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WEB App INTERNAL NAVIGABILITY MEASURES

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Author: Cristina Cachero
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1. INTRODUCTION

Nowadays, several approaches for developing Web applications have been proposed in the literature (e.g., OOHDM [8], WebML [4], OOH [5], W2000 [2] and OOWS [7]). Most of them extend existing object-oriented conceptual modelling methods or hypermedia methods, incorporating new constructors in order to model the navigational structure and the contents of Web applications. Such new constructors are commonly represented in a Navigational Model. As navigational models constitute the backbone of Web application design, their quality has a great impact on the quality of the final product which is actually implemented and delivered.

Comai *et al.* (2002) define two quality attributes that may contribute to assess navigability based on the navigational model: *correctness* and *usability*. Syntactic correctness (assured by the methodology meta-model) is distinguished from semantic correctness. In order to get an indicator of semantic correctness Comai *et al*. propose to measure the absence of conflicts, the absence of racing conditions and the reachability of units and pages, but they do not provide concrete formulae to compute these indicators. Regarding usability, Comai *et al*. distinguish among consistency, ease of navigation and low page density, but again they only give pattern examples in WebML, and fail to formally define any measure that could be generally applicable to other WE navigational models.

Abrahao *et al.* proposed a set of metrics for navigational models [1] that have been used for analyzing the quality of web applications produced by OOWS in terms of size and structural complexity (width, depth and edge-to-node ratio). These measures were defined and validated using a formal framework (DISTANCE) for software measure construction that satisfies the measurement needs of empirical software engineering research. Using the GQM template for goal definition [3], the measures are defined in the following context:

- Goal: *Analyse* the Navigational Model *for the purpose of* predicting *with respect to* its usability *from the point of view of* the web application final users *in the context of* 4th year Computer Science students
- Questions (to be answered by means of empirical evidence)
  - Assuming that the usability of the navigational models is potentially influenced by their size and structural complexity (both morphological characteristics of the software abstractions based on grapas), we can define the following questions:
    - How is usability (and its sub-characteristics effectiveness, efficiency and satisfaction) affected by the **size** of the navigational models?
    - How is usability (and its sub-characteristics effectiveness, efficiency and satisfaction) affected by the structural complexity due to **depth, width and connectivity level (ratio edge-to-node)** of the navigational models?
- Measures
  - Those presented in Table 1 and Table 2

Table 1: OOWS Measures for Navigational Models (Context level)

Metric Name	Metric Definition
Number of Navigational Contexts (NNC)	[1] The total number of navigational contexts in a navigational map.
Number of Navigational Links (NNL)	The total number of navigational links in a navigational map.
Density of a Navigational Map (DeNM)	An indicator of density of a navigational map.
Depth of a Navigational Map (DNM)	The longest distance of a root navigational context to a leaf context.
Breadth of a Navigational Map (BNM)	The total number of exploration navigational contexts.
Minimum Path Between Navigational Contexts (MPBNC)	The minimum amount of navigational links that are necessary to transverse from a source to a target navigational context.
Number of Path Between Navigational Contexts (NPBNC)	The amount of alternative paths in order to reach two contexts within a navigational map.
Compactness (Cp)	The degree of interconnectivity of a navigational map.

Table 2: OOWS Measures for Navigational Models (Subsystem level)

Metric Name	Metric Definition
Fan-In of a Navigational Context (FINC)	This counts the number of invocations a navigational context calls.

Fan-Out of a Navigational Context (FONC)	This counts the number of navigational links that call a navigational context.
Number of Navigational Classes (NNCl)	The total number of classes within a navigational context.
Number of Attributes (NA)	The total number of attributes of all classes in a navigational context.
Number of Methods (NM)	The total number of methods of all classes in a navigational context.

The fact that these measures are based on the graph theory makes them ideal candidates to be applied to navigational models developed with different Web methodologies, where the corresponding navigational models are also graphs. However, the nomenclature (and sometimes also the semantics) of the different WE navigational constructs differ from methodology to methodology. In order to overcome this problem, we have developed a navigational constructs equivalence list, which is presented in Table 3.

