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# A User Centric View of Lyee Requirements

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**Abstract.** The paper deals with the modelling of Lyee user requirements and guidelines to support their capture. The Sorbonne contribution to the Lyee collaborative project aims to reduce the software development cycle to two explicit steps, requirements engineering and code generation by coupling the code generation features of LyeeALL with an interface to capture user requirements. The paper presents a 2-layer meta-model relating the set of concepts to capture user requirements to the set of concepts for the formulation of software requirements that are the input of the LyeeALL generation mechanism. It exemplifies the concepts with example and introduces the guidance support for capturing these user centric requirements.

## 1. Introduction

The research of the Sorbonne group within the Lyee<sup>1</sup> collaborative project is aimed at developing a methodology that supports software development in two steps, requirements engineering and code generation. The former is the contribution of the Sorbonne group whereas the latter is provided by LyeeALL.

LyeeALL is a commercial Japanese CASE environment which aims at transforming software requirements into code. As shown in Figure 1, the underlying Lyee approach [16] [17] comprises an *original framework* to structure programs, an *engine* to control their execution and a *generation mechanism* to generate programs from given requirements. These requirements are expressed in rather low-level terms such as screen layouts and database accesses. Moreover they are influenced by the LyeeALL internals such as the Lyee identification policy of program variables, the generated program structure and the Lyee program execution control mechanism. As a consequence it is difficult to get the Lyee customer away from the burden of Lyee internals instead of focusing his/her attention on the requirements. Projects conducted in industry with LyeeAll show the need to separate clearly software requirements from user-centric requirements in order to acquire the former from the latter.

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<sup>1</sup> Lyee, which stands for Governmental Methodology for Software ProviDence, is a methodology for software development used for the implementation of business software applications. Lyee was invented by Fumio Negoro.

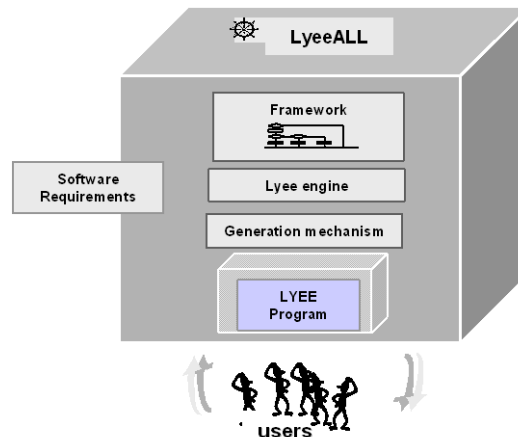


Figure 1 : LyeeALL

The Sorbonne group develops research towards meeting this need. As a first step, the group is aiming at:

- (1) defining a user-centric requirements model
- (2) developing methodological rules to support the capture of these requirements in a systematic way,.
- (3) developing a software assistant to guide the capture of user centric requirements
- (4) generating the Lyee software requirements from these user requirements

In a second step, the objective is to provide an intelligent software support for the elicitation of high level requirements and the automated generation of the Lyee software requirements.

In this paper we concentrate on points (1) and (2) above. In the next section we introduce the meta-modelling approach which was used to define the user-centric requirements model and we provide an overview of the model. Section 3 contains a description of the model concepts and illustrates them with examples. The next section deals with the process support to help in the capture of user-centric requirements. Some idea of future work is given in the conclusion.

## 2. Meta-Modelling Approach and Lyee Requirements Meta-Model

At the start of the project, it was quickly realised that Lyee was understood in operational terms such as Process Route Diagram (PRD), Pallets, Signification Vectors, Routing Vectors and the like and it was difficult to get a global, *systemic view* of it. The need for the latter was felt particularly strongly because :

- (a) user-centric requirements are to be related to Lyee software requirements. and a systemic model would help in clearly expressing this relationship.
- (b) additionally, the transition from user requirements to Lyee programs called for traversal across different levels of abstraction, a task that the area of modelling and meta-modelling is known to perform effectively.

Meta-modelling is known as a technique to capture knowledge about methods. It has been used for understanding, comparing and evaluating methods [7]. Meta-models were also used as a basis for method-engineering [4] and Case shell construction [3] [9] [13]. A number of meta modelling languages have been proposed to deal with (a) the representation of the product aspects of methods [1] [3] [8] [10] [15] [24] and (b) for modelling the process aspects of methods [12] [20] [21] [23].

We used a meta modelling approach to first model the set of concepts underlying the Lye software requirements and secondly, to abstract from them the user-centric requirements model. The result of this effort is a 2-layer meta model<sup>2</sup> expressed with UML notations. The upper layer corresponds to the user-centric requirements model whereas the lower layer identifies the set of concepts required to express software requirements in Lye terms.

Figure 2 shows the meta-model and highlights the separation between user requirements concepts and Lye software requirements concepts. The former constitute the user requirement layer whereas the latter form the Lye software requirements layer.

