A Novel Framework for Technological Evolution within Product Architecture

Yannick Chapuis*, Frédéric Demoly, and Samuel Gomes

IRTES-M3M,
Université de Technologie de Belfort-Montbéliard (UTBM),
90010 Belfort Cedex, France
{yannick.chapuis,frederic.demoly,samuel.gomes}@utbm.fr

Abstract. Nowadays, products are increasingly complex mostly in the area of high value-added products such as airplanes, oil rigs, digger or central power generation. More generally, these products are more complex due to successive and concatenation of innovations introductions while products constraints needs a capitalization of all developed technologies. This paper introduces a novel framework for technological evolution/introduction within product architecture in order to assess and manage product family and modular architecture to personalize and customize products. This framework is based on a medical analogy to walk through customer need recognition, product portfolio, and new technological introduction in all product lifecycle. To be proactive, this challenge highlight the need to capitalize knowledge and lesson learned on the past, present and future of the product architecture and technology used in today's products based on innovative processes. More than one part, a technology is characterized by resources needed by this artifact in order to answer to an added function, new requirements, or added services. So a methodology will be proposed to tackle this challenge to be innovative in product design.

Keywords: Product architecture, Technology impact, Technology introduction, Proactive engineering, Complex product.

1 Introduction

Nowadays, numerous design processes are proposed in literature to develop a product answering to customers' needs while guaranteeing cost and delay. This step is in accordance with PLM (Product Life Cycle) strategy which proposes an integrated management of all lifecycle data [20][4]. Moreover, linked to globalization of large scaled companies [24], delocalization of business actors leads to make the engineering more collaborative [11]. In addition to this collaborative engineering, productivity has forced engineering to reduce design times, improve responsiveness and thus spent a sequential cycle to said integrated concurrent engineering or even proactive [16][22]. In such acceleration, the design process

* Corresponding author.

V. Prabhu, M. Taisch, and D. Kiritsis (Eds.): APMS 2013, Part I, IFIP AICT 414, pp. 219–226, 2013.

for X [2] have emerged and proven. Despite these good intentions, the very large and competitive market, forcing company's product with high value and long life cycle such as oil platforms, digger, and airplane or energy production plant meet each offer. This requirement highlights the need for each company, each to be agile and therefore take into account the variability of the product [1] compared to variability of demand [12] and therefore the one to the other [21]. In addition, all of these processes must be applied to methods such as the waterfall model [17], the classic V-cycle [8] or even the iterative method [23]. In many cases, the R&D department is separated from operational service, this difference is at the origin of many shortcomings in the design of new products. Indeed, efforts to link the process of design and the innovative process are still numerous. From 'Black Box Model' of Schumpeter [19], where is the market which ask to companies to develop new products with innovation to Kline and Rosenberg model [13] where is the design process is addressed and directive, some models finer and complex, are still unable to aggregate the creativity and design. According with definition of 'Frascati manual' (1993) one innovation covers new products and new processes or technological modification of them. One innovation is done when it is introduce to the market. At the opposite of the invention, innovation induces social change, progressive or radical, and use. In the same view with Kline and Rosenberg [13], Design process is a sub-process of innovative process, and design process is a succession of stem from needs identification to specification book (destined to manufacturing phase).

2 Overall Methodology Descriptions

2.1 Multi-aspect Positioning

In accordance with ISEA framework (Fig. 1) where different aspects linked to technological introduction were described, authors propose a new method

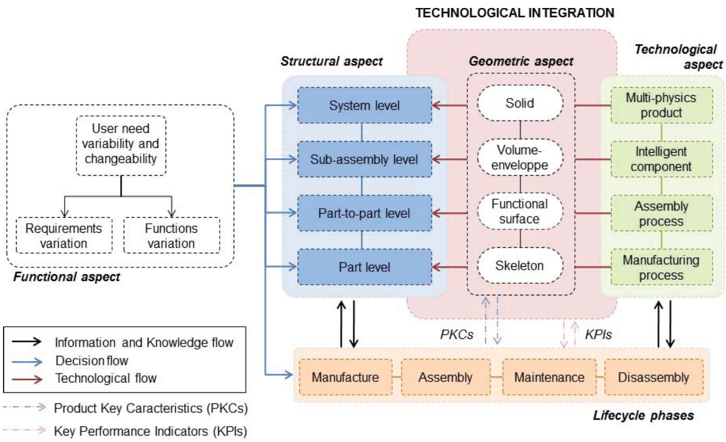


Fig. 1. ISEA Framework [3]