Table 3: Navigational Constructs Equivalence List

	OOWS	**OO-H**	**UWE**	**WebML**
Domain Model	*Object Model*	*Class diagram*	*Class Diagram*	*ER Model*
	Class	*Class*	*Class*	*Entity*
	Relationship (association, aggregation, composition)	*Relationship (association, aggregation, composition)*	*Relationship (association, aggregation, composition)*	*Relationship*
Navigation Model	*Navigational Map*	*Navigational Model*	*Navigational Model*	*Hypertext structure schema*
	Exploration Navigational Context	*Navigational Targets that contribute to a globally available collection*	*Package*	*Site View*
	Sequence Navigational Context	*Navigational Target*	*Package*	*Site View*

	Navigation Class	*Navigational Class*	*Navigation Node*	*Data Unit*
	Navigation Link	*Traversal Link* *Requirement Link* *Service Link*	*Navigation Link*	*Link*
	Navigation Patterns	*Navigation patterns*	*Access primitives*	*Sortable Unit*

With this table, we do believe that it is possible to adapt all the measures proposed in [1] to other methodologies. To empirically prove this assumption, next we are showing how it is possible to calculate all the measures presented in [1] with OO-H navigational models. For this demonstration to take place, we have converted the original OOWS navigational model presented in [1] into an equivalent OO-H navigational model.

2. APPLICATION OF OOWS MEASURES TO OO-H

Imagine that we want to model the audience member navigational view over the domain model presented in Figure 1.

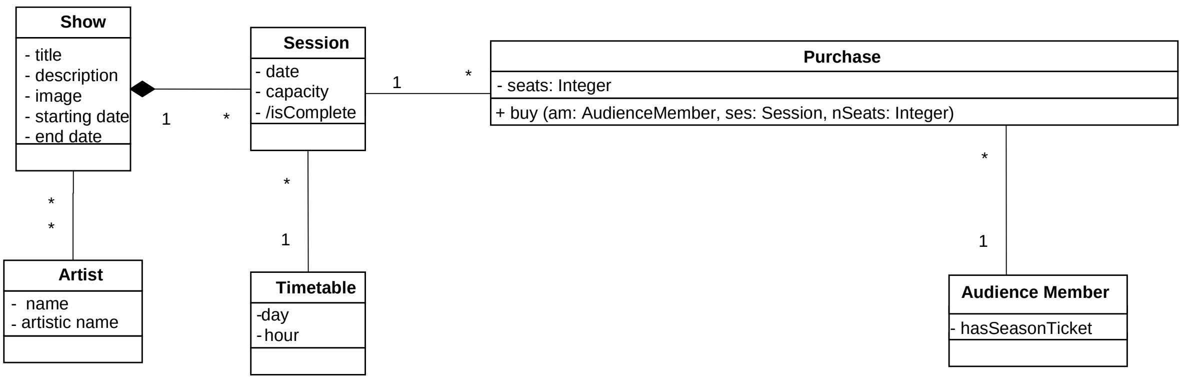

Figure 1: Domain Model corresponding to a Ticket Sales System

Let's now suppose that we subdivide the application in the eight subsystems presented in Figure 2. The measurement results associated to the measures contained in Table 1 when these measures are calculated over the OO-H navigational model depicted in Figure 2, once the constructs equivalences (see Table 3) have been applied, are presented in

Table 4.