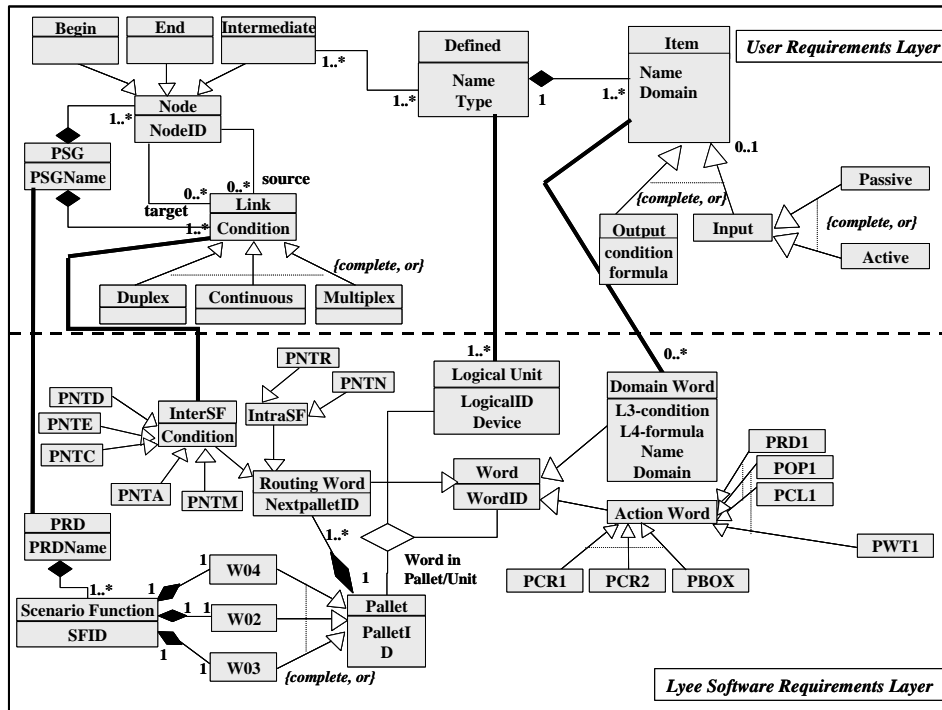


Figure 2 : Lye meta-model

Let us introduce first, the lower layer concepts to express Lye software requirements. The essence of the Lye approach is to reduce software requirements to the description of *program variables* called *words*, and to generate the *control structure* that logically processes these variables and produces the expected result. Despite the traditional design approaches in which both the variables and the control structure of the program must be designed, LyeALL generates the latter provided an appropriate description of the former is given.

- From the design view point, the approach can be compared to declarative approaches for information system design. In these approaches, system design is reduced to a set of predicates from which the state of the system can be derived at any point of time  $t$ . Lye relies on the notion of *word* and makes the distinction between input words ( these are given value through system communication with the external world) and output words produced by the system. Instead of predicates, Lye uses formulae to express how to produce an output word. The ordering of word production does not need to be given. In this sense the Lye approach is declarative.
- From the generation view point, LyeALL is similar to a forward inference engine of an expert system which generates new facts by applying to the existing base of facts at time  $t$  those rules having their premises true. Similarly, the Lye engine saturates the

<sup>2</sup> The term meta-model is used in the paper in the same sense as the term meta schema.

application of formulae till all the output words are determined. However, as the Lyee engine controls the execution of formulae which are procedural rules and not inference rules, the engine activates a proprietary function to a Lyee specific program structure, the *Process Route Diagram* (PRD). This structure is hierarchical : a PRD is composed of *Scenario Functions* (SF), composed of *Pallets* which are made of *Vectors*. In order to carry out the generated program control the function generates its own words, such as the action words related to vectors and routing words to distribute the control over the various SFs of a PRD.

The concept of *Word* is therefore central to the expression of Lyee software requirement, whereas the ones of *PRD*, *SF*, *Pallet* and *Vector* required by the word processing mechanism of LyeeALL are also part of the Lyee software requirements model. These concepts can be seen in Figure 2 as part of the lower layer of the meta-model.

The upper layer of Figure 2 is centred on three concepts only : *Defined*, *Item* and *PSG*. This reflects the fact that the user-centric model abstracts from the details of Lyee software requirements to identify the minimum set of concepts to capture the domain dependent requirements. However the simplicity of the upper layer results fundamentally from the declarative approach of Lyee.

We present the upper layer concepts in the next section and illustrate them with the *Split* example. *Split a Goal* is a functionality which, given a goal statement such as '*Withdraw cash from an ATM*', automatically decomposes it into a *verb* and its *parameters*. For example, *Withdraw* is the *verb*, *Cash* is the *target* parameter of the verb and *from an ATM* is the *means* parameter. The full functionality identifies 7 different parameters . However, in this paper we will consider only the two parameters exemplified above, *target* and *means*. Besides, the case considered in the following extends when necessary, the Split functionality in three different ways :

- (a) the storage of the goal and its decomposition in a database.
- (b) the retrieval of the goal name from a Goal table in a database.
- (c) the possible failure of the goal decomposition function.

### 3. The User Centric Requirements Meta-Model

- *Interaction driven user requirement capture*

In order to comply with the Lyee approach, the user requirements model should be centred on a notion which abstracts from the Lyee internal concept of word. Obviously words required by the Lyee processing mechanism are not relevant at this level. On the contrary, the concern is only with domain dependent words. Besides, there is a need to provide the requirement holder with a means to grasp a 'set of 'words' conceptually associated with one another. We propose the notion of '*system interaction*' for that purpose. We believe that the Lyee approach, which is output driven, fits with a use case [6] kind of user requirements capture.

