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Model Based Design for Intellectual Property

Kalpak Kalvit, Rajat Gupta, Hamid Piroozi, and Hazim El-Mounayri

Presenter Bios

Kalpak Kalvit is currently Autonomous Vehicles Controls & Functional Safety Engineer at FORD Motor Company.

Kalpak has received his MS in Mechanical Engineering degree from the MEE department in 2018. His Master's thesis research focused on 1D-Simultaion using MBSE-SysML. He has also worked in area of integrating MBSE (MagicDraw) tools with 1D/2D/3D CAE tools to achieve Industry 4.0 capabilities at IPLI. At FORD Motor Company, he works in the area of Model Based Systems Engineering using SysML. He works in the area of implementing functional safety using Model Based Systems Engineering, as well as exploring the simulation capabilities using SysML.

Rajat Gupta is currently a Systems Lifecycle Analyst at Cummins. Rajat has received his MS in Mechanical Engineering degree from the MEE department in 2017. His Master's thesis research focused on implementing Model Based System Engineering on a PLM platform. This work was presented at GLRC 10 and GLRC 11. He also worked extensively with IPLI to develop Digital Manufacturing platform (Industry 4.0) with Requirements Traceability.

At Cummins, he will be working on projects which aim to develop and provide Model Based Systems Engineering solutions (using SysML) to various parts of the company.

Presenter Bios

IUPUI

INITIATIVE FOR PRODUCT LIFE CYCLE INNOVATION
INDIANA UNIVERSITY-PURDUE UNIVERSITY Indianapolis

Dr. El-Mounayri is an associate professor of Mechanical Engineering and the director of the Initiative for Product Lifecycle Innovation (IPLI) at IUPUI, which aims at advancing process and product lifecycle practice in the manufacturing, healthcare, and life sciences industries. He received his PhD in Advanced Manufacturing in 1997. His research focus and interest are in digital manufacturing and advanced product/process development. Currently, he is leading an initiative to develop a Systems driven product development (SDPD) ecosystem for promoting MBSE/SDPD practice, supporting industry 4.0, and training the workforce of tomorrow. Dr. El-Mounayri has 20 years working in this field, including on applied research that aims at developing innovative digital manufacturing solutions that are rapidly transferred to industry to improve existing practice. Dr. El-Mounayri has more than 125 publications in his areas of expertise, and is a member of INCOSE, ASME, ASEE, and SME.

IUPUI

Dr. Piroozi serves as a Visiting Clinical Assistant Professor of Engineering on the IUPUI campus. There he oversees the formation and roll out of a new intellectual property minor in the engineering program. Students who complete the program will be able to take the patent bar and become a patent practitioner if they desire, work as a patent engineer, or for most, become better engineers. Prior to joining the IU faculty, Piroozi served as director of the legal department of the Purdue Research Foundation. In that job, he crafted a unique legal practice in which patent attorneys handled all of the intellectual property that was generated at Purdue University, approximately 400 disclosures every year, and over 1,000 active projects going on at any one time. Before working at Purdue, he was an engineer for 17 years, first working as a mechanical engineer and then as an electrical engineer. He received three Purdue engineering degrees, and has worked at three different metropolitan Indianapolis law firms on intellectual property matters.

Agenda

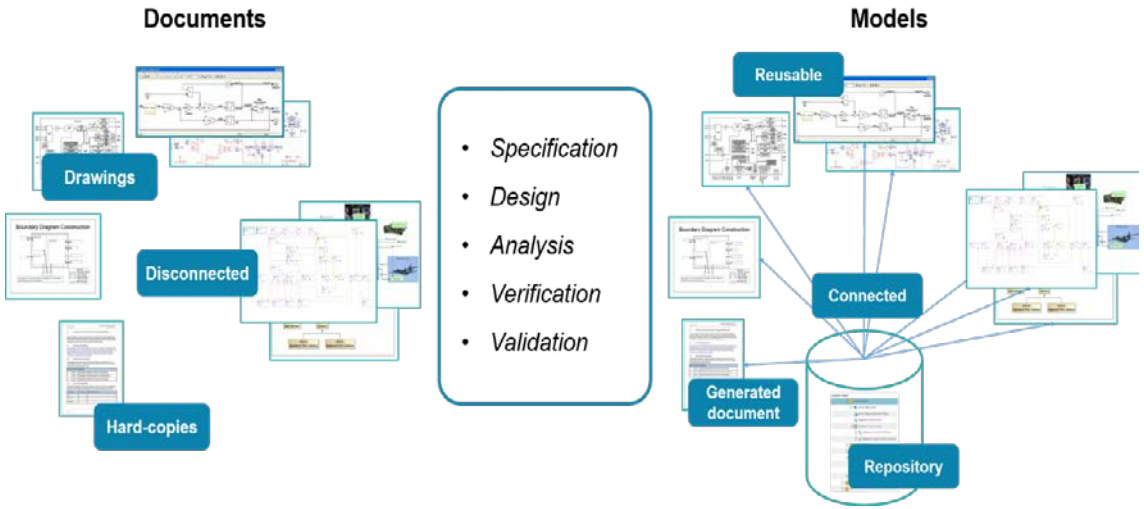
- Introduction
- Background:
  - MBSE
  - Design & IP (Current practice)
- Design for IP
- Designing around patents (or existing IP)
  - Ex1: Desk extender
  - Ex2: Washing machine
- Patent representation
  - Document based
  - Model based (using MBSE)
- Document based vs. Model based: Case study of Washing machine
- MBSE for automating infringement checking
- Future work: MBSE for product line engineering

Introduction

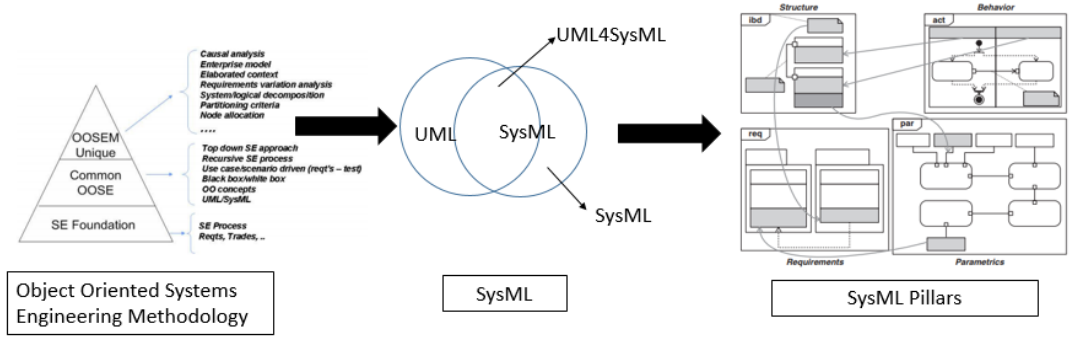
Current limitation: Designing around existing Intellectual Property (IP) and avoiding infringement with existing patents is currently a very manual process that relies on browsing a large number of document-based patents.

Proposed solution: MBSE using SysML offers a model-based alternative that enables the automation of the process. This work proposes the use of SysML based MBSE to convert document based patent representation to model-based representation. Requirements, functional (behavior), structure, and parametrics views are created to achieve a complete model-based representation of a new design or redesign that does not only replace document-based patent applications but produces a more powerful artifact that provides an unambiguous representation as well as supports the potential automation of patent infringement checking. The new approach is illustrated using the case of a washing machine.

Background: Model Based Systems Engineering



MBSE is the model-based version of SE



[Weilkiens, 2011], [Friedenthal, Moore, and Steiner, 2014]

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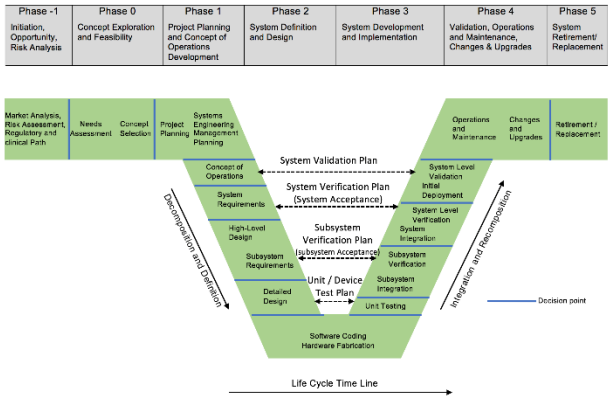
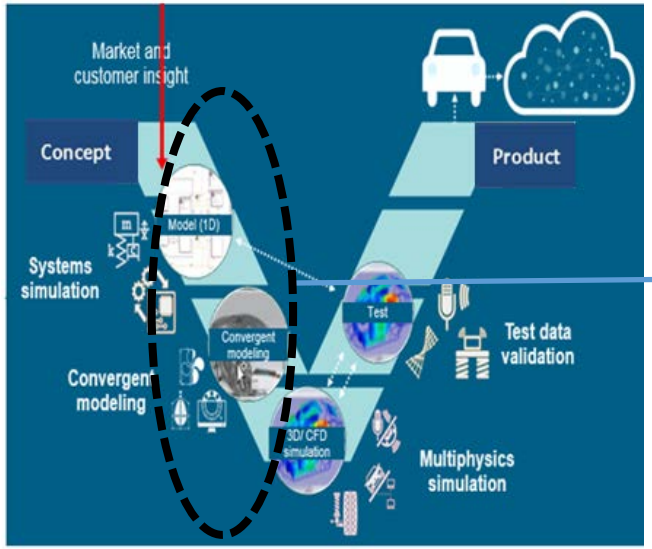
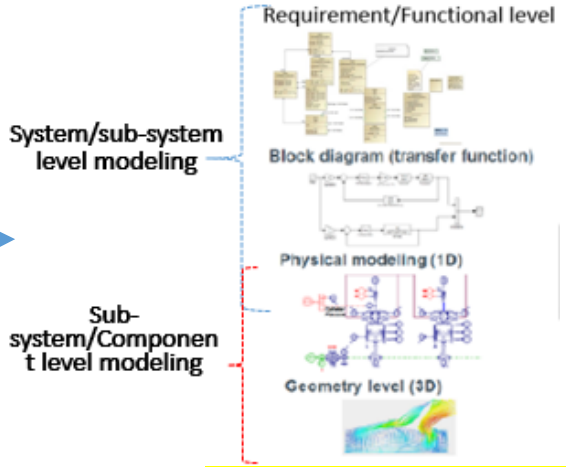
Model Based Systems Engineering is an approach and it requires a methodology i.e. collection of related processes, methods, tools and environment.