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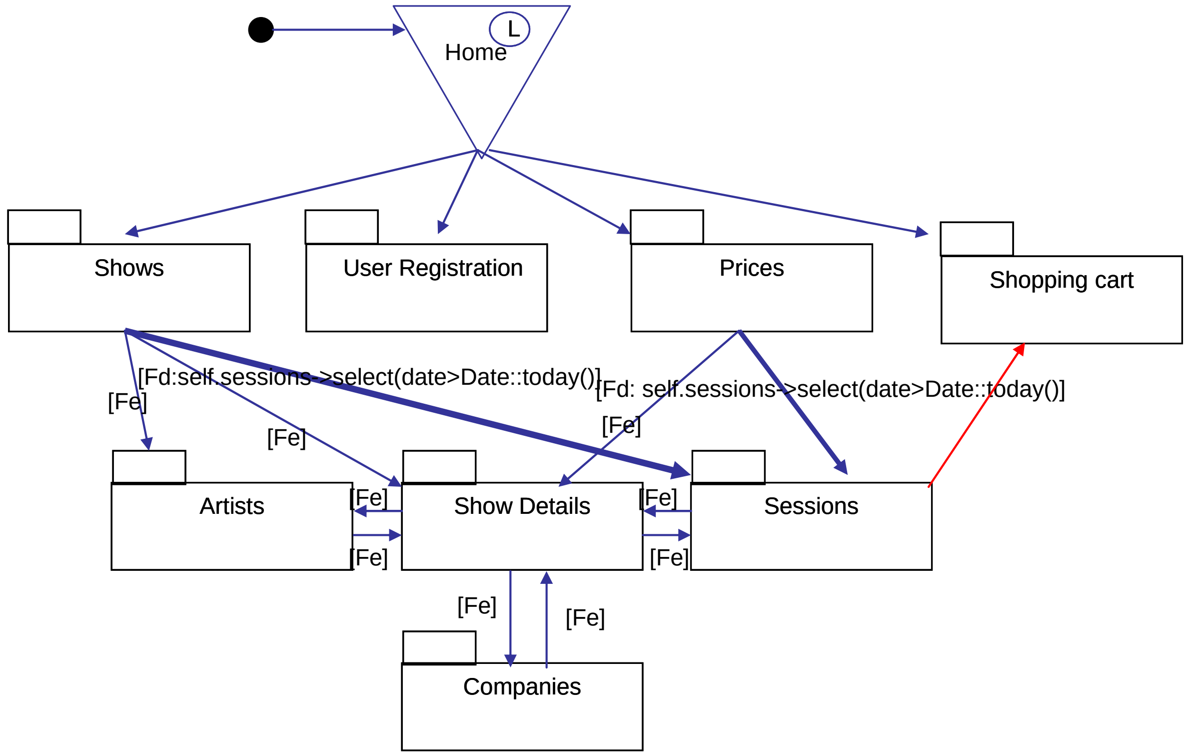

Figure 2: OO-H Navigational Model (Context Level)

Table 4: Measures results over OO-H model example (Figure 2) of Context-level OOWS Measures (Table 1)

Number of Navigational Contexts (NNC): 8
Number of Navigational Links (NNL): 16
Density of a Navigational Map (DeNM): 16/8=2
Depth of a Navigational Map (DNM): 3
Breadth of a Navigational Map (BNM): 4
Minimum Path Between Two Given Navigational Contexts (MPBNCa-b): Shows-companies: 2 Shows-artists: 1 Session-Artists: 2 Shopping cart-show details: not applicable …
Number of Paths Between Two Navigational Contexts (NPBNCa-b): Shows-companies: 3 Shows-artists:5 Sessions-Artists: 2 Shopping cart-show details: 0
Compactness (Cp): complex calculus needed

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Now, let's explode the Navigational Target Sessions (see Figure 3)