Our suggestion to the Lyee user is to reason in terms of a *goal driven interaction* as shown in Figure 3. The interaction is meant to be between the user and the system viewed as a black box. The interaction is *goal driven* in the sense that the user asks the system to achieve the goal he/she has in mind without knowing how the system will do it. The user provides some input and receives the output which corresponds to the expected result. It is the achievement of the goal which produces the *output*. The *input* is necessary to achieving the goal. We refer to this goal as the *interaction goal*.

In generic terms, any interaction is characterised by the user goal '*Get a result*'; it produces an *output*, given some user *input*. In the Split example, the user goal is to get

support from the system to decompose a goal statement. Thus, ‘Split a Goal’ is the interaction goal. If, for example, the input is the goal statement ‘Withdraw cash from the ATM’, then the achievement of the goal produces the output i.e. the decomposed form of the goal : Withdraw *verb* cash *target* from the ATM *means*.

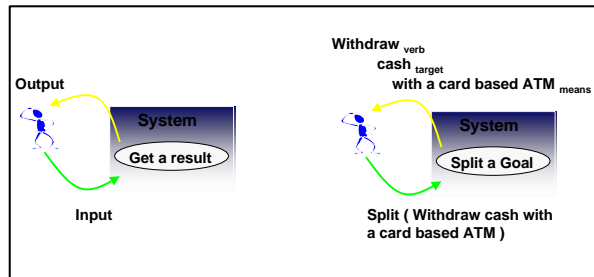


Figure 3 : The interaction view point

- *Words in interaction*

An interaction delineates a number of input and output ‘words’ logically assembled together. The former correspond to meta-model *items* belonging to the same *defined* (see below).

In order to systematise the collect of requirements, we identify generic classes of ‘words’ that will be instantiated in any such interaction and represented as items in the requirements formulation. Let us introduce so far three of them :

- $W_{input}$  : the *input* provided by the user
- $W_{result}$ : the *result* of the goal achievement
- $W_{output}$  : : the *output* displayed to the user

In the ‘Split a Goal’ interaction of Figure 4,  $W_{input}$  is the goal statement given as input by the user, the result  $W_{result}$  produced by the achievement of the goal ‘Split a Goal’, is the set  $\{verb, target, means\}$  and the output  $W_{output}$  presented to the user is identical to the result, i.e. the set  $\{verb, target, means\}$ .

$$W_{input} : \{goal,\}$$

$$W_{result} : \{verb, target, means\}.$$

$$W_{output} = W_{result}$$

As illustrated with the Split example, the set of output words  $W_{output}$  might be the same as the set of result words  $W_{result}$ ; however the semantics is different as the former are the ones whose values are presented to the user whereas the latter are the ones resulting of the interaction goal achievement.

In addition, as shown underneath a relationship can be established between the  $W_{input}$  and  $W_{result}$ :

$$W_{result} \leftarrow W_{cmd}(W_{input})$$

Indeed, to get the interaction goal achieved, the user has to provide the input and to give some kind of command ( $W_{cmd}$ )

- *The concepts of Defined<sup>3</sup> and Item*

All the words of an interaction shall be represented with the meta-model concept of *Item*. The above typology helps identifying the items to be identified and described for a given interaction.

<sup>3</sup> In the following concepts are in italics with a capital as first letter. Instances of concepts are in italics with a small first letter. For example, *Item* refers to a concept whereas *item* refers to an instance of the concept *Item*. A specific item such as *goal* is in small letter and italics.

$$Item \leftarrow W_{result}, W_{cmd}, W_{input}, W_{output}$$

The *items* belong to the same *defined*. A *Defined* is a container of *Items* logically related to each other. Defined and Items are the keys to expressing user requirements compliant to our meta-model.

In the Split example there are 5 *items*, namely *goal*, *cmdSplit*, *verb*, *target* and *means*. All belong to the same *defined*, *Split1*. Figure 4 presents the instantiation of the meta-model for formulating the Items and defined of the Split example. The instance is drawn with the UML object diagram notations.

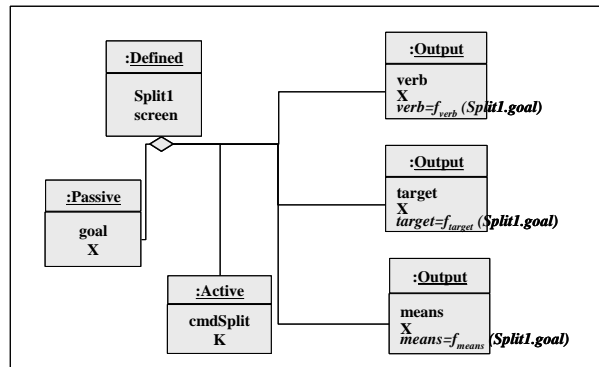


Figure 4 : Items & Defined of the Split interaction

In the meta-model, the concepts of *Defined* and *Item* have attributes: Every *defined* has a *name* (*Name*) and a *type* (*Type*) which identifies the physical device of the container (screen, file, database etc..). An *item* has a *name* (*Name*) and a *domain* (*Domain*): numeric (9), char(X) and (K) for screen buttons. In the Split example, *goal* is the name of an *item* of the *defined* *Split1* which has a string of characters as *domain*(X).