SE V-model

Digitalization of SE V-model

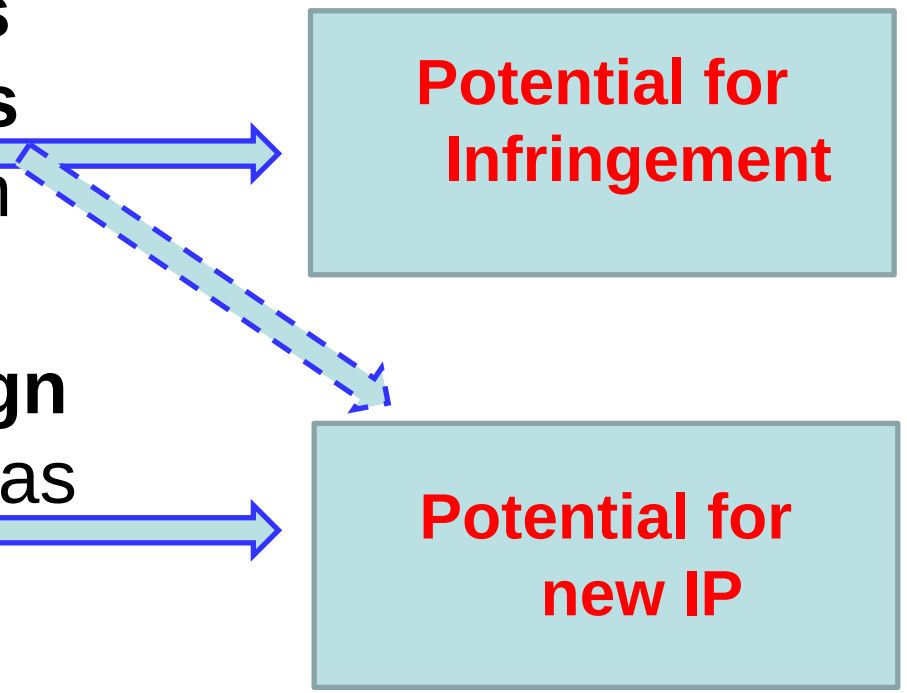




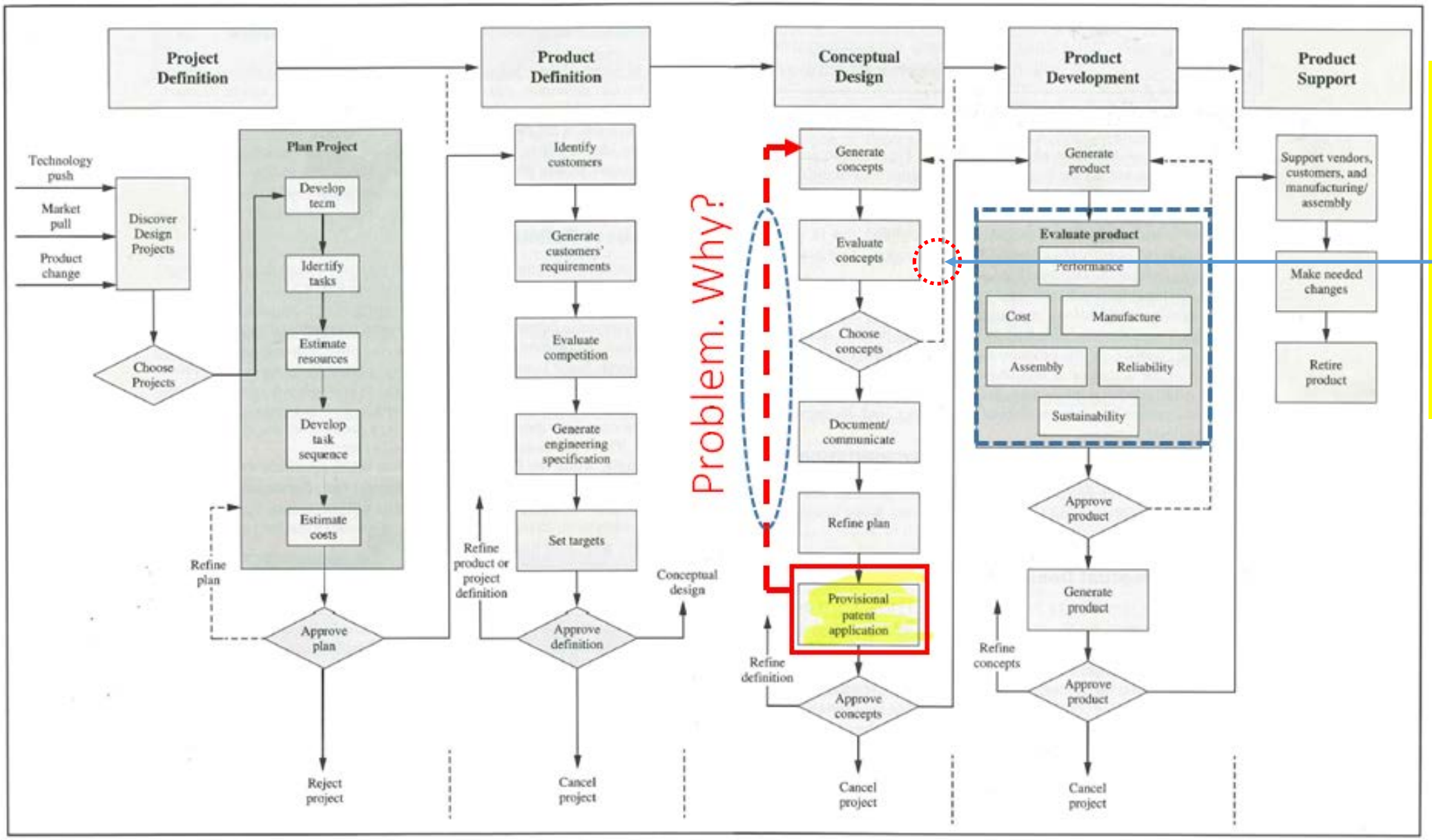
MBSE: Modeling

Background: Design & Intellectual Property (IP)

- **Most design problems are redesign problems** since they are based on prior, similar solutions.
- Conversely, **most design problems are original** as they contain something new that makes prior solutions inadequate!



Design for IP: Current limitation



Provisional patent application filed <u>after</u> concept is selected:
Concept evaluation lacks IP (existing patents) consideration

Design Process: Ullman, 2016

Linking the Design process to IP by *Extending "Design for XX"*

Current/common practice

- Design for Manufacturing (DFM)
- Design for Assembly (DFA)
- Design for environment
- Design for sustainability
- Design for reliability
- Design for cost
- Design for ergonomics
- Design for Test and Maintenance (DFTM)
- ….

Expanding to:

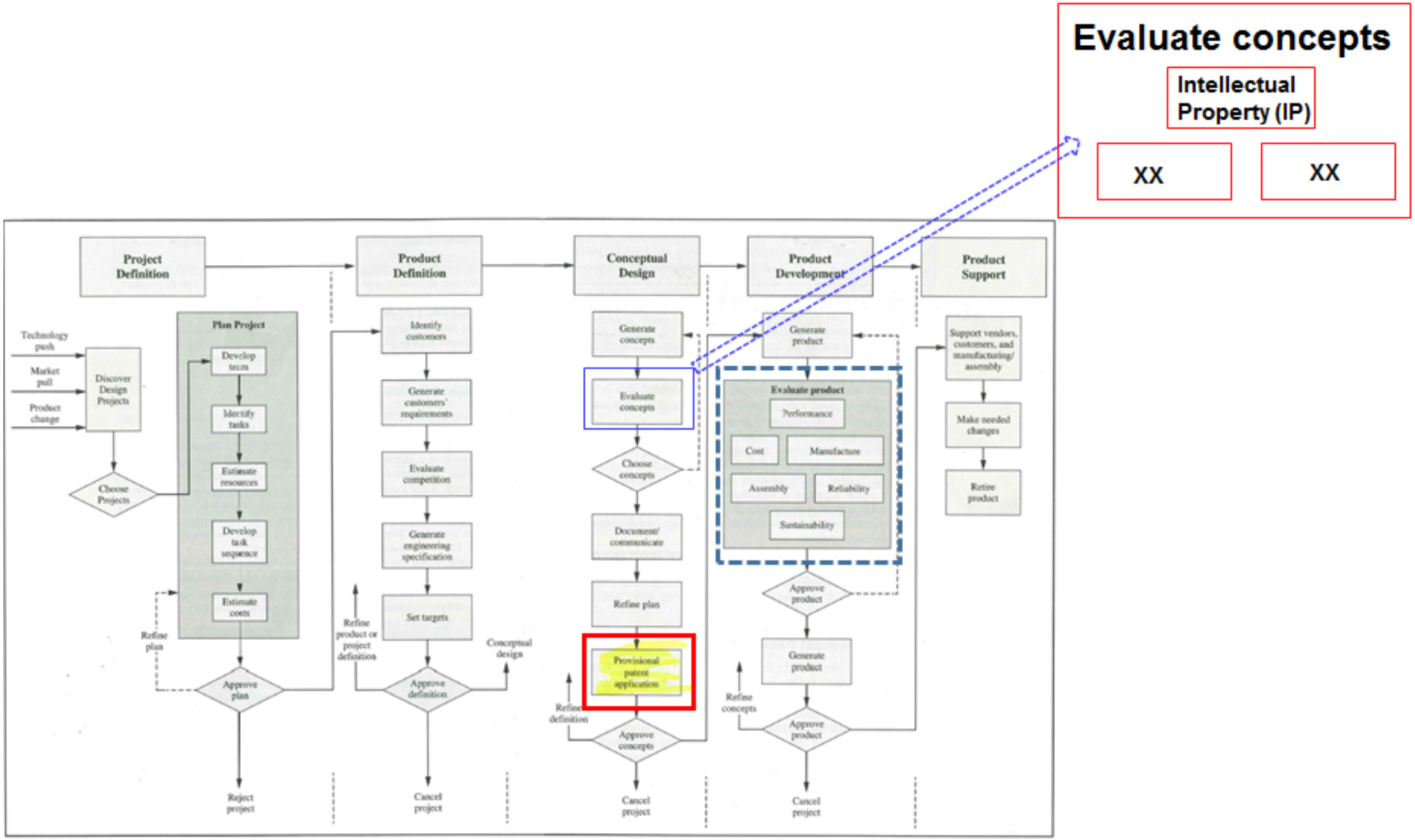
Uncommon practice

Design for Intellectual Property (DFIP)

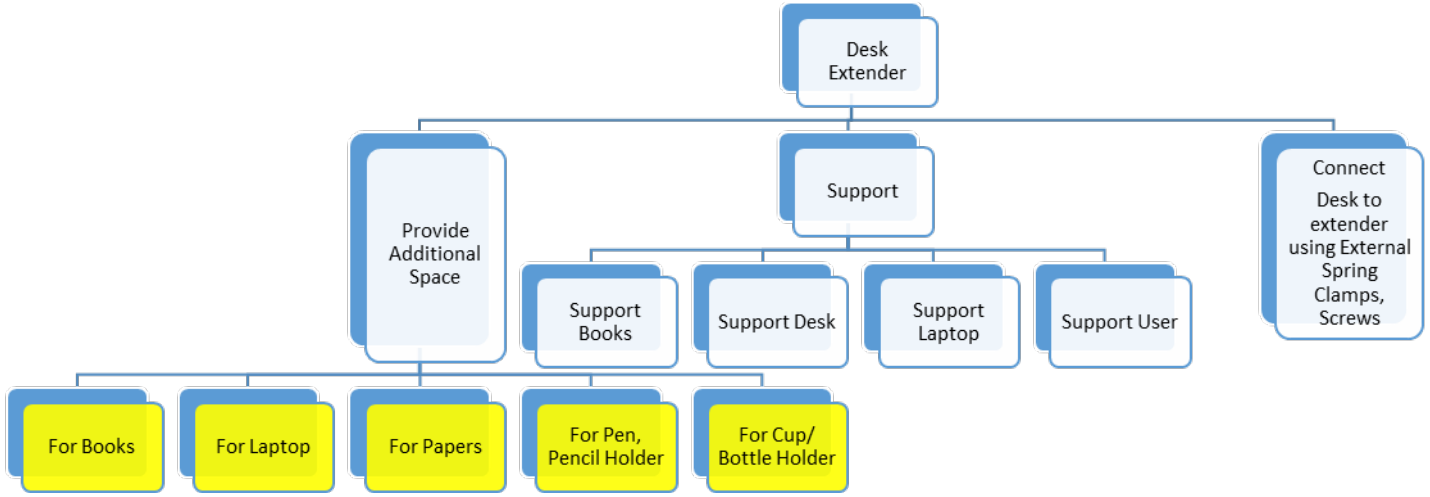
Designing around existing IP (i.e. Avoiding infringement with existing patents)