(Fig. 2) which allows technological transplantation seen in [3]. One can note this framework deals with several aspects, there is no knowledge notion because it is included in each aspect (engineering knowledge management). First of all, it is necessary to understand and to manage the state of art of the current product. This work, in the frame of an application, must be guaranteed not to miss out different aspects proposed in (Fig. 2).

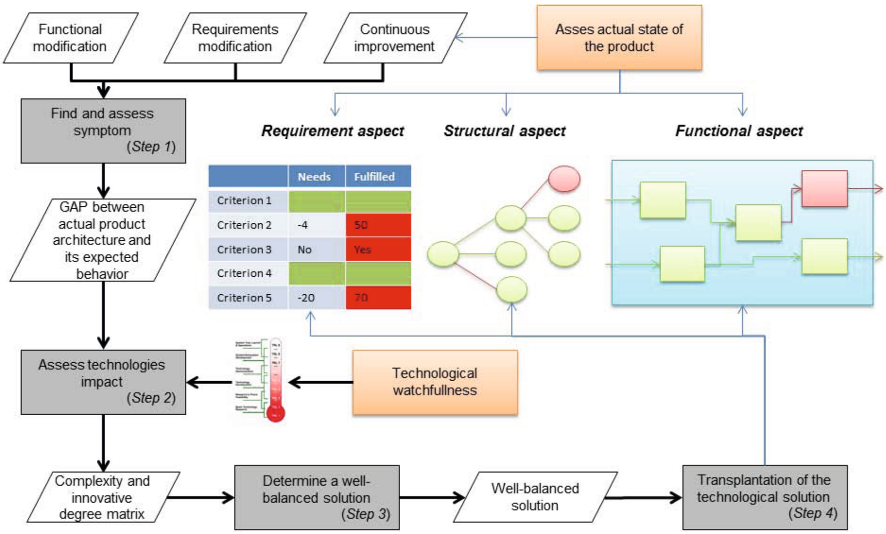


Fig. 2. Method for new technological integration

2.2 Symptoms Research: Semiology

Semiology is particularly used in the medical area but also in geography or cinema. Indeed, this science which studies signs in the medical area, studies symptoms of a disease, the way to capitalize it and to propose a diagnosis. Make a diagnosis need before this step to detect a disease through some elements. These elements are, in product design frame, a change or limitation of requirements, a dysfunction, function not integrated, a service not included or more generally, a product improvement. So the first activity of this method is trigger by one or several aforementioned. The limitation requirements are the easier to visualize. Indeed, by a feedback on products already introduced in markets, it is easy to assess components capacities already developed and integrated. Thus a matrix is allowing the realization of multi-criterions viewing of the customer expectations compared to product capacities. In the way of a non-capacity, it is possible to check more precisely limiting components and to propose a new technology, a new component (assembly or sub-assembly) to answer customer needs. All triggering elements can also directly affect the structural aspect. A customer can, expressly request a specific component, sub-assembly, assembly or a system for its maintenance globalization for example. It is possible to assess the product tree extent in order to measure and manage product options and interactions between products. Finally, it is possible to customize and personalize a functional point of view to ensure the better offer to clients. It is necessary to assess the margin between several models ('Black Box Model') and customer requirements. Generally, this step consists in having a product overview on complete and global product architecture. Furthermore, this kind of catch permits to trace impacts from a view to another such as Königs explains in [14]. Thus, complex product semiology is presented, and to join the proactive idea, an effort to capitalize knowledge for the entire lifecycle product as manufacturing [5], is required in a PLM tool for example. In this way, limiting systems can be known and solution research furnishing an answer can now be started.