The meta-model specialises *Item* into *Output* and *Input*. An output is produced by the system whereas an input is captured from the user. *Input* is further specialised into *Passive* and *Active*. An *active input* triggers a system action whereas a *passive input* represents values captured from the user. A screen button such as *cmdSplit* in the Split example is an *active item* whereas *goal* is a *passive one*. Both specialisations (*Item* into *Output* or *Input* and *Input* as *Active* or *Passive*) are partitions of the set of *items* i.e. they are complete and exclusive.

Finally, the concept of *Output Item* has two specific attributes : *Formula* and *Condition*. The *Formula* is mandatory whereas the *Condition* is set by default to true. Due to the declarative nature of the Lye approach, calculation dependencies among items do not need to be expressed through conditions. Therefore, only constraints such as validity constraints on input items might become conditions associated to outputs depending on the validity of these inputs. The formula is the calculation rule. In the Split example, the verb will be associated to the formula,  $verb = f_{verb}(goal)$ . The function  $f_{verb}$  when applied to a goal statement produces the verb of its goal statement.

- *Housekeeping goals*

The achievement of the interaction goal ‘*Get a result*’ is not always as straight forward as in the case considered so far. It can happen that it requires some additional goals to be fulfilled. We refer to these goals as *housekeeping goals*. Typical examples are the extension (a) and (b) of the Split case introduced above in the paper. In case (a) the decomposition is stored in the database and in case (b) the goal statement is retrieved from the database. ‘*Store Goal Decomposition*’ and ‘*Retrieve Goal Statement*’ are *housekeeping goals*. They are additional to the interaction goal ‘*Split a Goal*’.

It shall be noticed that there is a fundamental difference between the two types of goals, *interaction goal* and *housekeeping goal*. Whereas the ‘*Get a result*’ type of goal is the essence of the interaction, the *housekeeping* goals contribute to the performance of a successful interaction but do not determine its purpose. The *interaction* goal is user-centric whereas the *housekeeping* goals are system-centric. Following goal decomposition in requirements engineering [3] [6] [23], housekeeping goals can be regarded as sub goals of the interaction goal ‘*Get a result*’.

However housekeeping goals implies new *items* and new *defineds* to be introduced. Let us understand the nature of these items by extending the typology of ‘words’ as defined previously in cases similar to extension (a) of the Split example. A similar reasoning can be done for each type of housekeeping goal [25].

In cases similar to extension (a) of the Split example, words to be memorised in a persistent manner such as in a database or a file,  $W_{indb}$  have to be identified as part of the user requirements formulation.

$$W_{indb} \leftarrow W_{cmddb}(W_{dbkey}, W_{output})$$

The above expression characterises the production of  $W_{indb}$ . In order to store output words  $W_{output}$  in specific database words,  $W_{indb}$ , the database key  $W_{dbkey}$  is required and the user shall activate a command,  $W_{cmddb}$ .

Consequently, new items shall be introduced :

$$\text{Items} \leftarrow W_{indb}, W_{cmddb}, W_{dbkey},$$

Housekeeping goals lead to specific *defineds* as they use a specific device distinct from the one characterising the defined of the interaction. In the Split example, the requirement formulation (Figure 5) includes the *defined GOAL* of type database with the associated *items*, *goalid*, *goal*, *verb*, *means* and *target*. In contrast, the  $W_{cmddb}$  is part of the defined associated to the interaction. In the Split example the command button, *CmdOK* is an *item* of the defined *Split1*.

As there are several *defineds* a precedence relationship between these shall be introduced. The concept of PSG in the meta-model captures this aspect.

- *The concept of PSG*

The meta-model includes the notion of a *PSG*, the *Precedence Succedence Graph* to stipulate ordering conditions between *Defineds*.

As shown in Figure 2, a *PSG* has *Nodes* and *Links* between *Nodes*. *Nodes* are classified into *Intermediate*, *Begin* and *End*. *Begin* and *End Nodes* are predefined nodes to start and end the program whereas *Intermediate Nodes*. are related to *Defineds*.

*Links* between *Nodes* are of three different types : *Continuous*, *Duplex* and *Multiplex* Whereas all links indicate the processing order of the related *defineds*, a *continuous link* is a forward link between two *defineds* while *duplex /multiplex links* are backward links between two *defineds*. The choice between a *duplex* or a *multiplex* link depends on whether or not data have to be transferred to process the backward *defined*. In the Split example, the *defined GOAL* is multiplex- linked to the *defined Split1* to get back to an empty Split screen after a goal decomposition was performed. In this case there is no data transfer associated to the backward link to *Split1* and therefore, the *GOAL-Split1* link in the *psgSplit* is a multiplex one. It shall be noticed that this information is user driven : it is a user decision to choose an iterative process allowing to capture a goal statement and ask for its decomposition several times.



Finally, the meta-model shows that a *Link* might have an associated *Condition* which constraints its occurrence.

Figure 5 presents the instantiation of the meta-model to formulating the Split a Goal requirements in case (a). The instance is drawn using the UML object diagram notations. It shows that there are two *defined*, (a) *Split1* of type screen, gathering the input and output *items* of the interaction and (b) *GOAL* of type database composed of the *items* representing the attributes of the relational table to store the goal decomposition.