Designing to generate new IP (i.e. Producing new patents)

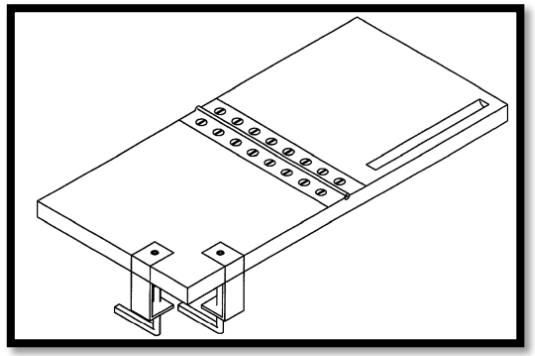
Implementing Design for IP as part of Concept evaluation

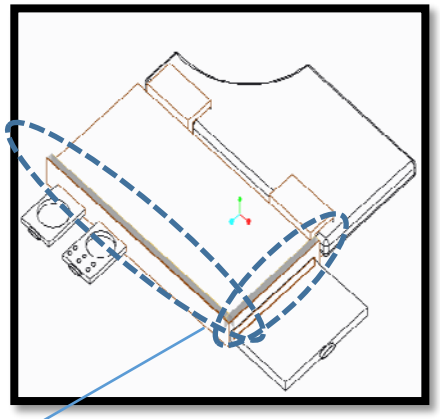


Design for IP: Designing around patents

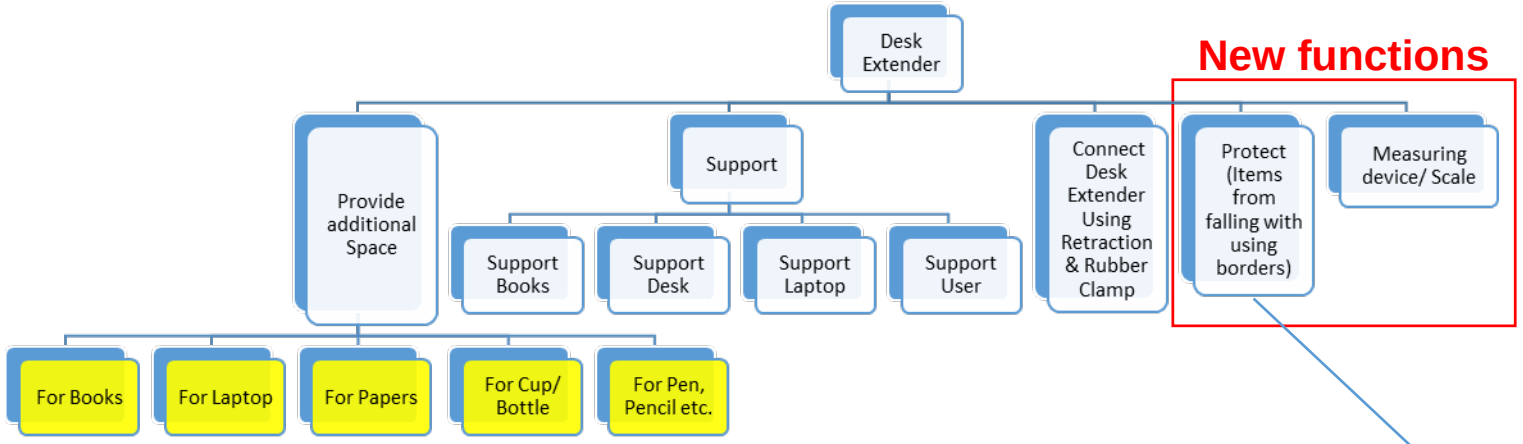


Functional decomposition of target patent





Designing around patents by ***adding new <u>functions</u>***

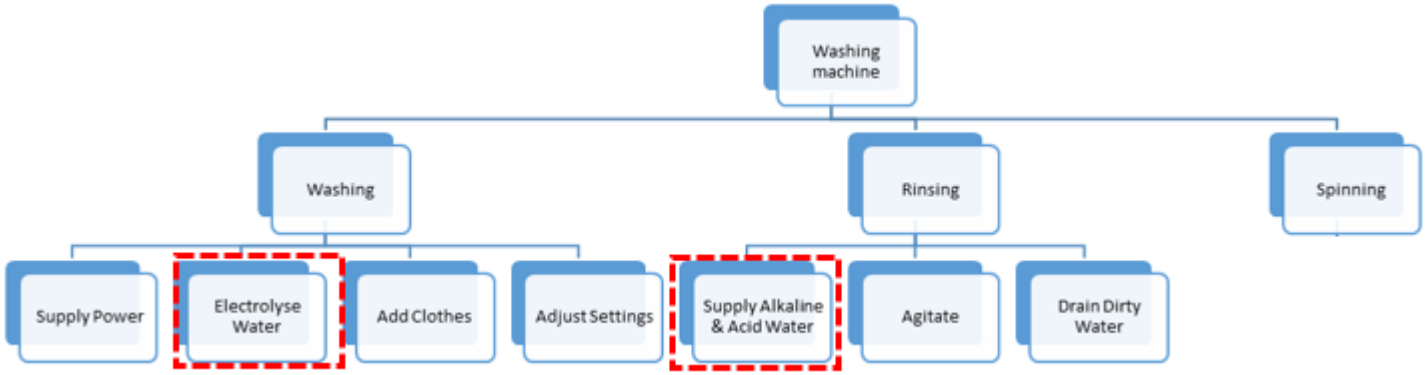


Functional decomposition of new design

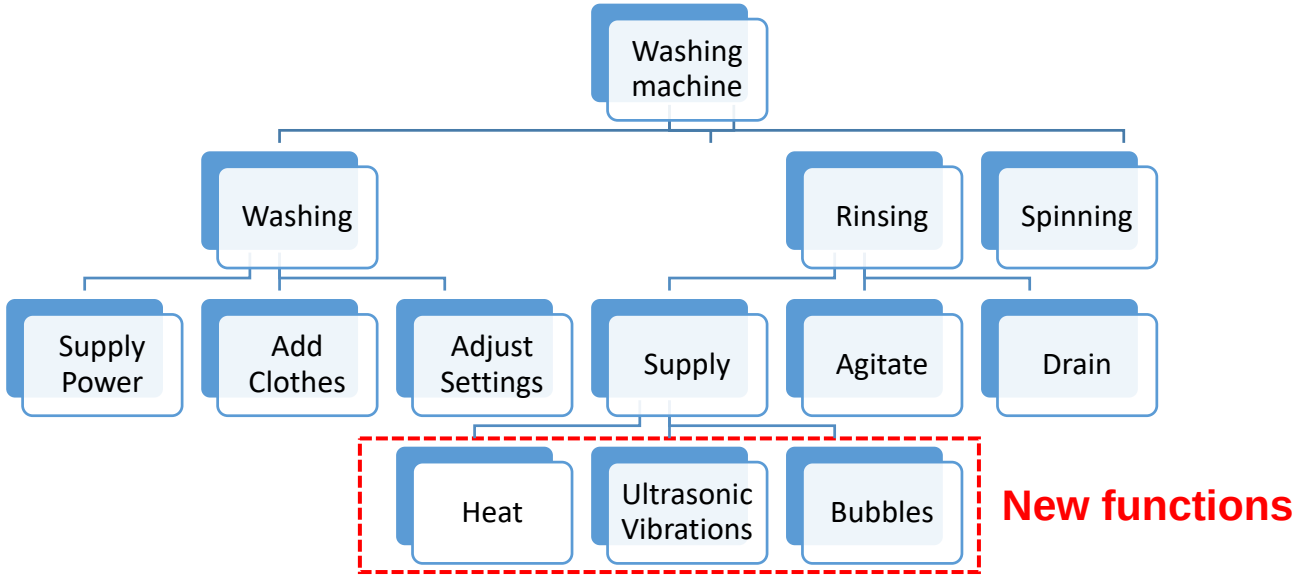
Designing around patents: Desk Extender case study

Based on TRIZ principle#6 (“Make a part or object perform multiple functions”): Add borders to protect objects from falling; also, it can be used as a scale and measuring instrument

Design for IP: Designing around patents

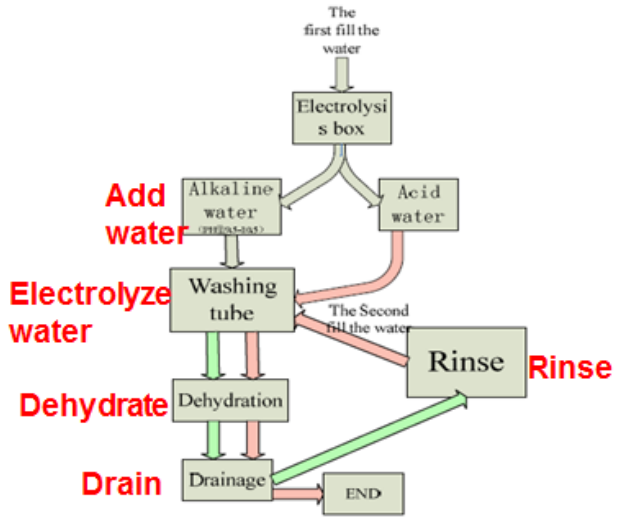


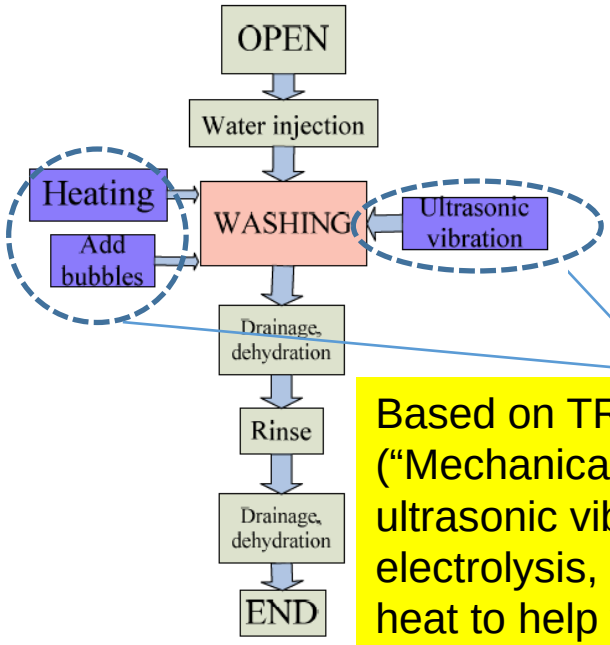
Function decomposition of target patent (# CN04\00797)



New functions

Function decomposition of new design





Designing around patents by ***adding new/changing existing functions***

Based on TRIZ principle#18 (“Mechanical Vibration”): To use ultrasonic vibration to replace the electrolysis, and add air bubble and heat to help with the decomposition of dirty.

