all, some precisions must be revealed concerning the granularity of data. Several authors already set a taxonomy of data, information and knowledge [Prudhomme et al. 01] here after these different definitions are summarise:

- **Data** is the atomic element of information exchanged between designers: for example numbers, words, illustration, part of a plan…
- **Information** is a set of organized and structured data with a semantic. They are that are exchanged in a context,
- **Knowledge** is processed information, that should be:
    - **Explicit knowledge** could be easily expressed orally or in writing,
    - **Tacit knowledge** or know-how acquired by experience,

The propose method, deals with formal exchange of information in the collaborative activities. Information is made of data. To explain the different state of these data during the design phase, a set of three data elements is proposed:

- **Data TBD** "To Be Defined": indicates the objectives to comply with, it's the structure of the future information without the content. Objective has to be defined and need to be stable, it expresses the needs.
- **Hypothesis data**: the global information relies on hypothesis made on non validated data that could be modified until their delivery. At the beginning of the design most of the data are hypothesis.
- **Reliable data**: is the part of consolidated data. Only a serious change could affect this part of the information, which is stable by definition. For example, the constants are always reliable data…

4. Information, place of data maturity evaluation

4.1 Concept of maturity

To perform this evaluation we propose the concept of maturity. This is based on a level of maturity named "Relative Maturity" (Mr). This level is the ratio between the "Absolute Maturity" (Ma) and "Objective Maturity" (Mo) defined hereafter : (Equation 1)

$$Mr = \frac{Ma}{Mo}$$

Caption
- Ma : absolute maturity
- Mo : objective maturity
- Mr : relative maturity

Equation 1: Maturity formula

- "**Absolute Maturity**" (Ma) identifies the current maturity level evaluated by the provider and the receivers of the data. *At the design beginning, the absolute maturity is null, then absolute maturity increase to reach the objective maturity level.*
- "**Objective Maturity**" (Mo) characterizes maturity level that data must reach at a given milestone (program, product) and represents the objectives pursued by designers. *Mo is defined at the start of the collaboration.*
- "**Relative Maturity**" (Mr) is the global maturity indicator. It highlights the gap between Mo and Ma. This indicator is a ratio between the absolute and objective maturity. *So "Mr" stands between 0 (at the design beginning) and 1 (when Ma reaches Mo).*

For each exchange, on both sides, the provider and the receivers perform their own evaluation of the different maturity ("Ma" evaluated, "Mr" calculated):

- The provider indicates an evaluation of the provided data (the progress of his work).
- The receivers send a feedback on the usability of the data sent by provider.

4.2 Metric for evaluation

The maturity concept is defined as a level (more clearly as a ratio). Up to now, the possible values of maturity (Ma and Mo) have not been yet validated. Indeed, the evaluation of maturity is subjective. Provider and receivers define their own parameters in order to estimate the maturity of data (content in the information exchanged). Parameters are considered as an understandable reference language for each points of view (provider and receivers) even if designers have different skills: i.e. hydraulics, mechanics, electronics,… or knowledge. The next table (Table 1) shows an example of parameter. Each parameter could take several values defined by the users. Eventually, provider and receiver may have common parameters.

Table 1. Example of provider and receiver parameters values definition

	Parameters	Possible values of the parameters				
Provider	Complete	TBD		Draft		Full
	Precise	Null	Poor	Medium	Correct	High
	Final	NO				YES
	Consolidated	NO				YES
Receiver	Comprehensive	NO	To describe	More info	To precise	YES
	Consistent	Null	Poor	Medium	Correct	High
	Exploitable	NO				YES
	Actual	Obsolete				Actual
	Acceptable	NO	To modify	N/A	To discuss	YES
	Values	0	25	50	75	100

5. Dynamic aspects

The provider and receivers jointly specify the objectives of information (document, plan, etc.) in term of quality and quantity of data that is described by “Mo”. During each exchange, both designers (provider and receivers) give an evaluation “Ma” of data and calculate the ratio “Mr” according to their point of view.

- First situation: the “Mr” ratio evolutes (increase) for each point of view: in this case the different actors converge for the iteration of the exchange. The data (included in the information sent by provider) correspond to the receiver expectations.
- Second situation: the “Mr” ratio evolution of each point of view diverges: in this case, a receiver disagrees with the provider. This highlight that they have to discuss together in order to found an agreement.