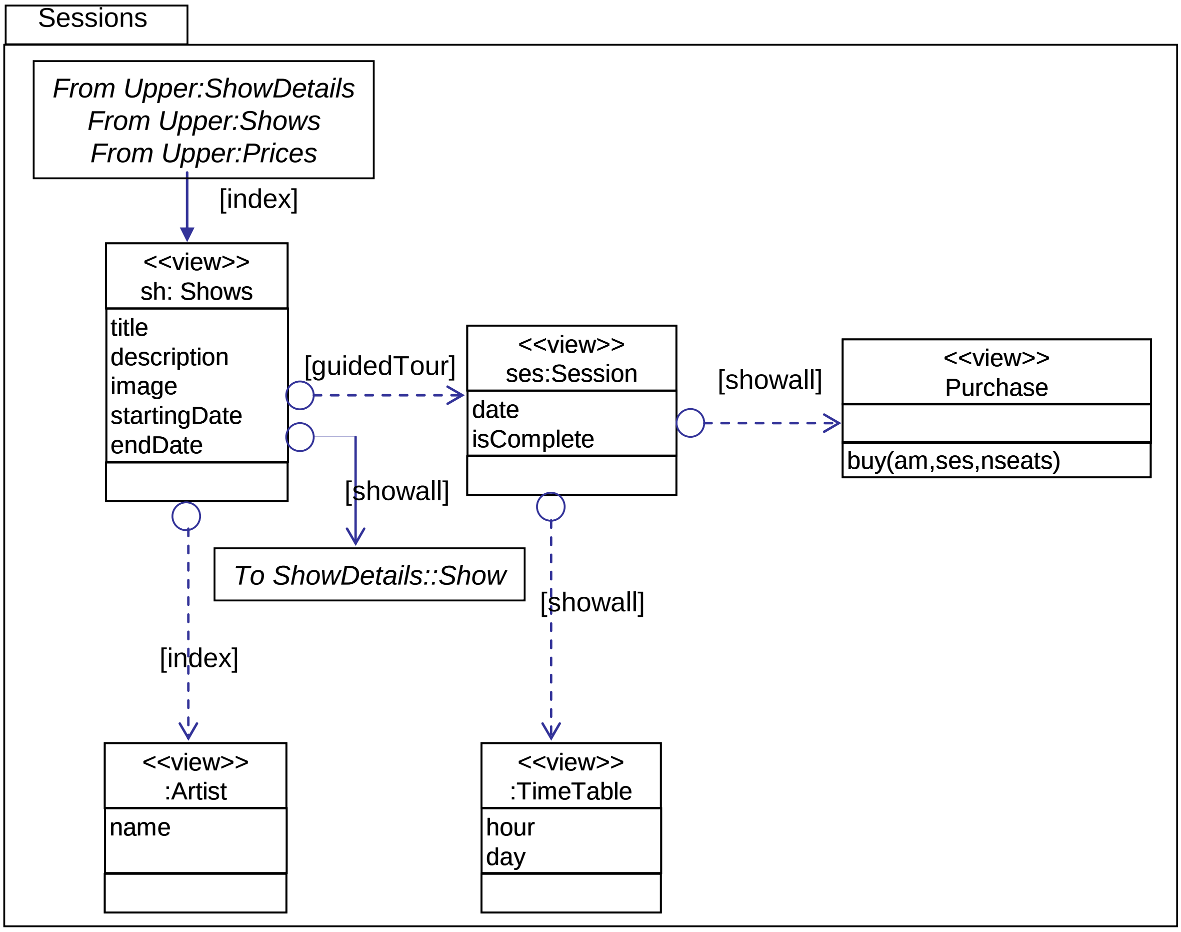

Figure 3: OO-H Navigational Model (Sessions Subsystem)

The measurement results associated to the measures contained in Table 2, when these measures are calculated over the OO-H navigational model depicted in Figure 3, once the constructs equivalences (see Table 3) have been applied, are presented in Table 5.

Table 5: Measures results over OO-H model example (Figure 3) of Subsystem-level OOWS Measures (Table 2)

Fan-In of a Navigational Context (FINC): 3
Fan-Out of a Navigational Context (FONC): 1
Number of Navigational Classes (NNCl): 5
Number of Attributes (NA): 10
Number of Methods (NM): 1

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3. NEW OO-H MEASURES

To the measures presented in [1], OO-H adds a set of new ones that can be calculated over navigational models at context level, at subsystem level, at service level or considering the whole model as a flat model. Next we are presenting each subset of new OO-H measures.

3.1. NEW OO-H NAV MEASURES AT CONTEXT LEVEL

The set of OO-H measures that can be calculated over navigational models at context level is presented in Table 6.

Table 6: OOH Measures for Navigational Models (Context level)

Metric Name	Metric Definition
Max(MPBNC)	The longest minimum path between any two navigational subsystems.
Min(NPBNC)	The minimum number of paths between any two navigational subsystems.
Avg(MPBNC)	The average minimum path between any two navigational subsystems
Avg(NPBNC)	The average number of paths between any two navigational subsystems

Following our example, the application of these measures to the OO-H navigational model of Figure 2 would give the measurements results presented in Table 7.

Table 7: Measures results over OO-H model example (Figure 2) of Context-level OO-H Measures (Table 6)

Max(MPBNC): 2
Min(NPBNC): 0
Avg(MPBNC): Complex calculus needed
Avg(NPBNC): Complex calculus needed

3.2. NEW OO-H NAV MEASURES AT SUBSYSTEM LEVEL

The set of measures that can be calculated over navigational models at subsystem level is presented in Table 8.