Designing around patents: Washing machine

IP Case Study : WASHING METHOD/MACHINE

Assignees: **HAIER GROUP CORPORATION**, Shandong (CN); **QINGDAO HAIER WASHING MACHINE CO., LTD.**, Shandong (CN)

Appl. No.: **10/566,767**

PCT Filed: **Jul. 13, 2004**

PCT No.: **PCT/CN04/00797**

§ 371(c)(1),
(2), (4) Date: **Nov. 15, 2006**

Case Study Objective:
To implement Model Based Approach for Patent Publication.

- Represent the information in existing patent publication by Model Based Engineering using different SysML views.
- Implement Model Based Systems Engineering approach using MagicGrid framework for patent publication
- Develop method for detecting IP Infringement using MBSE-SysML for two similar functioning products

US 20070180866A1

(19) **United States**

(12) **Patent Application Publication**
Cao et al.

(10) **Pub. No.: US 2007/0180866 A1**

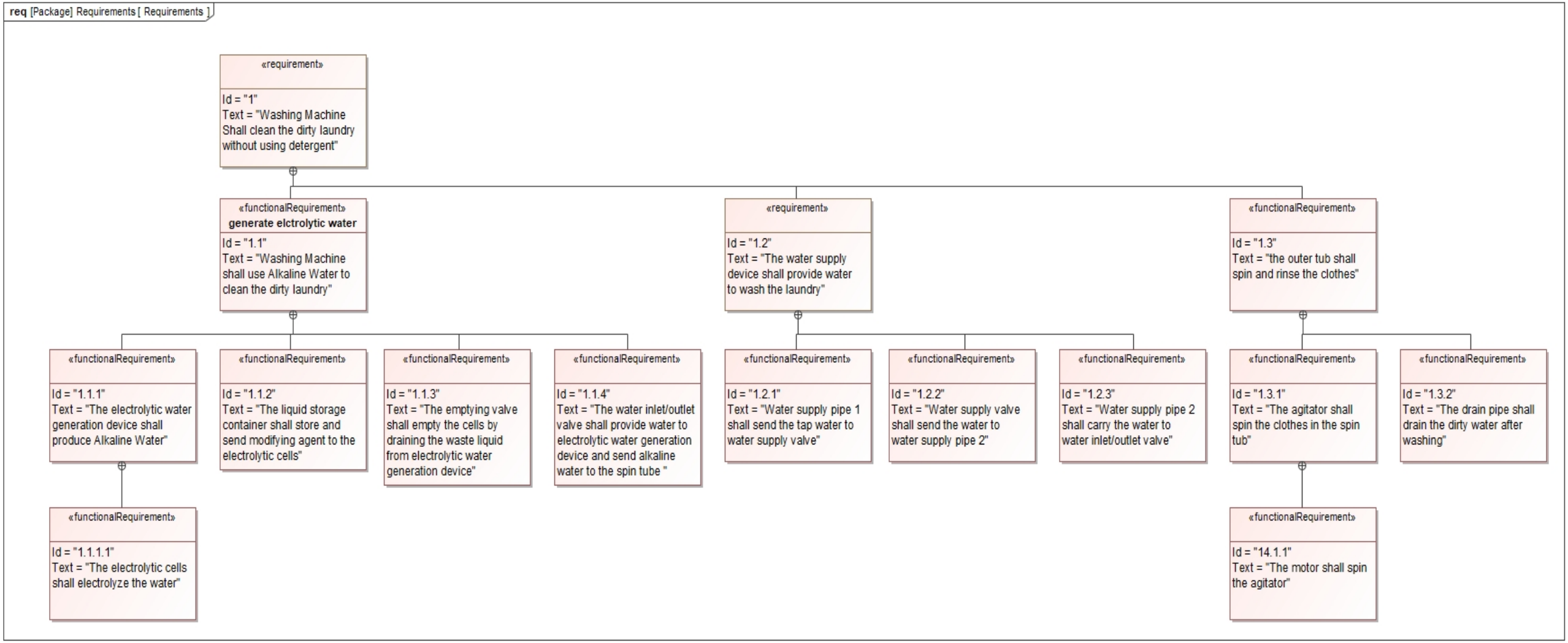
(43) **Pub. Date: Aug. 9, 2007**

(54) **WASHING METHOD WHICH HAS NO NEED OF ADDING DETERGENT BY THE USER AND THE WASHING MACHINE THEREOF**

(30) **Foreign Application Priority Data**

Jul. 31, 2003 (CN) 03143942.X
Nov. 14, 2003 (CN) 200320121901.3

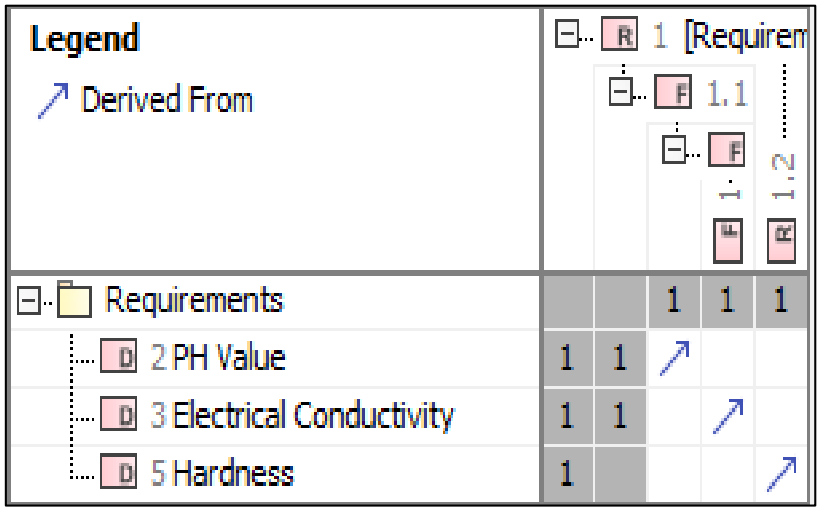
Functional Requirements for Washing Machine



Requirements Diagrams provide modeling constructs to represent text-based requirements and relate them to other modeling elements.

Design Constraint Requirements

#	Name	Text
1	2 PH Value	The PH of the said liquid used for washing shall be between 8.5 to 10
2	3 Electrical Conductivity	The Electrical Conductivity of said liquid shall be between 261 to 875 micro siemens per meter
3	4 Surface Tension	The surface tension shall be 2540 mN/m
4	5 Hardness	Hardness of the said liquid shall be between 5 to 400 ppm



Requirement Derivation Matrix

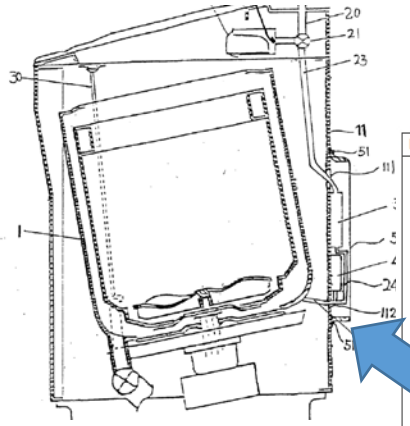
(57) **ABSTRACT**

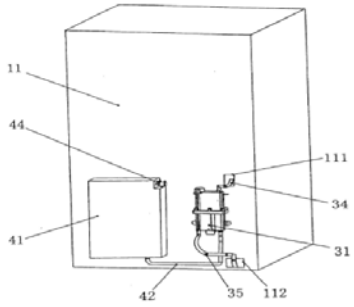
A washing machine which has no need of adding detergent by the user and the washing method thereof the said washing method comprises balancing setting the PH surface tension electrical conductivity and hardness of the washing liquid in certain range, washing in general automatic washing machine with the use of a high PH electrolyzed water combined with a regulator; in which the PH of the said washing liquid is in the range of 8.5-1 I, the electrical conductivity of it is in the range of 261 us/cm-875 us/cm the surface tension is in the range of 2540 mN/m, the hardness is in the range of 5-400 ppm, if necessary 0.20.3 g/time of the regulator could be added in the above condition according to, the method of the invention it is possible to, realize washing without detergent; because the washing liquid is subjected to the treatment, the cost of the detergent will be saved and the pollution caused by detergents will be avoided, at the same time, the fabric hardening due to, it will be overcome, and an optimum washing condition will be obtained.

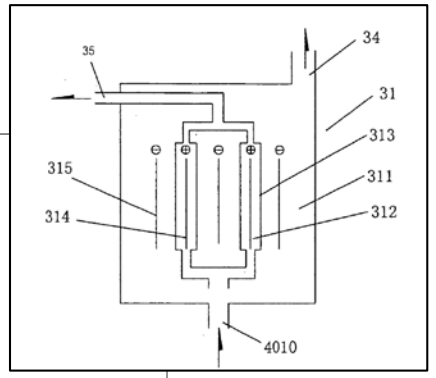
A Design Constraint is a requirement that specifies a constraint on the implementation of a system or on a part of it.

Block Definition Diagram of Washing Machine

***Relationship used**: Directed Composition*



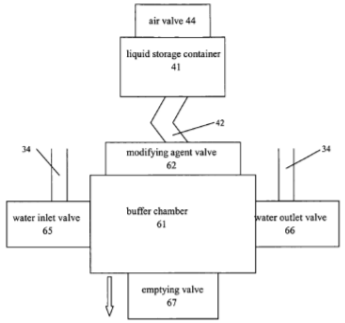




bdd [Package] WM_complete_struct [WM_complete_struct]

«block» Washing Machine

- housing → «block» Housing
  - water Supply Device → «block» Water Supply Device
    - water Supply Valve → «block» Water Supply Valve
    - water Supply Pipe 1 → «block» Water Supply Pipe 1
    - water Supply Pipe 2 → «block» Water Supply Pipe 2
  - drain Pipe 3 → «block» Drain Pipe 3
  - outer Tub → «block» Outer Tub
    - spin Tub → «block» Spin Tub
    - agitator → «block» Agitator (parts: motor : Motor)
- liquid Storage Container → «block» Liquid Storage Container
- electrolyzing Cell → «block» Electrolytic Water Generation Device
  - emptying valve → «block» emptying valve
  - modifying Agent Valve → «block» Modifying Agent Valve
  - water Inlet/Outlet Valve → «block» Water Inlet/Outlet Valve
  - electrolytic Cell → «block» Electrolytic Cell
    - ion Penetrated Diaphragms 8 → «block» Ion Penetrated Diaphragms
    - anode Chamber 4 → «block» Anode Chamber
    - cathode Chamber 5 → «block» Cathode Chamber
- drain Pipe 2 → «block» Drain Pipe 2
- drain Pipe 1 → «block» Drain Pipe 1
- cover Plate → «block» Cover Plate