2.3 Technology Impacts Assessment

As previously seen, new technology introduction in the product is necessary to fulfill customer needs. These new technologies can be part of a set of innovative processes. Indeed, technological surveillance can tackle limits of high value added product. That is why the first sub-step in this phase (Phase 2 of (Fig. 1)) is to position technology in a scale from an overall technological point of view (technology versus maturity). This Technology Readiness Level (TRL) is amply accepted and was introduced by the United States Department of Defense [7] and the National Aeronautics and Space Administration. After a modernization of level definitions and numbers, it allows to position and extend development and applicability of numerous technologies in governmental and industrial companies. In this case, main steps of this model are Fundamental research (1, 2), Applied research (3), Experimental development (4, 5), Prototype (6, 7) and Industrial development (8, 9).

This common scale permits to understand the state of a technology, assess the risk with this choose but the assessment of this technology in a complex product is difficult. In fact the point of view of the technology readiness level is centered in the technology (in its maturity). Nowadays, it is important to express this point of view in the complex product to assess the impact of the technology in the architecture. The majority of technologies are developed in companies whose need it, it is important to introduce this technology and so on, to be innovative, to measure the adaptation of this technology in two companies and, two products. Therefore the concept of donor and recipient (as in the medical area) is introduced. Since technology integration issues in product design covers conceptual and detailed design stages, the proposed analogy is made at various abstraction levels (related to the complexity level of the technology) and according to the origin of technology area. As such, (Table 1) presents three distinct technological introductions based on medicine experience: graft, transplant and establishment. For each introduction scenario, some properties have been added in order to know if the proposed integration requires particular attention to the relationships with existing product components and related stakeholders for both sides (i.e. receiver and donor). Another relevant property is the initial

Table 1. Analogy of medical transplantation

Properties	Graft	Transplant	Establishment
With relationship	❍	●	●
Same domain	●	●	❍
Medical analogy	Cells	Kidney	Pacemaker
Engineering Examples	Standard part replacement	Car fuel switching	Added service inclusion

domain of the technology which must be incorporated. For instance, graft and transplant are processed within the same domain, whereas establishment is carried out in another one in order to fulfill the novel requirements. In that precise case relationship property can be illustrated with kinematic pairs, energy flows, information flows, etc. Finally a mechanical engineering example is introduced. Following the targeting between donor and recipient, it is possible to estimate the variation between developed and integrated technology into the product from new technology. This variation can be modeled by a technology S curve (Fig. 4) [9] [15] which shows the potential benefit of a technology introduced compared with a technology already developed. However, a concept not developed in the new technology integration may need some resources with technological dependences which could be cons indication of treatment for a person. These necessary resources need a modeling in a black box model [10]. Thus, the dependencies of materials, energy, flow information can be modeled and therefore focus on the presence or absence of a system for co-integration of technology. When electric technology was introduced in the automotive area, the modification of technology has required many changes in the product architecture. For example, for the same model from thermal engine to all electrical motor the system linked to the engine could be removed (tank, fuel pump . . .) while some binds to the

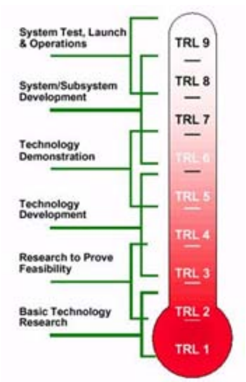


Fig. 3. Technology Readiness Level [7]