6. Multi-users

In design phase, exchange is done between more than two designers (a provider and several receivers). The needs of receiver differ (in term of data maturity):

- they don’t necessarily use the same parameters to evaluate the data maturity,
- the evaluation made by several receivers on a common parameter could differ

Consequence: it becomes hard for the provider to take into account the feedback of the whole receivers. He may have several recommendations coming from the different receivers. As he is the focal point of the discussion and centralizes all opinions, he could be quickly submerged by numerous feedbacks (Figure 2).

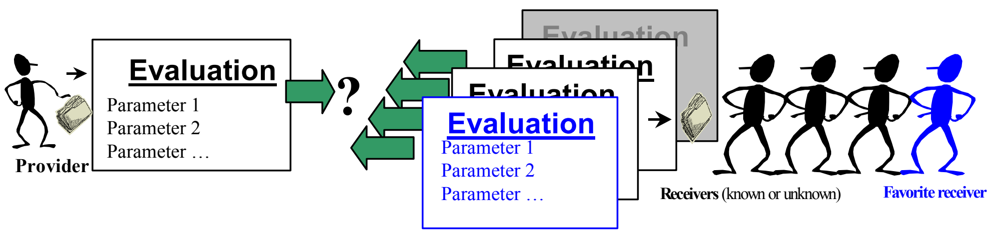

Figure 2. Multi user evaluation

He needs a mean to aggregate the different feedbacks of receivers in order to have a global vision of the situation.

To answer this problem, an aggregation matrix, an integration matrix and a dashboard are proposed.

“Aggregation matrix”: it combines the value given by several receivers for each maturity parameters. Each level in the parameter scale is represented by a value in the table. The following table shows an example of aggregation matrix (Table 2).

Table 2. Example of aggregation matrix

Name	Coefficient	Comprehensive	Consistent	Exploitable	Actual	Acceptable
		Parameters				
Receiver 1	8	5	4	5	6	5
Receiver 2	2	4	3	5	1	1
Receiver 3	1	12	2	1	3	1
Receiver 4	1	2	5	1	4	1
	Minimum	2	2	1	1	1
	Maximum	12	5	5	6	5
	Average	5,17	3,75	4,33	4,75	3,67
	Maturity	5,78	3,67	3,89	4,33	3,44

The aggregation matrix takes into account the importance of each receiver (coefficient of importance); so for each parameter, an average value is calculated with the following formula (Equation 2).

$$Average_{parameter} = \frac{\sum_{Receiver} (Value\_parameter_{receiver} \times Coefficient\_favorite_{receiver})}{\sum_{receiver} Coefficient_{receiver}}$$

Equation 2. Parameter average

Then a “global objective maturity” (Equation 3) is calculated by balancing each parameter average.

$$Total_{parameter} = \frac{Max_{parameter} + (4 \times Average_{parameter}) + Min_{parameter}}{6}$$

Equation 3. Global objective maturity

Aggregation matrix is used to give a synthetic point of view of the different receiver’s feedbacks for each parameter. It helps the provider to realise a first large evaluation level corresponding to the different parameters used to define data maturity.

“Correspondence matrix”: it is settled in order to link and translate parameters (aggregated or not) from the receiver language to the provider one, vice versa. A parameter of the provider is function of the parameters of the receivers. So a “linking coefficient” fixes the dependence level between them. Note that coefficient must be set according to the whole participants of the collaboration. The correspondence matrix (Table 3) permits to link and valuate the absolute maturity to the objective maturity (i.e.: the provider’s and receiver’s parameters).

Table 3. Correspondence matrix between provider and receiver parameters

		Receiver parameters				
		Comprehensive	**Consistent**	**Exploitable**	**Actual**	**Acceptable**
Provider parameters	**Complete**	2	1	5	1	0
	Precise	1	6	1	0	3
	Final	4	0	3	6	1
	Consolidated	2	1	0	7	9

“Dashboard”: as the matrices are not user-friendly and some processes must be “transparent” for designers, a dashboard shows pertinent and synthetic information relating to the exchanges. This allows to highlight particular problems linked to a specific parameter for one receiver (for example divergence on a single maturity level).