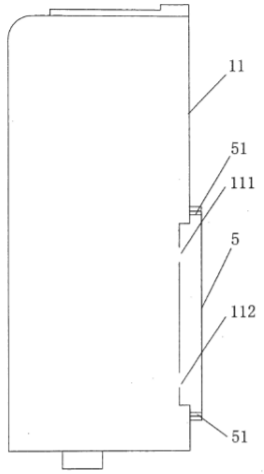
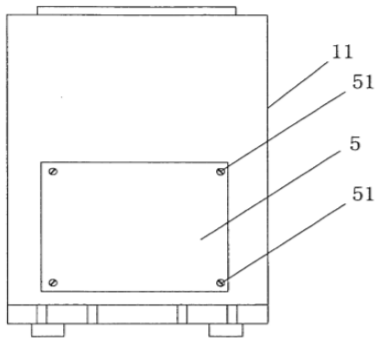
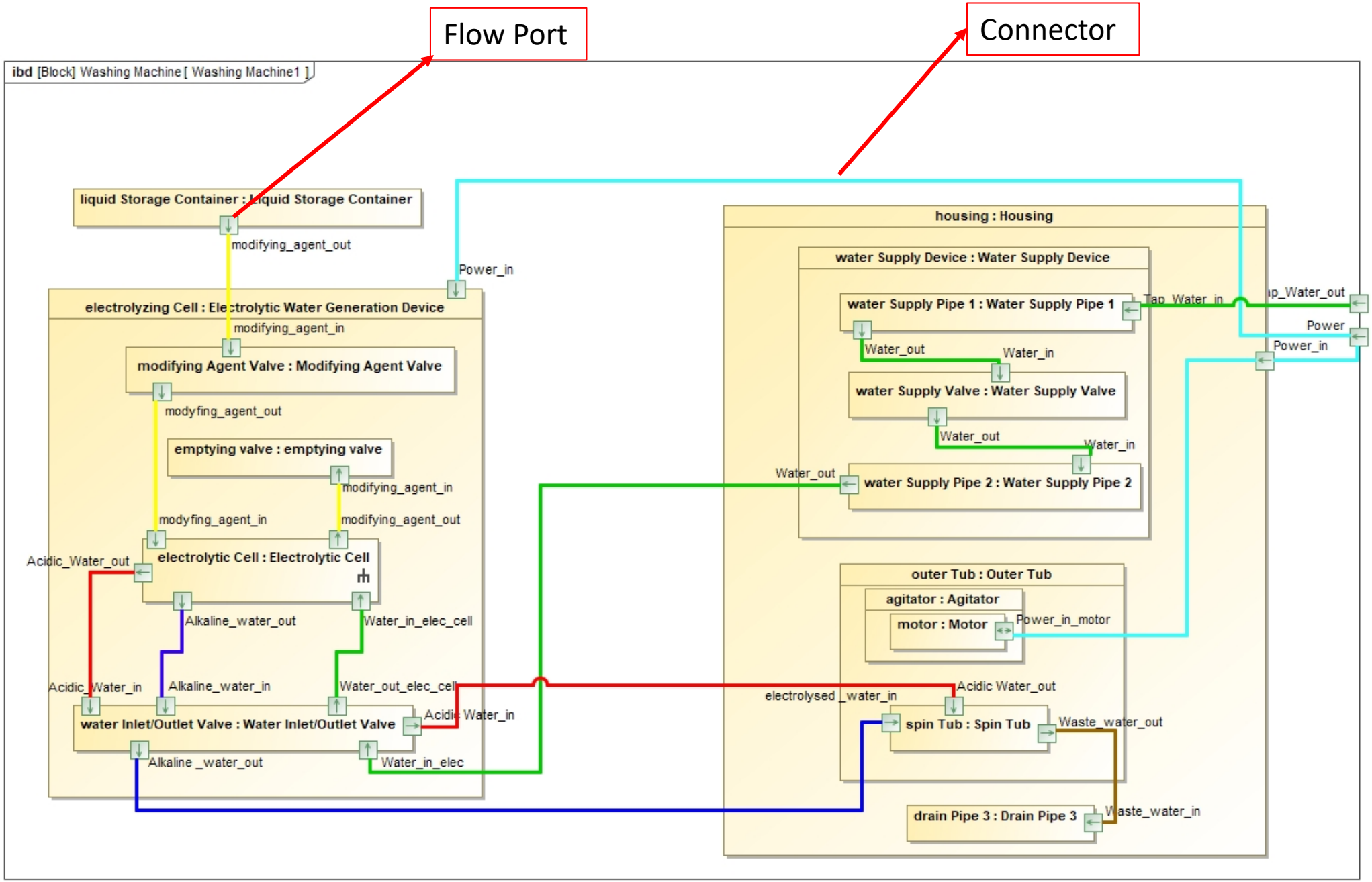


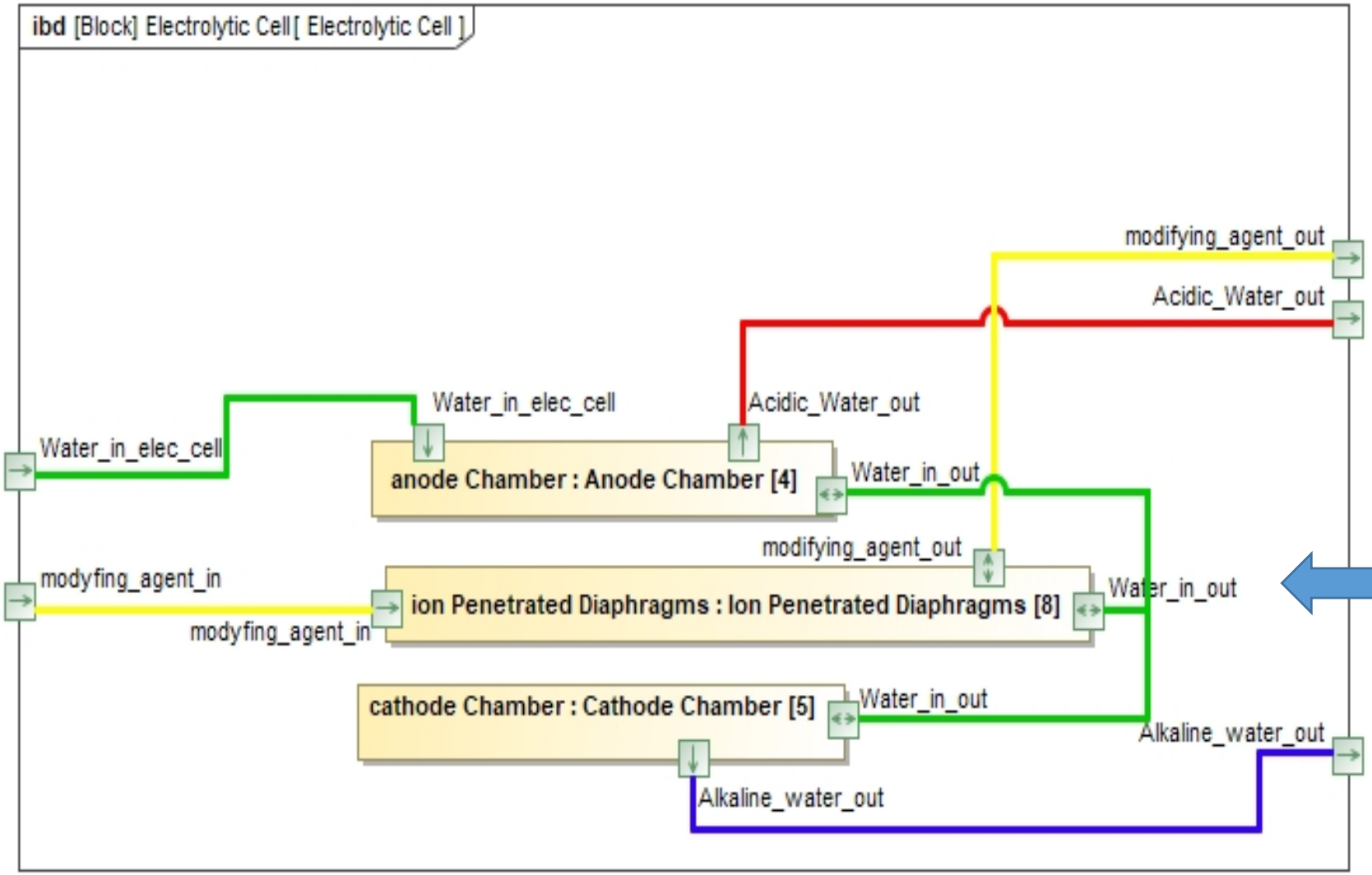
FIG3

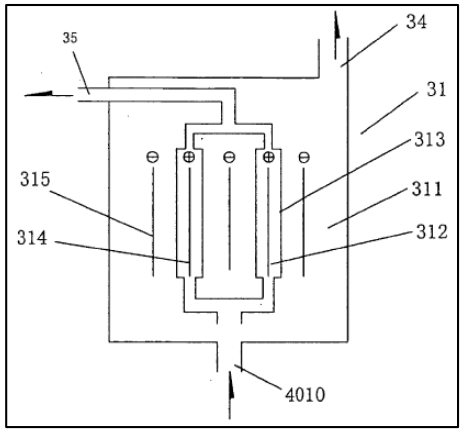




"An Internal Block Diagram captures the internal structure of a Block in terms of properties and connections among properties. A Block includes properties so that its values, parts, and references to other blocks can be specified. However, whereas an Internal Block Diagram created for a Block (as an inner element) will only display the inner elements of a classifier (parts, ports, and connectors)."