*Split1* comprises *active items* (*cmdSplit*, *cmdOK* and *cmdCancel*) whereas *GOAL* has only passive items. Some *items* in *Split1* are typed *input* (*cmdSplit*, *cmdOK*, *cmdCancel*, *goal*) whereas the others are *output items* (*verb*, *target*, *means*). All *items* in *GOAL* are typed *output* as they are produced by the program and stored in the database. Each of the *output items* in the *defined Split1* are associated with a *formula* that is its calculation rule. In compliance with the meta-model, the *output items* of the *defined GOAL* have *formulae* which are rules for expressing that the values of the attributes of the database table *GOAL* are the ones of corresponding *items* of the *defined Split1*.

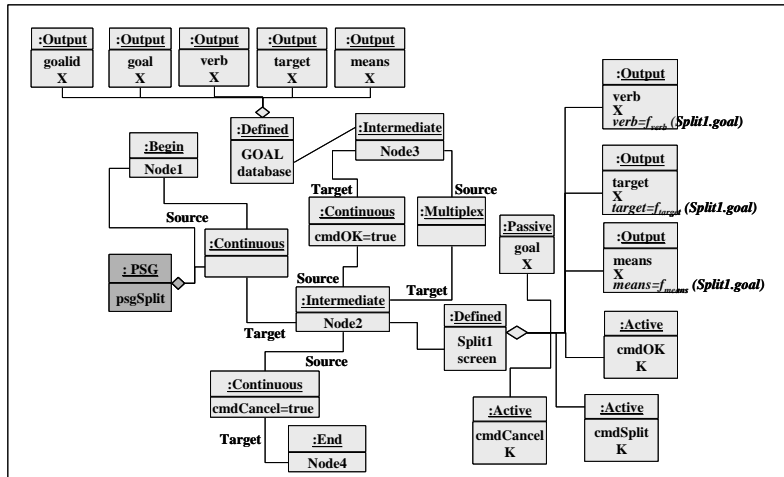


Figure 5 : Formulating the Split requirements through meta-model instantiation

The *psgSplit* comprises two *nodes*, *Split1* and *GOAL* in addition to the *Begin* and *End nodes*. They are related by a continuous forward link which is activated in the processing when the button OK has been pushed and a multiplex link in the backward direction which is processed as soon as the goal decomposition has been stored in the database.

- *Considering Obstacles to ‘Get a result’*

The notion of *obstacle* has been introduced in requirements engineering by Colin Potts in [19] and further developed in [3] [29] [30] [31]. An obstacle is defined as anything which happens and causes a failure in achieving a goal. From a requirement viewpoint, it is important to identify obstacles as the system under construction shall be prepared to react to obstacle happenings. In our case, identifying the risks of interaction goal failure is a means to complete the requirements related to the interaction.

Considering obstacles to the achievement of ‘*Get a result*’ leads to the introduction of new types of words,  $W_{case}^i$  characterised as follows :

$$W_{case}^i = P(W_{output}) : f_{boolean} = true$$

$$W_{output} = \cup W_{case}^i$$

The set of words referred to as  $W_{\text{case}}^i$  corresponds to the subset of output words,  $W_{\text{output}}$  which are produced under a certain condition ( $f_{\text{boolean}} = \text{true}$ ). The entire set of output words to be considered in the interaction is therefore the union of  $W_{\text{case}}^i$ .

Let us consider case (c) of the Split example, assuming that the  $f_{\text{verb}}$  function might fail if the name of the verb extracted from the goal statement is not in the table of verbs used by this function. The interaction might then, fail in achieving the interaction goal 'Split a Goal'. Consequently, there are two cases of output :

- case <sup>1</sup> occurs when the verb, target and means items are presented to the user, whereas
- case <sup>2</sup> occurs when the decomposition cannot be performed; the message 'Impossible Split' is shown to the user.

$$\begin{aligned} \text{In this case } W_{\text{output}} &= W_{\text{case}}^1 \cup W_{\text{case}}^2 \\ W_{\text{case}}^1 &= \{\text{goal, target, means, verb}\} \\ W_{\text{case}}^2 &= \{\text{'Impossible Split'}\} \end{aligned}$$

An *item* has to be introduced for every word of each  $W_{\text{case}}^i$ .

Figure 6 shows the instantiation of the meta-model to formulating case (c) of the Split example. Two new *defineds* *Scase1* and *Scase2* have been added and linked to the *defined* *Split1* through forward continuous links. These links are labelled with conditions identifying the two cases, case <sup>1</sup> and case <sup>2</sup>. Each of the *defineds* aggregates the appropriate items : {*goal, target, means, verb, cmdOK*} for the *defined* *Scase1* and {*M1, cmdOK*} for the *defined* *Scase2*.