7. Illustrator EMICA

An illustrator was developed on Windchill© in order to test the concepts and to automate the calculus maturity of data. Based on the maturity cycle, two workflows were been created and implemented in a demonstrator called EMICA: Evaluation of Maturity of Information in Aeronautical Design. The first workflow aims to do the follow-up of the maturity of documents (Figure 3). The second is used to support the iterative evolution of the maturity of documents (Figure 4).

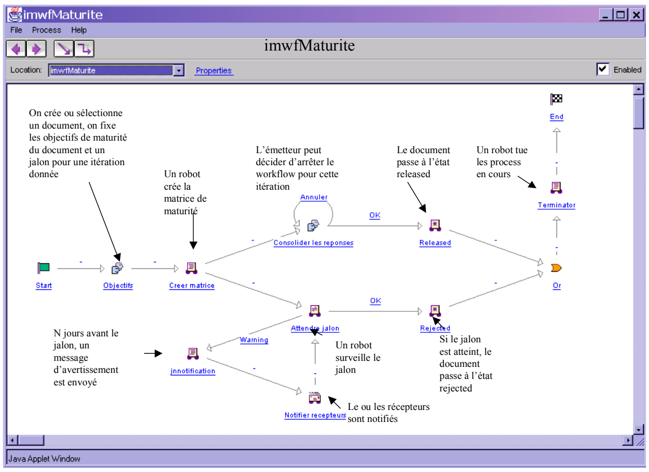

Figure 3. Maturity follow-up workflow

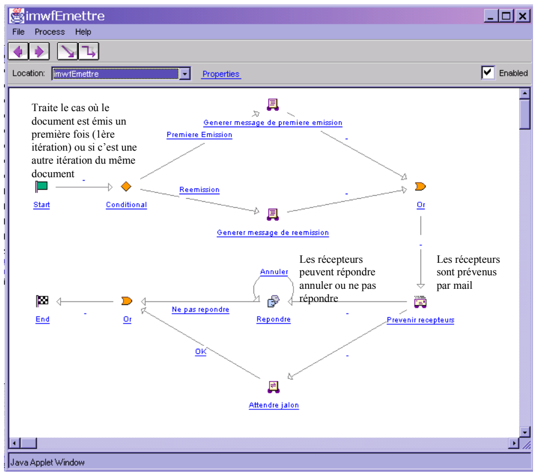

Figure 4. Iterative evolution of the maturity workflow

EMICA tool improves communication between collaborative teams allowing designers to follow-up data exchange and the evolution of their maturity between two main milestones. When he starts a new document, the provider defines the corresponding maturity parameters and informs the different designers that will receive the document. After its reception, each receiver read the document and informs automatically the provider (by a dedicated process) about its awaited maturity (with the parameters).

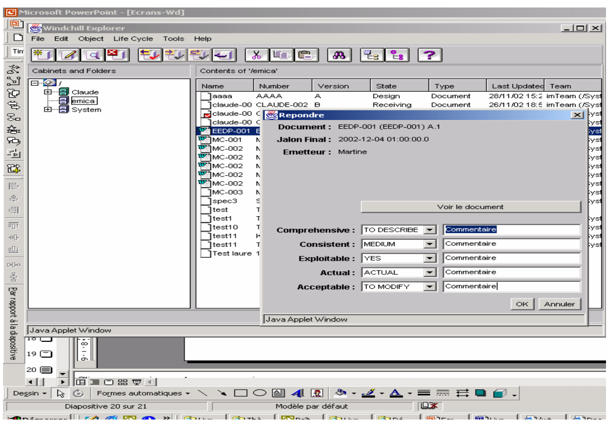

Figure 5. Receiver feedback

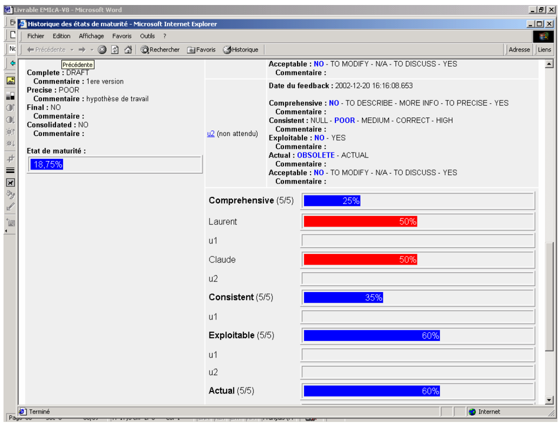

Figure 6. Maturity history

The answer of receivers (Figure 5) is taking in account and the value of their parameters is calculated to define the maturity of the document. Each evolution is included in an iterative loop, allowing to evaluate the objective maturity and the relative maturity. Then the provider can consult the maturity history of the information (Figure 6).