Internal Block Diagram For Block Electrolytic Cell

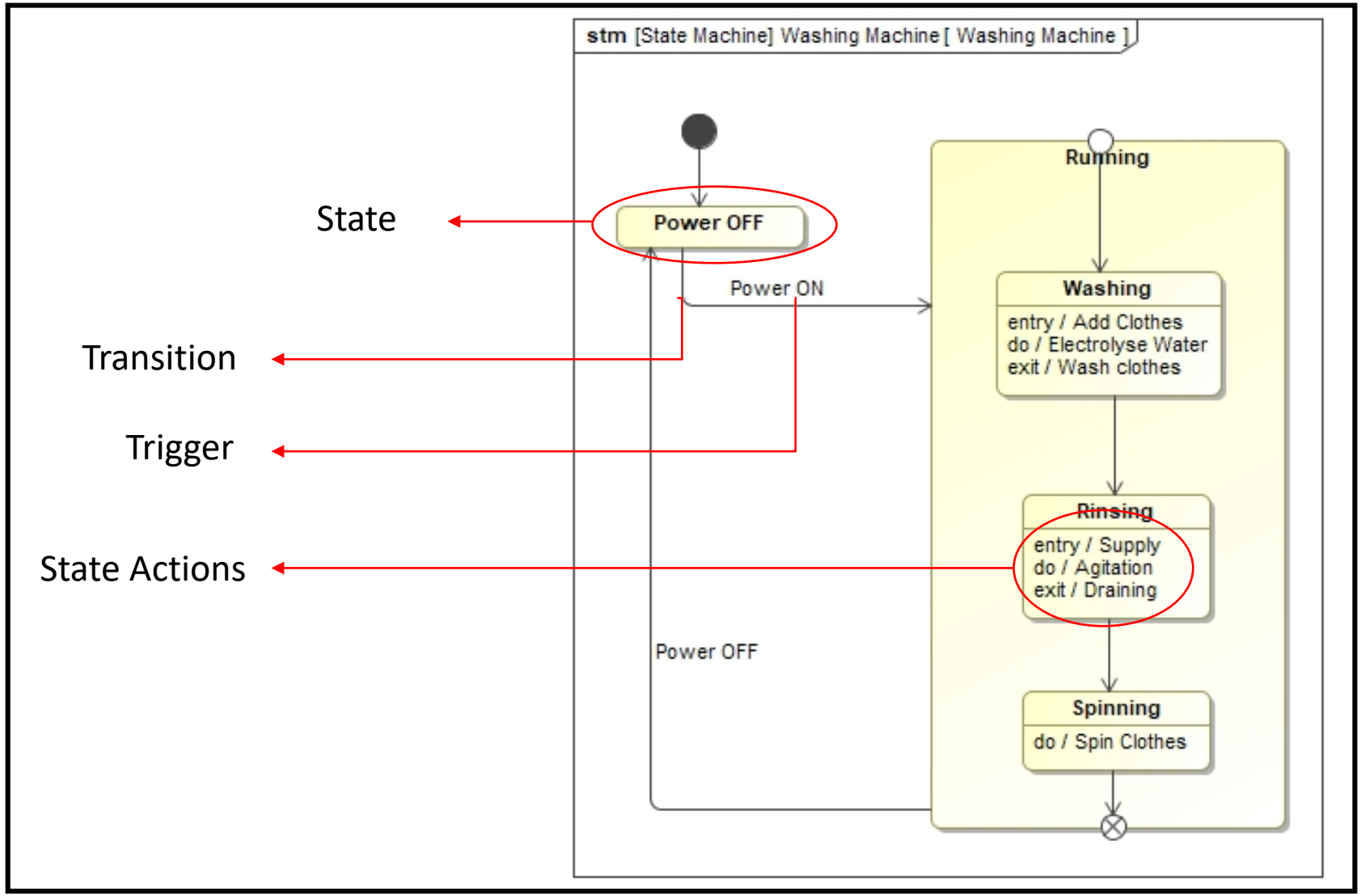




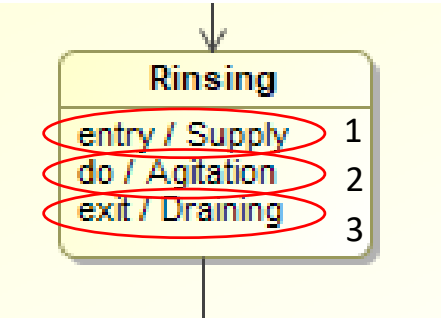
[0051] FIG. **5** shows an embodiment of electrolyzing cell with diaphragm, which comprises five cathode chambers **311** and four anode chambers **312**, and all the chambers are arranged separately from each other by the eight ion-penetrated diaphragms **313**; alternatively, the electrolyzing cell may also comprises seven cathode chambers **311** and six anode chambers **312**, whereas the chambers are arranged separately from each other by the twelve ion-penetrated diaphragms **313**. The ratio of cross-sectional area of flow passage for cathode chamber **311** against anode chamber **312** of the said electrolytic chamber is from 10:1 to 2:1, preferably, the ratio value is between 6:1 and 3:1.

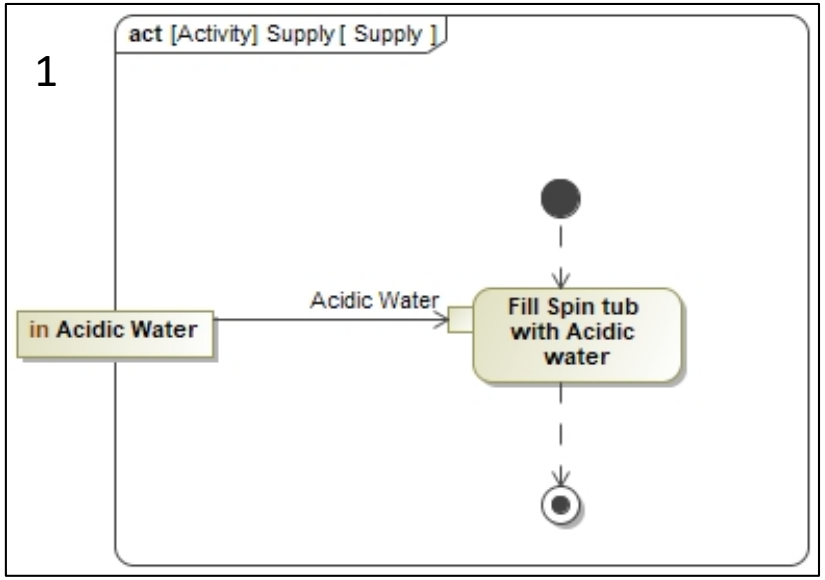
State Machine Diagram for Washing Machine

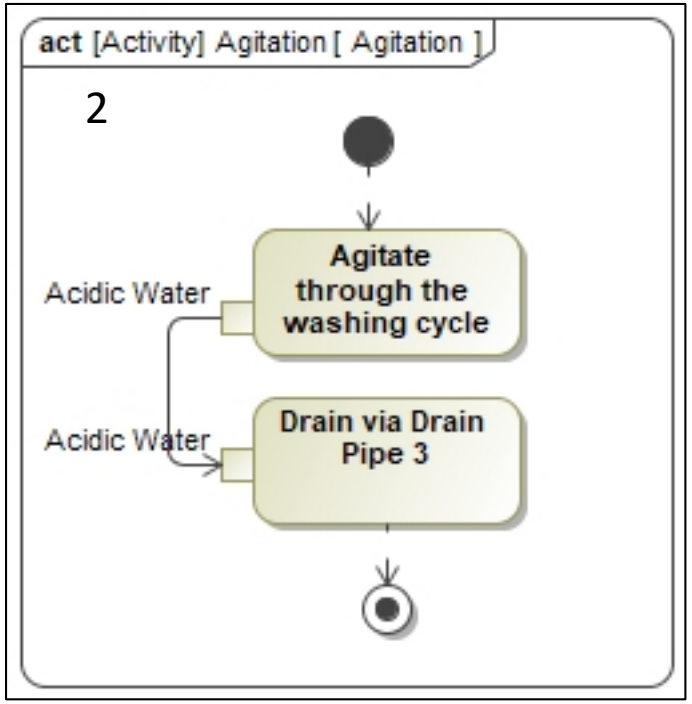
- State Machine Diagram represents the function flow of the system.
- State actions are the decomposition of the functional flow of the system and are represented by activity diagrams