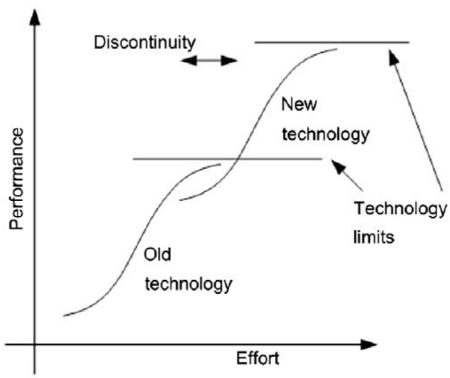
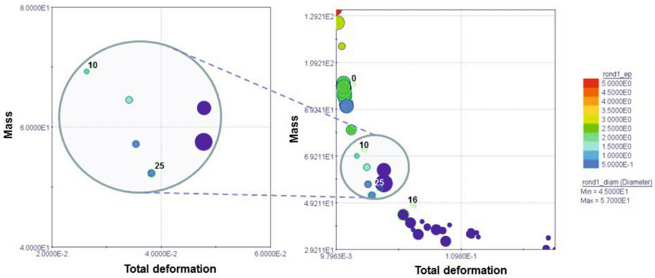


Fig. 4. Technology S curve [9] [15]

electric motor system were introduced (battery, calculator . . .). This famous example of a high abstraction level illustrates the dependence of some technological resources available in a product. For example, the notion of co-system is highlighted. It is therefore necessary to model all product architecture based on the technology used but also to ensure the traceability of resources linked to technology as part of a next improvement.

2.4 Well-Balanced Solution and Optimization

This final step before grafting [3] by geometric modeling issues in a top-down manner [6], is necessary to validate and weigh each technological solution used. This optimization phase of the overall product compared to a criterion (dependent of the current limit of the product but also the needs of the client) is based on fuzzy logic (Fig. 5) [18] [25]. This tool is the receptacle of all previous data (donor data, technological maturity, potential benefits . . .), but also the brain in which reasoning is built to compare and decide the best possible solutions in relation to elements of the overall process beginning. This tool will also make available the functional block in which the co-integrated systems hinterland. This gives up the context modeling.



<ID>	carre_cote	carre_ep	rond1_diam	rond1_ep	rond2_diam	rond2_ep	rond3_diam	rond3_ep	deformee_totale (mm)	masse (kg)
0	35	2.5	54	3	30	2	25	2	0.016	95.5
10	40	1.5	45	2	30	2	25	2	0.026	69.3
16	35	1	51	0.5	30	2	25	2	0.063	44.1
25	35	1	48	1.5	30	2	25	2	0.038	52.3

Fig. 5. Fuzzy logic optimization

3 Conclusions and Future Work

In this paper, authors proposed a method to take into account the earlier as possible the technological introduction in product design with a lifecycle point of view. This consideration is necessary in order to achieve innovative process to improve the product and to be able to be more competitive. Finally, different issues needs furthers research as criterion of technologies resources, tree learning occurs through the technological knowledge, fuzzy agent matrix to trade off the well balance of solutions. And in the more distant future, architecture is able to learn all technological links with associated system in the product and vision board quantitative change of entry criteria in relation to overall suitability.

Acknowledgments. The research activity is part of the INGéPROD (Productiveness for Product-Process Engineering in a Design Chain context), which has been funded by French Automotive Cluster Pôle de Compétitivité Véhicule du Futur. The authors would like to thank General Electric for this collaboration and all the financial supports of this research and technology program: DRIRE de Franche-Comté, Communauté dAgglomération du Pays de Montbéliard, Conseil Général du Doubs and Conseil Régional de Franche-Comté.