Table 8: OOH Measures for Navigational Models (Subsystem level)

Metric Name	Metric Definition
SNAP: Subsystem Number of abstract pages	Number of abstract pages generated by the navigational subsystem
NRSDC: Number of relevant Subsystem Domain Classes	Number of domain classes that collaborate in the fulfilment of the requirements covered by this subsystem for this actor of the system

	(in collaboration with domain model and requirements model)
NSDC: Number of supporting Subsystem Domain Classes	Number of (distinct) domain classes that actually support the subsystem (in collaboration with domain model)
SDCC *(Subsystem Domain-Concept Coverage)*	NSDC/NRSDC (in collaboration with domain model and requirements model)
SNRDR: Subsystem Number of relevant domain relationships	Number of domain relationships that, given the set of domain classes that collaborate in the fulfilment of the requirements covered by this subsystem for this actor, could be supported in the navigational subsystem. (in collaboration with domain model and requirements model)
SNSDR: Subsystem Number of supported domain relationships	Number of distinct domain relationships supported in the model. (in collaboration with domain model)
SDRC *(Subsystem Domain-Relationships Coverage)*	NSDR/NRSDR (in collaboration with domain model and requirements model) *Percentage of domain relationships that, being defined among the concepts in which a certain user type is interested in this subsystem, can be in fact navigated by such user.*
SDCNM (Subsystem Domain Coverage of the Navigational Model) It is a measure of the cohesion of the requirements coverage	Avg (SDCC,SDRC) (in collaboration with domain model and requirements model)
SNI *(Subsystem Navigation Intuitivity)*	Number of links that, inside the subsystem, imply navigation and support a domain relationship/ total number of links that imply navigation.
SNCx *(Subsystem Navigation Contextuality):*	SNI+Links that imply navigation and that give access to a new requirement fulfillment/ total number of links that imply navigation
SNPC *(Subsystem Navigation Pattern Coherence):*	Coherence in the use of navigational patterns (index, guided tours, etc.) - % use of index

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	- % use of guided tours - % use of showall - % use indexed-guided-tours
+ Every average, min, max, Standard deviation etc among the measurement results applied to each subsystem and /or to the model. E.g. Conceptual Model Coverage (CMC)	CMC: % of domain relationships and concepts covered by this subsystem (regardless of the requirements) (in collaboration with domain model)

For these measures to be calculated, it is necessary to take into account information that comes from both the requirements model and the domain model. For the sake of the example, let's suppose that the Sessions subsystem of Figure 3 is aimed at fulfilling a single requirement 'purchase tickets', and that for this requirement to be fulfilled all the classes of the domain model (see Figure 1) except for the audience member, and all the relationships of the domain model except for the audienceMember2Purchase relationship are necessary.

With these assumptions, the application of the measures of Table 8 to the OO-H navigational model of Figure 3 would give the measurements results presented in Table 9.
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Table 9: Measures results over OO-H model example (Figure 3) of Subsystem-level OO-H Measures (Table 8)

SNAP: 1
NRSDC: 5
NSDC: 5
SDCC: 1
SNRDR: 4
SNSDR: 4
SDRC: 1
SDC: 1 (100%)
SNI: ½=0.5
SNCx: ½+ ½ =1
SNPC: Index: 2/6 Showall: 3/6 Guided tour: 1/6
Conceptual model coverage: 5/6 (covered domain classes)+4/5 (covered domain relationships)

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3.3. NEW OO-H NAV MEASURES AT SERVICE LEVEL

OO-H also proposes two measures to deal with service interface complexity. In fact, OO-H represents the access to domain operations with a special kind of link: the Service Link. This link establishes the way in which users introduce each parameter.

The way of entering information regarding each parameter may vary:

- The parameter may have assigned a constant value, not presented to the user (hidden parameter)
- The parameter may have a constant value assigned that can be seen but not modified by the user (constant parameters)
- The parameter may be introduced by means of a textbox, with or without default parameters associated. Also, a text string may be chosen out of a set of given values by means of checkboxes, comboboxes etc. (simple parameters)
- The parameter may be a system object, selected in a single step (e.g. buy means of a selection on a combo box e.g.) (object parameters)
- The parameter may be a system object, and the user may have to navégate through the system in order to select such object (navigational object parameters)

The number and type of parameters involved in a service interface influence its complexity. The measures proposed by OO-H to assess such complexity are presented in Table 10.