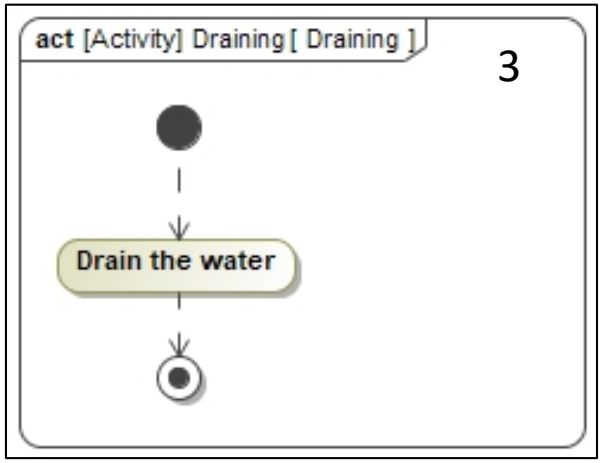


Activity Diagrams for State Rinsing

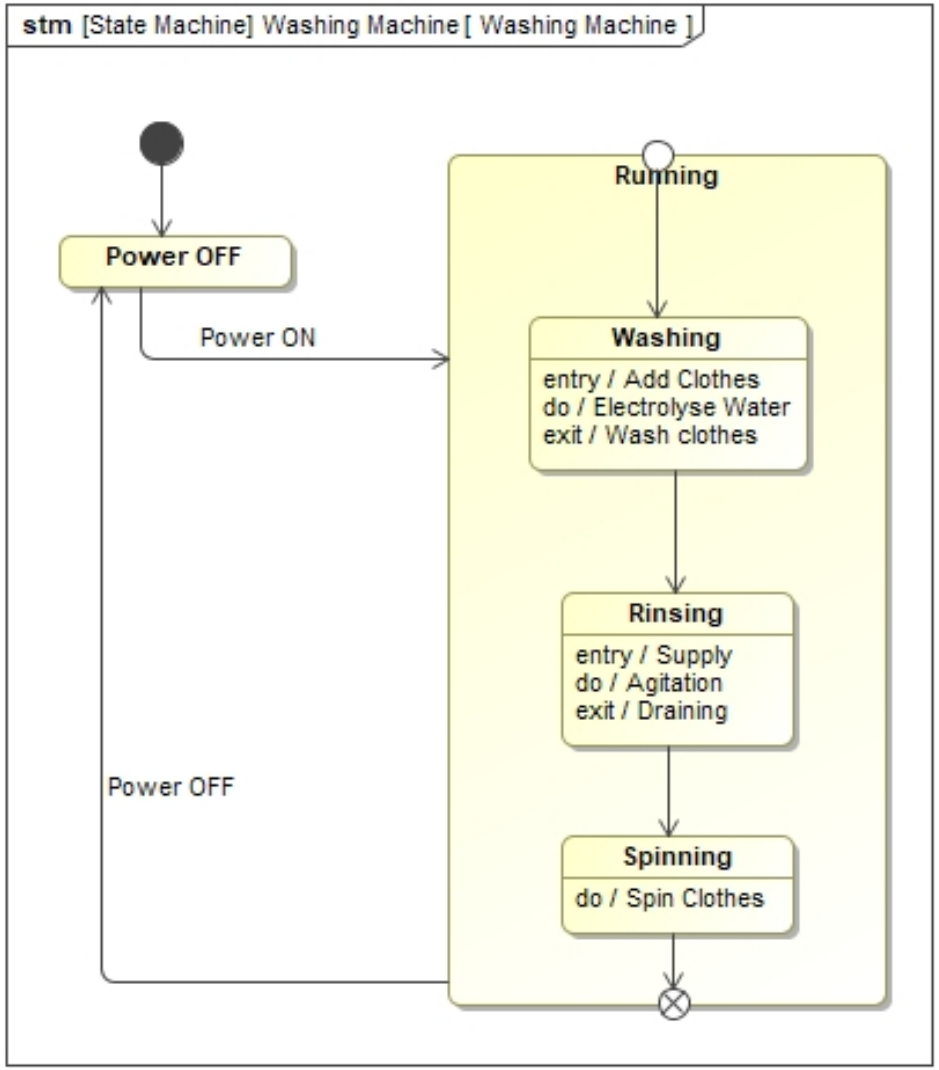


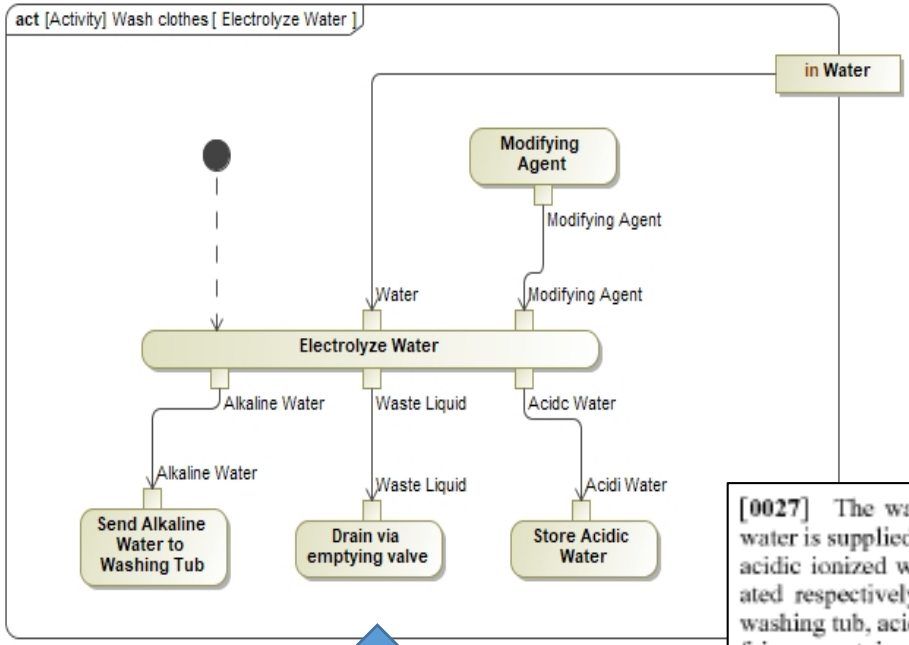


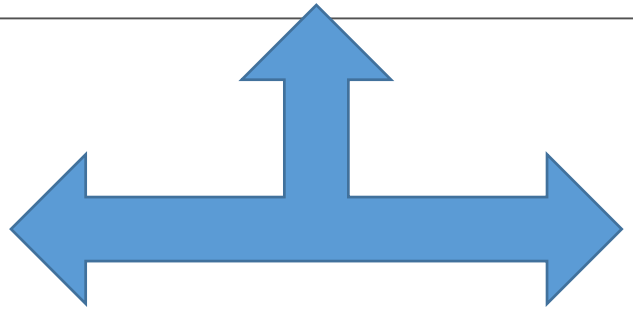




Document to Model Based Mapping

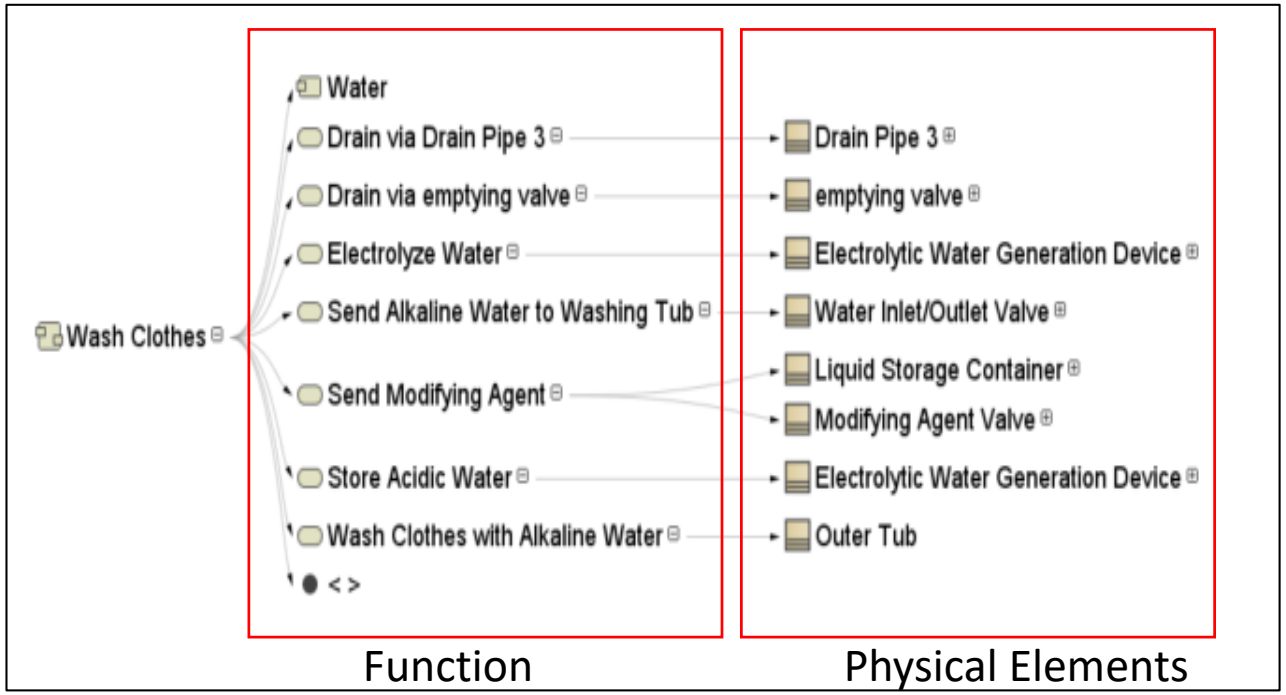


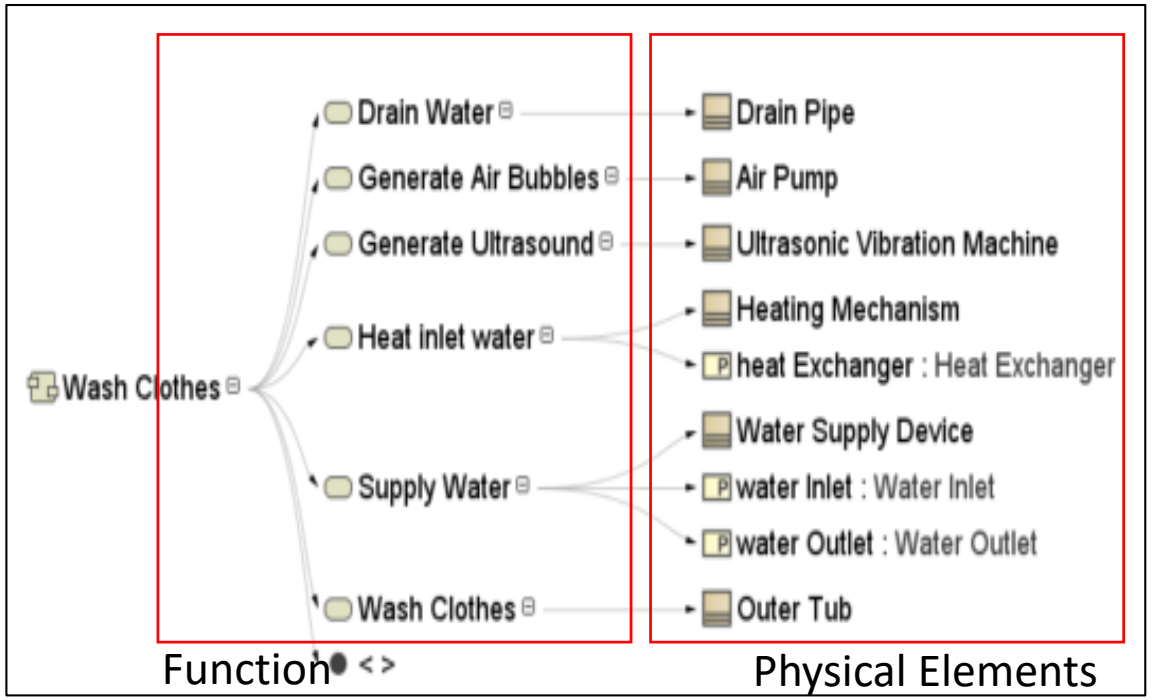




[0027] The washing process comprises the steps of: tap water is supplied to the electrolyzing cell to be electrolyzed, acidic ionized water and alkaline ionized water are generated respectively, and alkaline water is supplied into the washing tub, acidic ionized water is discharged; then, modifying agent is added to the alkaline ionized water from modifying agent feeding device, and it will be activated accordingly. As the alkaline ionized water activated by the modifying agent fed by the modifying agent supply device reaches the predetermined water level, normal washing process starts. The rinsing operation is performed after water is supplied into the washing tub again, electrolytic polarity of the electrolyzing cell is changed to produce acidic ionized water and alkaline ionized water respectively, acidic ionized water is fed into the washing tub, alkaline ionized water is discharged, and some tap water is introduced to meet the predetermined water level to fulfill the entire rinsing operation.

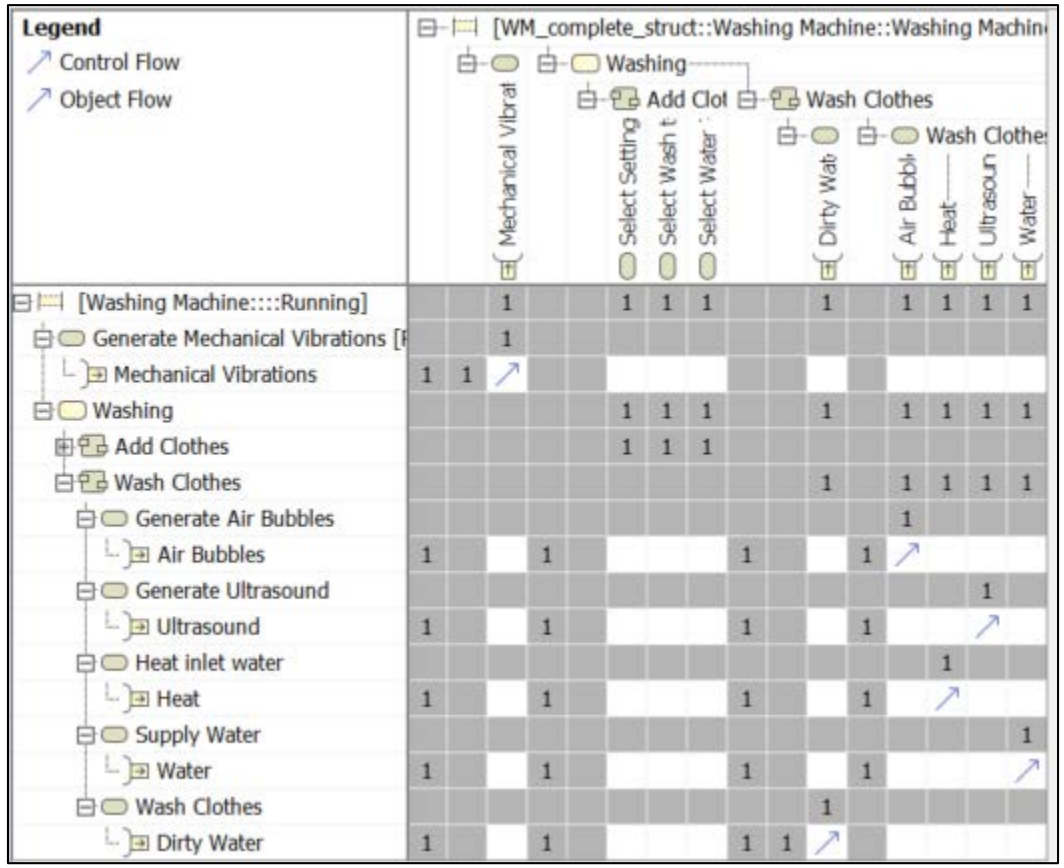
Triz Principles 6 and 18





The diagram shows functions and corresponding physical elements responsible to carry out that function.
Differences can be seen clearly in a simple diagram using MBSE.