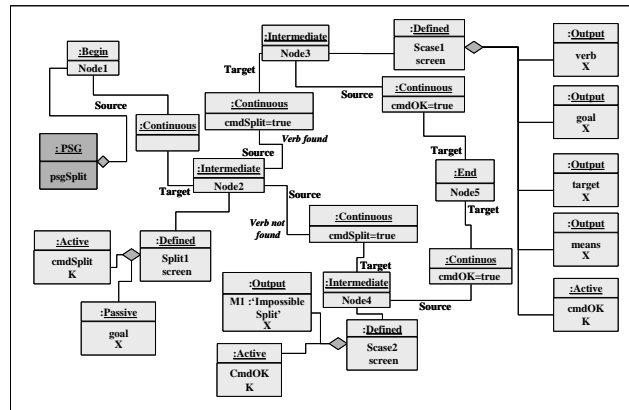


Figure 6 : Formulating the Split case (c ) through meta-model instantiation.

- *Compound interaction*

In real projects the user has to deal with more gross-grained interactions than the Split interaction drawn in Figure 3. We suggest a distinction between a *simple interaction* and a *compound interaction*. The former is associated to one *single atomic interaction goal* whereas in the latter the goal is an *aggregate of interaction sub-goals*

Figure 7 is an example of compound interaction where the goal 'Get Confirmed Booking' is an aggregate of two sub-goals : 'Request for Booking' and 'Confirm & Pay'. The request parameters are the inputs necessary to achieve the first sub goal which results in an offer to the customer. This offer is the input for the achievement of the second sub goal.

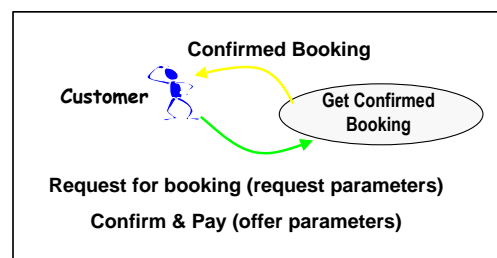


Figure 7: Booking interaction

The notion of AND decomposition of a goal is well known in requirements engineering [5] [6] [19] [22] and business process modelling [3] [11] [14] [18] [26] and seems to fit our needs. The interaction goal of a compound interaction is decomposable in two or more ANDed sub-goals. As shown in Figure 9, the interaction goal ‘Get Confirmed Booking’ is decomposable in two sub-goals ‘*Get Booking Offer*’ and ‘*Confirm Booking Offer*’

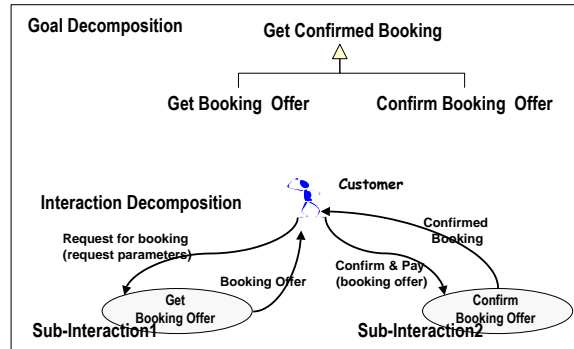


Figure 8 : Decomposition of the ‘Get Confirmed Booking’ interaction

It is important to notice that sub-goals are *interaction goals*. In other words, the compound interaction can be seen as a sequence of atomic interactions, each of them corresponding to one sub-goal of the compound interaction goal. This is exemplified in Figure 8 that shows the compound interaction to ‘*Get a Confirmed Booking*’ as composed of two interactions, the first one to ‘*Get Booking Offer*’ and the second one to ‘*Confirm Booking Offer*’. Each of these interactions follows the pattern explained above and might include housekeeping goals. Each of these will have to be scrutinised as explained before to identify the involved *items* and *defineds*.

To sum up, the user centric layer of the meta-model identifies three key concepts, *Defined*, *Item* and *PSG*. These three concepts are used to express the set of domain dependent requirements and this expression is necessary and sufficient to derive the Lye software requirements. *Items* are the essence of Lye user requirements, the external form of Lye internal words. A *Defined* is a group of items that are conceptually related to one another and are bound together in a simple or compound interaction. In addition to the *Defineds* flowing from the interaction, housekeeping goals introduce complementary *defineds* that require the use of devices such as databases, files or Internet communications. The concept of *PSG* captures the ordering of the *defineds* required by the user.

From a semantic viewpoint, this paper proposes to relate the user-centric requirements to the notion of an *interaction* and introduces an *interaction frame* with a *typology of ‘words’* to reason systematically about the requirements implied by this interaction. It was shown that a complex interaction case can be mastered using a decomposition mechanism that breaks down the compound interaction in ANDed atomic interactions. This introduces the problem of guiding the process to capture user-centric requirements compliant with the meta-model. This problem is dealt with in the next section.

#### 4. Guiding the Requirements Capture

Any method is defined as composed of a product model and a process model [20]. Whereas section 3 was dealing with the *product model* of the Lye method, we consider here the *process aspect* of the method. Our aim is to systematise the capture of user-centric requirements and their formulation in terms which comply with the upper layer of the meta-model as presented in the previous section. Ultimately, our goal is to implement a software assistant to support the capture and formulation of these requirements.

Our process modelling approach is *Pattern* based. The concept of a pattern has been introduced by Alexander in architecture [2] and borrowed by IT engineers to capture software design knowledge. According to Alexander, a pattern refers to ‘a problem which occurs again and again in our environment and describes the core of the solution to that problem, in such a way that you can use this solution a million times over, without ever doing it the same way twice’. The key idea of a pattern is thus, to associate a *problem* to its *solution* in a well identified *context*. The formulation of the problem and of its associated solution are generic.