Table 10: OOH Measures for Navigational Models (Service level)

Metric Name	**Metric Definition**

Operation Interface Complexity (OIC)	The complexity of an operation interface. It is calculated as follows:
	- $\sum$complexity (parameter$_i$) / number of parameters, where the complexity function returns:
	  - 0 if the parameter does not appear in the interface or if it appears as fixed text.
	  - 0.25 if the parameter is a simple value and has a default.
	  - 0.5 if the parameter is a simple value
	  - 0.75 if the parameter is an object and the user can select the value from a predefined set.
	  - 1 if the parameter is an object and the user selects the value navigating through the system.

Operation Interface Guidance (OIG)	- Degree of service interface guidance. It is calculated as follows:

	- ∑guidance ($parameter_i$) / number of parameters, where the complexity function returns: - 0 if the interface does not provide any guidance for the introduction of the parameter value. - 0.25 if the interface provides a default or sample value that can be changed by the user. - 0.5 if the interface provides syntactic validation of the parameter value. - 0.75 if the interface provides semantic validation of the parameter value. - 1 if the interface provides a set of values for the user to select the desired one or if the value of the parameter is ommited or fixed.

Let's imagine that the service interface for the purchase (AudienceMember,Session,Integer) operation consists in one text and two textboxes where:
- the fixed text presents the data of the session in which the user is interested (gathered from the navigational context information)
- the first textbox the user must introduce her userID
- the second textbox the user must introduce the number of seats she would like to buy

Given this interface, the OIC and OIG measurement results are presented in Table 11.

Table 11: Measures results over OO-H model example (Figure 3) of Service-level OO-H Measures (Table 10)

OIC: (0+0.5+0.5)/3=0.33
OIG: (0+0+1)/3=0.33

3.4. NEW OO-H NAV MEASURES AT SYSTEM LEVEL

Finally, all the new measures proposed for subsystems are also relevant to assess the complexity of the whole navigational model (which consists in the flattening of every subsystem in a single model).

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These measures are presented in Table 12, together with their definition.

Table 12: OOH Measures for Navigational Models (Whole model level)

NAP	Number of abstract pages generated by the whole navigational model
NRDc: Number of relevant Domain Classes	Number of domain classes that collaborate in the fulfilment of all the requirements for this actor of the system
NSDc: Number of supporting Domain Classes	Number of (distinct) domain classes that actually support the navigational model
DcCNM *(Domain-Classes Coverage of the Navigational Model)*	NSDC/NRDC
NRDr: Number of relevant domain relationships	Number of domain relationships that collaborate in the fulfilment of all the requirements for this actor of the system
NSDr: Number of supported domain relationships	Number of distinct relationships that are actually supported in the model.
DrCNM *(Domain Relationships Coverage* of the Navigational Model*)*	NSDr/NRDr *Percentage of domain relationships that, being of interest for the user to fulfill her goals, can be in fact navigated by such user.*
DCNM (Domain Coverage of the Navigational Model)	**Avg (DcCNC,DrCNM)** ***Percentage of domain classes and domain relationships that, being of interest for the user to fulfill her goals, can be in fact navigated by such user.***
NI *(Navigation Intuitivity)*	Number of links in the navigational model that imply navigation and support a domain relationship/ total number of links that imply navigation.
NCx *(Navigation Contextuality):*	NI+Links that imply navigation and that give access to a new requirement fulfillment/ total number of links that imply navigation
NPC *(Navigation Pattern Coherence):*	Coherence in the use of navigational patterns (index, guided tours, etc.) - % use of index - % use of guided tours

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	- % use of showall - % use indexed-guided-tours
+ Every average, min, max, Standard deviation etc among the measurement results applied to each subsystem and /or to the model.	E.g. average cohesion of requirements coverage in the whole navigational model: calculated as an average of the cohesion of subsystems. Requirements Cohesion off the navigational model: min cohesion of all subsystems cohesion.

The calculus of these measures would require the whole development of the example, which is out of the scope of this Technical Report.

Next we are presenting one of the (from our point of view) most relevant measures introduced by OO-H in detail: The Domain Coverage of the Navigational Model (DCNM), which has been marked in bold in Table 12.