Comparison through functions



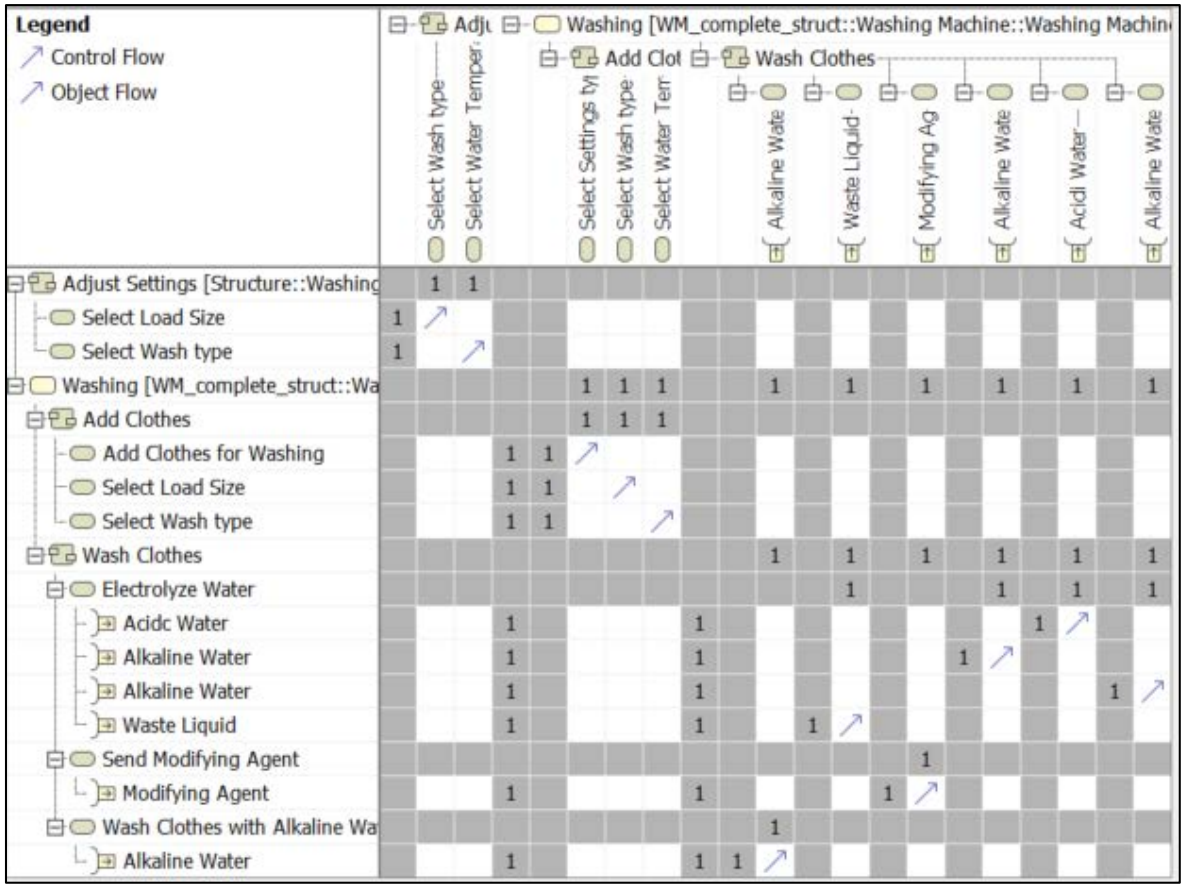
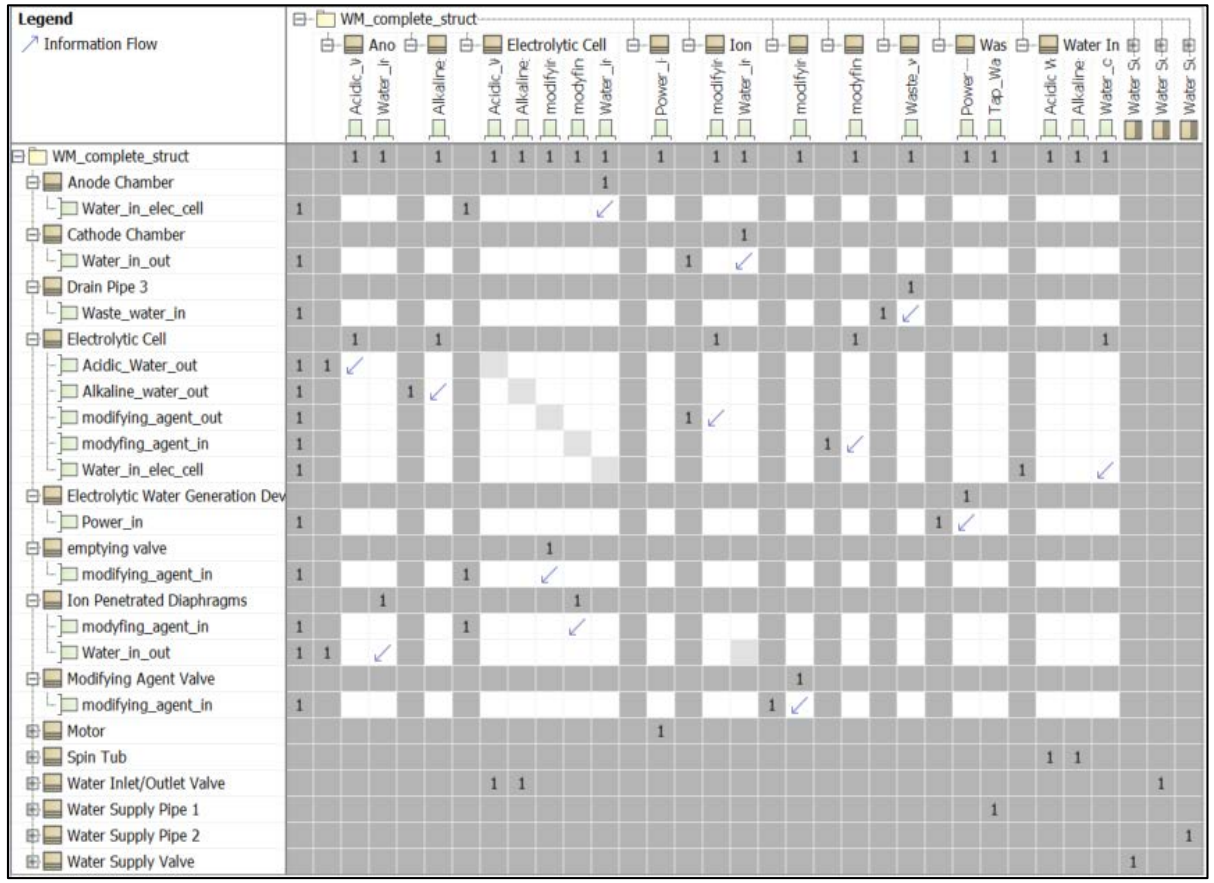
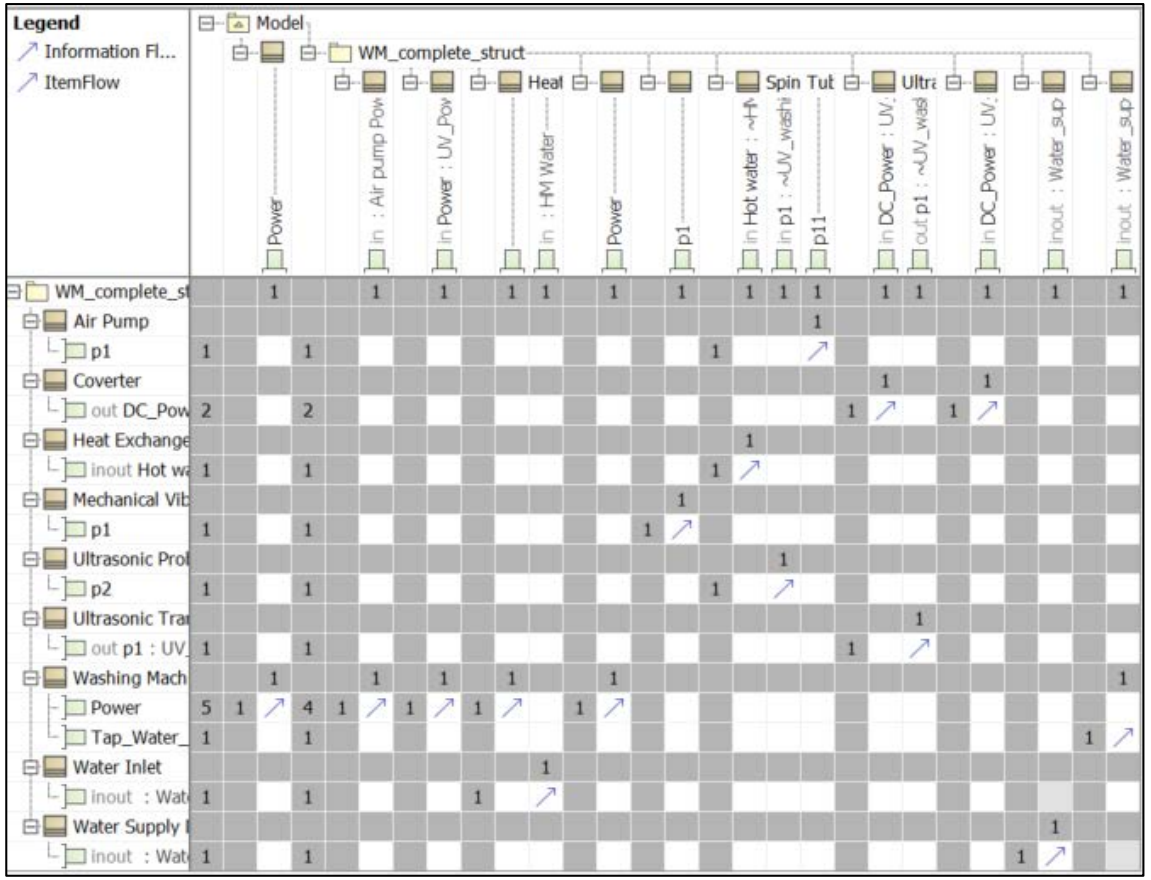


Diagram shows flow between different functions, flow of physical properties as well as flow of the order in which functions are been executed

Comparison through physical elements





Conclusion

- These diagrams represent the content in the patent publication documents in term of different SysML views
- The system of washing machine was represented in the form of different SysML views, the different diagrams show the structural decomposition as well as the functional decomposition of the system.
- The data given in the patent publication was not enough to create a full representation of the system and to create requirements traceability. If a full view of the system needs to be created we might need more documents than the current resources.
- The SysML model represents the system in a much more sophisticated and structured manner than the documentation used to create the model. Many more diagrams such as context diagram, sequence diagrams etc. can be built to represent many more aspects of the system