8. Method advantages

The main result of this work is the definition of the "maturity" concept. Relative maturity stays between 0 and 1, different representative levels of maturity could be affected to these values. For example a distribution with four levels (created, hypothesis, consolidated, delivered) could be proposed. All those concepts where integrated in the method of evaluation of the maturity (Figure 7, Figure 1).

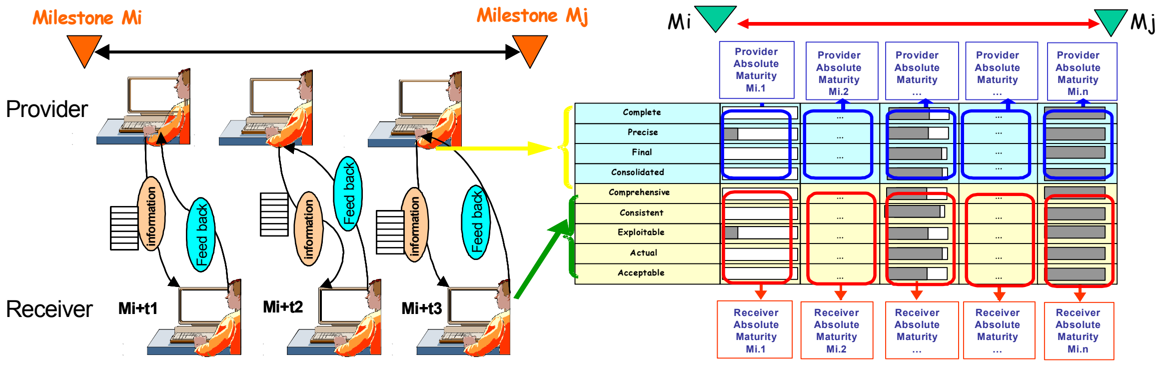

Figure 7. Main view of maturity concept

Both integration and correspondence matrix facilitate communication in the collaboration team. Provider and receivers fulfil these matrixes only one time, at the beginning of the exchange. Firstly, they fix objectives (Mo). They also select the number and type of parameters they will use to define their maturity (Table 1), the weight of each receiver (aggregation matrix) as well as the linking coefficient between the parameters (correspondence matrix).

Then, during exchanges, they evaluate their maturity level and discuss if there is a problem of convergence. With EMICA, the use of matrix is transparent for the users. In fact, providers and receivers only need to indicate their parameters table (Figure 5) (when they send information and feedback) and, at last, analyse information and progress of the maturity on the dashboard.

9. Conclusion and perspectives

This methodology enables to show the data maturity evolution. It constitutes a mechanism of anticipation in order to allow designers, belonging to a collaborative team, to converge more efficiently and quickly through a common goal without waiting the milestone. Future research is axed on a formalization of collaborative teams and their exchanges, and then on the specification of a collaborative platform. This platform will allow the designers to manage themselves their processes and exchanges in a specific design context. A part of the concept of maturity is integrated in the IPPOP meta model [IPPOP]. Maturity is both linked with the information (product data) and with the transition between activities. This work treats only formal information, informal information are not managed in the method.

The characterization of the parameters and the maturity level is complex and depends on the skill specificity. For the designer's point of view, the maturity seems as a qualitative representation of the information they must transform in a quantitative way to evaluate. The correspondence matrix seems a really good tool to manage the maturity evolution of information in the collaborative teams (that becomes more and more hard). The development of a global method on managing and decision making in collaborative processes will help users to improve exchange, to valuate their work and to anticipate design evolution. At last but not least, the main advantage of such method (and its application) concerns the new ability of designers to know more exactly the usefulness degree of their information.

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