4. RATIONALE OF OO-H MEASURES

4.1. DCNM MEASURE

4.1.1. Definition

DCNM (Domain Coverage of the Navigational Model)	**Avg (DcCNC,DrCNM)** ***Percentage of domain classes and domain relationships that, being of interest for the user to fulfill her goals, can be in fact navigated by such user.***

4.1.2. Rationale

The rationale of this measure lies in the assumption that users may expect to find in the Web application the same relationships that exist among concepts in the problem space.

4.1.3. Hypothesis

Therefore, not finding these relationships in the application may diminish their general satisfaction with the application. Our hypothesis is therefore that 100% of the relationships should be found in the navigational model.

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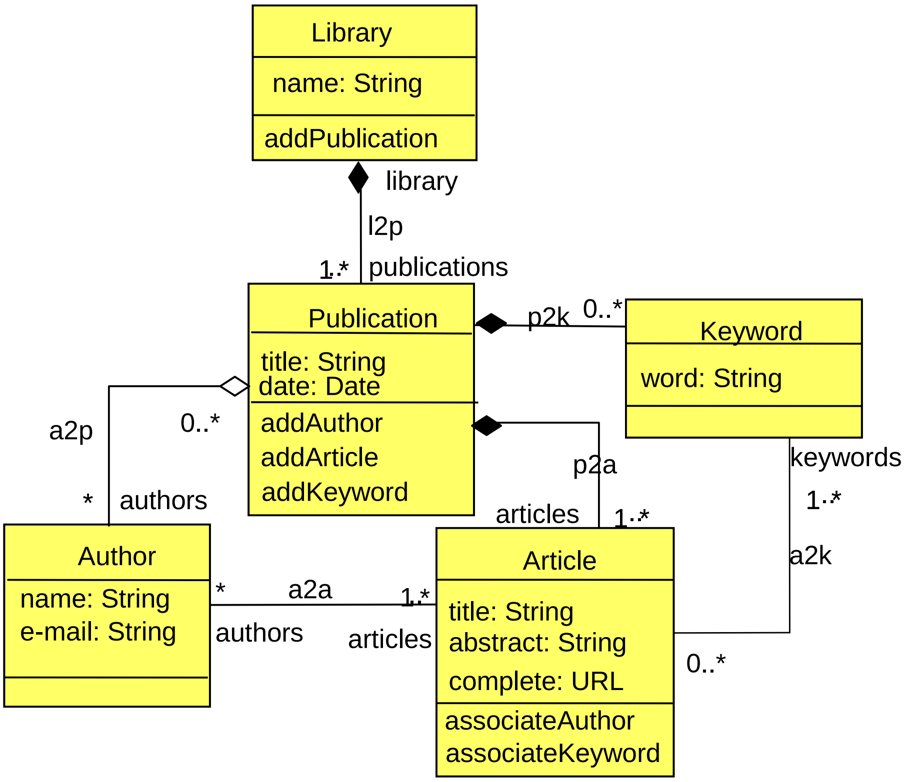
4.1.4. Example