References

1. Agard, B.: Contribution à une méthodologie de conception de produits forte diversite. Laboratoire GILCO 'Gestion Industrielle Logistique et COnception', Grenoble, Institut National Polytechnique De Grenoble. Thése de Doctorat (2002)
2. Baxter, D., Gao, J., Case, K., Harding, J., Young, B., Cochrane, S., Dani, S.: A framework to integrate design knowledge reuse and requirements management in engineering design. Robotics and Computer-Integrated Manufacturing 24(4), 585–593 (2008)
3. Chapuis, Y., Demoly, F., Gomes, S.: Towards an approach to integrate technological evolution into product design. In: International Conference on Engineering Design (2013)
4. CIMdata Incorporated. PLM Market Growth in 2008 'A Mid-Year Look in 2009-Weathering the Storm'. White Paper (August 2009)
5. Demoly, F., Troussier, N., Eynard, B., Falgarone, H., Fricero, B., Gomes, S.: Proactive assembly oriented design approach based on the deployment of functional requirements. Journal of Computing Information and Science in Engineering 11(1), 014501-1 (2011)
6. Demoly, F., Toussaint, L., Eynard, B., Kiritsis, D., Gomes, S.: Geometric skeleton computation enabling concurrent product engineering and assembly sequence planning. Computer-Aided Design 43(12), 1654–1673 (2011)
7. DOD.: Defense Acquisition Guidebook (2006)
8. Forsberg, K., Mooz, H.: The Relationship of System Engineering to the Project Cycle. National Council for Systems Engineering (NCOSE), Chattanooga, Tennessee (1991)
9. Foster, R.N.: Innovation: The Attacker's Advantage. Summit Books, New York (1986)
10. Han, X., Xie, W., Fu, Z., Luo, W.: Nonlinear systems identification using dynamic multi-time scale neural networks. Neurocomputing 74(17), 3428–3439 (2011)
11. Jagdev, H.S., Browne, J.: The extended enterprise-a context for manufacturing. Production Planning and Control 9, 216–229 (1998)
12. Kerbrat, O., Mognol, P., Hascoet, J.Y.: Manufacturing complexity evaluation at the design stage for both machining and layered manufacturing. CIRP Journal of Manufacturing Science and Technology 2(3), 208–215 (2010)
13. Kline, S., Rosenberg, N.: An overview of innovation. In: Landau, R. (ed.) The Positive Sum Strategy. Harnessing Technology for Economic Growth, pp. 275–306 (1986)

14. Königs, S.F., Beier, G., Figge, A., Stark, R.: Traceability in Systems Engineering - Review of industrial practices, state-of-the-art technologies and new research solutions. Advanced Engineering Informatics 26(4), 924–940 (2012)
15. Nikula, U., Jurvanen, C., Gotel, O., Gause, D.C.: Empirical validation of the Classic Change Curve on a software technology change project. Information and Software Technology 52(6), 680–696 (2010)
16. Prasad, B., Morenc, R.S., Rangan, R.M.: Information Management for Concurrent Engineering: Research Issues. Concurrent Engineering 1(1), 3–20 (1993)
17. Royce, W.W.: Managing the Development of Large Software Systems. In: IEEE WESCON 26 (1970)
18. Saridakis, K.M., Dentsoras, A.J.: Integration of fuzzy logic, genetic algorithms and neural networks in collaborative parametric design. Advanced Engineering Informatics 20(4), 379–399 (2006)
19. Schumpeter, J.: Business Cycles: a Theoretical, Historical and Statistical Analysis of the Capitalist Process (1939)
20. Stark, J.: Product Lifecycle Management: 21st Century Paradigm for Product Realisation. Springer London Ltd., London (2004) ISBN: 978-1852338107
21. Tang, D., Qian, X.: Product lifecycle management for automotive development focusing on supplier integration. Computers in Industry 59(2-3), 288–295 (2008)
22. Tichkiewitch, S.: De la CFAO á la conception integree. Hermes, Paris (1994) ISBN 0298–0924
23. Whitten, J.L., Bentley, L.D., Dittman, K.C.: Systems Analysis and Design Methods. Irwin/McGraw-Hill (2004) ISBN: 025619906X
24. Willaert, S.S.A., de Graaf, R., Minderhoud, S.: Collaborative engineering: A case study of Concurrent Engineering in a wider context. Journal of Engineering and Technology Management 15(1), 87–109 (1998)
25. Yadav, O.P., Singh, N., Chinnam, R.B., Goel, P.S.: A fuzzy logic based approach to reliability improvement estimation during product development. Reliability Engineering & System Safety 80(1), 63–74 (2003)