We identified ten typical situations (*the problem*) in Lyee user-centric requirements capture (*the context*) and associate to them ten guidelines (*the solution*) to help in the requirements elicitation and formulation. We coupled the situation and associated guideline in a *Requirement Pattern* and therefore, the process model takes the form of a *Catalogue of Requirements Patterns*.

Each pattern captures a requirement situation and guides the formulation of the requirement in compliance with the requirement meta-model. In fact each pattern tells for the given situation, what are the concepts of the meta-model to instantiate and how, which are the attributes that have to be considered and what are the links between concepts that must be instantiated.

The ten patterns will be applied again and again in the different software projects using Lyee. Even if actual situations are different from one project to another, each of them should match one pattern situation and the pattern will bring the core solution to the requirements capture problem raised by this situation.

- *Identifying generic activities of requirements capture in an atomic interaction*

In order to systematise the requirements capture, we first founded our reasoning on the notion of atomic interaction and investigate the possibility to identify generic activities of requirements capture within the context of an atomic interaction. We end up with the view that the capture of requirements related to an atomic interaction comprises four activities to, respectively:

- Start the interaction (*To Start* requirement)
- Perform the action (*To Act* requirement)
- Prepare the output (*To Output* requirement)and,
- End the interaction (*To End* requirement)

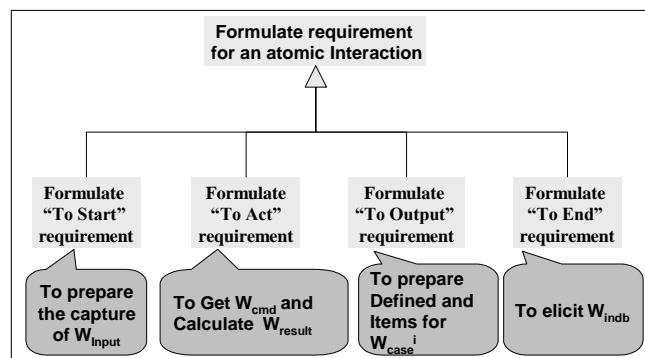


Figure 9 : Generic activities of requirements capture in an atomic interaction

As shown in Figure 9, each of these activities is linked to the ‘word’ typology introduced in section 3 as each activity is associated to one type of ‘words’. The requirement activity is concerned with the elicitation and definition of these ‘words’, their grouping in *defineds* and the positioning of those in the *PSG* of the interaction.

- The *To Start* requirement deals with the capture of  $W_{input}$

- The *To Act* requirement is concerned by the elicitation of the  $W_{cmd}$  and the calculation of  $W_{result}$
- The *To Output* requirement shall help eliciting and defining  $W_{case}^i$
- Finally, the *To End* requirement considers  $W_{indb}$

- *Identifying typical situations in requirements capture*

The relationship between a requirement activity and its associated type of word was essential to identify generic situations for requirements capture. For instance, we identified two different situations dealing with the capture of  $W_{input}$  : either the input value is directly captured from the user or it is indirectly captured through the satisfaction of a housekeeping goal. In the Split example this corresponds to the initial case and case (b), respectively. In the initial case the user provides the goal statement whereas in case (b) it provides the *goalid* which is used to retrieve the goal in the database table.

We identified two generic situations for each of the four generic activities of requirement capture introduced above. These situations are described in the Table1 below.

Situation	Requirement Activity	Situation Characterisation
S2	To Start	$W_{input}$ are captured directly from the user
S3	To Start	$W_{input}$ are captured indirectly through some housekeeping goal to retrieve the input value from a database or a file
S1	To Act	$W_{result}$ are calculated by simple formulae which do not require the calculation of intermediate words
S8	To Act	$W_{result}$ are calculated by complex formulae which do require the calculation of intermediate words and possibly the access to data in a file or database.
S6	To Output	There is no obstacle neither in the capture of $W_{input}$ nor in the production of $W_{result}$
S7	To Output	A number of different cases of output production shall be considered due to possible obstacles either in the capture of $W_{input}$ or in the production of $W_{result}$
S4	To End	The interaction ends normally without additional housekeeping activity.
S5	To End	Some housekeeping activity shall be performed such as storing part or the totality of $W_{outputs}$

Table 1 : Generic situations in requirements capture

It shall be noticed that the two situations of each activity are orthogonal. Given an interaction and one requirement activity , let say ‘To Act’ either S1 or S8 will be true but not both as the same time.

- *Identifying requirements patterns*

- *Atomic interaction patterns*

To each of the 8 situations of requirement capture presented above, we define a guideline that helps in the performance of the requirement activity. As the result of any of these requirements activities is an instantiation of the meta-model concepts, guidance tells which *items* shall be introduced, to which *defineds* they must be associated and how these *defineds* must be positioned in the PSG. Every guideline provides exactly this type of knowledge : given the situation at hand, the guideline advises on *items*, *defineds* and their *attributes* as well as *defineds precedence relationships* required by the situation.

We couple the *situation* and the *guideline* in a pattern, namely a *Requirement Pattern*. Figure 10 shows the 8 patterns corresponding to the 8 situations described in Table1. These are *atomic* patterns in the sense that they do not call for applying other patterns.