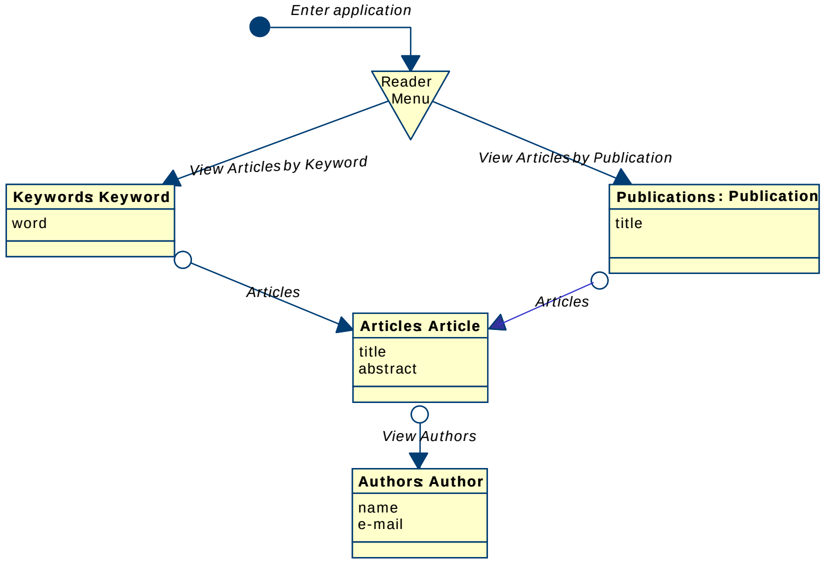


The Domain model of such system is depicted in **¡Error! No se encuentra el origen de la referencia.**. There, we can observe how the library keeps track of a set of publications, each one having a set of keywords by which it is characterized. Each publication is composed of a set of articles. Each article has a title, an abstract and an URL to the complete text. The articles are authored by zero or more authors, and are defined by one or more keywords among those defined for the publication in which they are contained.

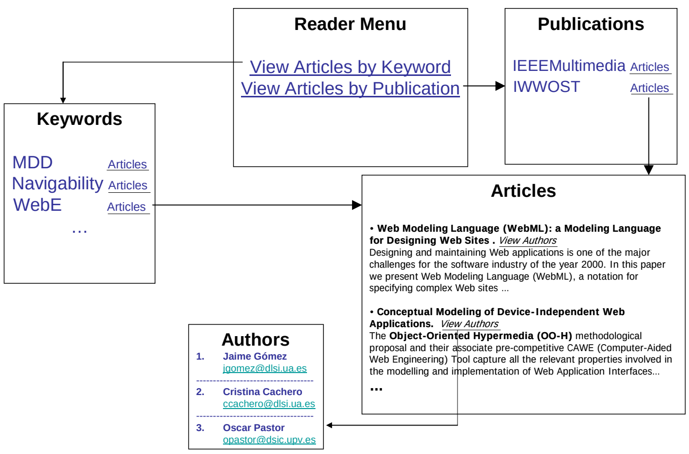
Now, let's design the reader navigational view of the system. This navigational model is constructed on the basis of the Domain model. In the navigational model however only classes, attributes, operations and relationships relevant for a given user type are presented in her navigational view.

For the sake of the example let's suppose that in order to fulfill the reader requirements, all classes and all relationships except for the library class and the l2p relationships are relevant, that is, the Number of relevant Domain Classes (**NRDc)=4** and the Number of Relevant Domain Relationships **(NRDr)=5.**

Also, let's suppose that the navigational model of this actor is simple enough as to be reflected in a single level. This Navigational Model is presented in Fig.



This model reflects a system whose navigation is organized around a collection that, depicted as an inverted triangle, represents the *Reader Menu*. This menu allows the user to decide between two paths: *View Articles by Keyword* and *View Articles by Publication*. Both paths are defined by means of traversal, which also serve to connect the remaining navigational classes that compose the model: *Keywords*, *Publications*, *Articles* and *Authors*. These navigational classes are in fact in OO-H views over the corresponding UML domain classes. For example, *Publications* is a view over the domain class Publication, where all the operations and the *date* attribute have been hidden. As we have stated above, traversal links may reflect underlying domain conceptual relationships. If this is the case, OO-H decorates the traversal link icon (an arrow) with an additional circle. In our example, the traversal link *'Articles'* defined between *Keywords* and *Articles* is an example of a traversal link that has been defined over the underlying conceptual relationship *a2k* that was presented in. To further understand the navigational model depicted in **¡Error! No se encuentra el origen de la referencia.**, a storyboard of the resulting application is presented in.



As we can observe in the model, the Number of supporting Domain Classes (NSDc)=4 and the Number of supported domain relationships (NSDr)=3.

With these four values, it is possible to calculate both the DcCNM *(Domain-Classes Coverage of the Navigational Model)*=NSDc/NRDc=4/4=1 and the DrCNM (Domain-Relationships Coverage of the Navigational Model)=NSDr/NRDr=3/5=0.6

If we now calculate the Domain Coverage of the Navigational Model as the avg(DcCNM,DrCNM), the result would be 0.8.

4.1.5. Practical impact (if the hyphotesis get confirmed)

If the hypothesis gets confirmed the practical impact would be that the use of the domain model and the requirements model for the automatic generation of the navigational model improves the user satisfaction. Also, it would mean that the so-called 'problem' of applications design being directed by the structure of data would not be such a problem in data-intensive web applications.

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