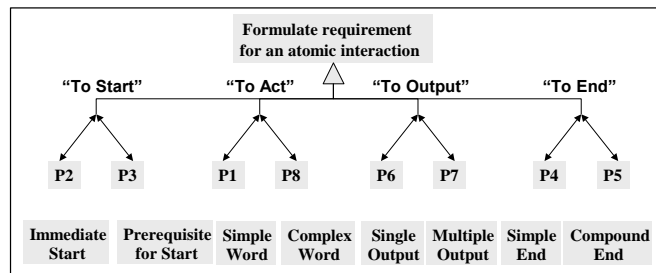


Figure 10 : Requirements Patterns for an atomic interaction

These 8 patterns provide advice to capture and formulate requirements for each of the generic requirements activities:

- P2 & P3 support the 'ToStart' requirements activity, i.e. the setting of requirements to ensure that Winput will be properly defined
- P1 & P8 help in the elicitation of requirements which guarantees that Wresult can be calculated by the Lyee program
- P6 & P7 advice in discovering obstacles to interaction goal achievement and to formulate the appropriate *items*, *defineds* and *PSG links* for handling these obstacles in the Lyee program.
- P4 & P5 ensure that the interaction will end correctly and that housekeeping goals will be taken care of.

- *Composite pattern for atomic interaction*

Each of the previous 8 patterns deals with one single requirement activity whereas to get the complete set of requirements for a given problem, the requirements engineer has to perform one of each type of activity. The complete set of requirements requires that each of the following be performed once: 'To start', 'To Act', 'To Output' and 'To End'.

To obtain advice on this, a new pattern, Pattern P9, is introduced. As shown in Figure 11, the requirement pattern P9 is a compound pattern composed of the 8 atomic patterns, P1 to P8.

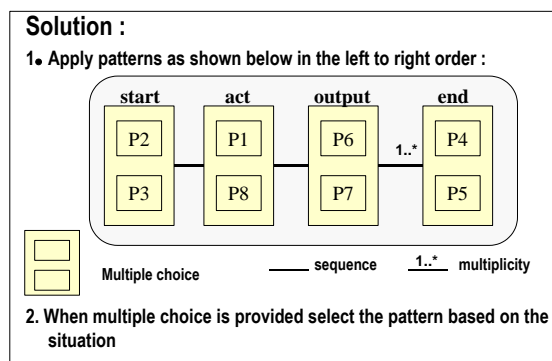


Figure 11 : The compound requirement pattern P9

P9 simply advises that one pattern for each of the four activities needs to be applied to complete one interaction requirements formulation. The choice of the right pattern to apply for each activity is based on the situation at hand. Since the situations of the two candidate patterns of any activity are orthogonal, the decision making is facilitated. For instance, in the simple case of the Split example (get the goal statement and outputs the

goal decomposition), P2 is applicable as the input is directly got from the user; P1 must be applied as the decomposition function produces the goal decomposition directly from the goal statement; P6 is the right pattern because there is no obstacle either in getting the input or in calculating the result and P4 is applicable in this case as there is no additional task to perform than displaying the goal decomposition to the user.

Thus, for a given interaction, the requirements process will consist of a path within P9. For instance, P2, P1, P6, P4 is the path for dealing with the basic Split example whereas P3, P8, P7, P5 is the path for the extended Split example (combining (a), (b) and (c)).

- *Composite pattern for compound interaction*

Finally, the requirement pattern P10 deals with a compound interaction as introduced in the previous section. As shown in Figure 12, P10 is a composite pattern which calls for the iterative application of P9.

As suggested by the figure, the pattern gives advice on how to decompose a compound interaction into atomic interactions to which the pattern P9 should be applied. In fact, the pattern helps in recognising that the interaction is not an atomic one in the first place.

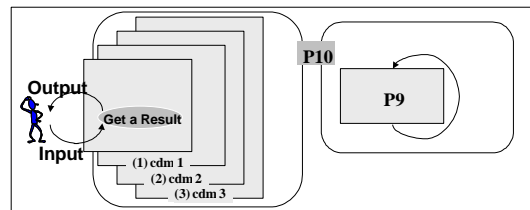


Figure 12 : The composite requirement pattern P10

## 5. Conclusion

The UP1 activity presented here relies on meta-modelling. Meta-modelling has been used in Information Systems as a way of developing abstractions of methods to aid in method understanding, evaluation and comparison. In extending this to Lyee we expected to gain a better understanding of how the Lyee method generates programs from given software requirements. Indeed the lower of the two layers of our meta-model achieved this purpose. The upper layer added a new abstraction level which makes it possible to deal with user requirements and not with low level software requirements. With this capability comes the possibility of generating Lyee programs directly from user requirements. The next step to be taken is to formalise the mapping rules between the two sets of concepts.

Meta-modelling addresses both, process and product aspects of methods. The meta-model presented in this paper is a product meta-model. To complete the formalisation of the method it is necessary to also model the way-of-working. The paper introduced the pattern approach and the ten patterns which are currently under development to support the acquisition of user requirements. Each pattern identifies a generic situation in user requirements capture and proposes a solution to elicit and formulate the requirement typical of this situation. The next step will be to validate the pattern through extensive experiments and to develop a CASE tool to guide the requirements engineers in the application of patterns.

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