	**HoliDes** **Holi**stic Human Factors **Des**ign of Adaptive Cooperative Human-Machine Systems	HoliDes

Human Factors Concepts Ontology

Project Number:	332933
Classification:	Public
Work Package(s): **Milestone:** **Issue Date:** **Document Timescale:**	WP 1 M 5 September 2016 Project Start Date: October 1, 2013 Written July 2016 - Sept 2016
Deliverable Overview:	**Main document:** D1.7 – HF-RTP Version 2.0 inc. Methodology and Requirements Analysis update. <Confidential>
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RECORD OF REVISION		
Date	Status Description	Author
26.07.2016	Annex first version	Sonia Bilbao, TEC
12.08.2016	Final contributions for internal review	Sonia Bilbao, TEC
02.09.2016	External Review	Morten Larsen, AWI, Fabio Tango, CRF
09.09.2016	Final version	Sara Sillaurren, TEC

Table of Contents

1 Human Factors Concepts Ontology

The HF ontology defines the interoperability standard to exchange information related with human factors that apply to each of the four domains covered in HoliDes project: aeronautics, control rooms, automotive and health care. This ontology formalizes in OWL language the concepts identified in the HF-CMM (Task 1.6).

The methodology used to build the HF ontology is based on the methodology by Uschold and King[2]. It contains the following steps[3]:

1. Identification of the purpose. It is important to be clear why the ontology is being built and what its intended uses are. In HoliDes, the ontology is built to provide a common model and format for human factors modelling and exchange.
2. Identification of the key concepts and relationships in the domain of interest, i.e. scoping (in all AdCoS and HF-RTP tailoring processes).
3. Provide precise unambiguous text definitions for such concepts and relationships
4. Identification of the terms to refer to such concepts and relationships (classes and properties of the ontology)
5. Coding of the ontology in RDF/OWL language. This step involves explicitly representing the knowledge acquired in previous steps in a RDF/OWL language.
6. Integrating existing ontologies. During either or both of the capture and coding processes, there is the question of how and whether to use ontologies that already exist.

Following the above methodology, the HF ontology is used to model:

- HF issues definition
- HF methods
- Regulations, standards and guidelines related to HF issues

[2] Uschold, M. Building Ontologies: Towards A Unified Methodology. Expert Systems 96. Cambridge. 1996

[3] Mariano Fernández-López and Asunción Gómez-Pérez. 2002. Overview and analysis of methodologies for building ontologies. Knowl. Eng. Rev. 17, 2 (June 2002), pages 129-156.

- HF data measurements
- Subjects used to measure HF data and conditions in which HF data are measured
- Human Operator Models and predictions
- HF evaluation results

Figure 1 shows the relationship between the main classes in the ontology.

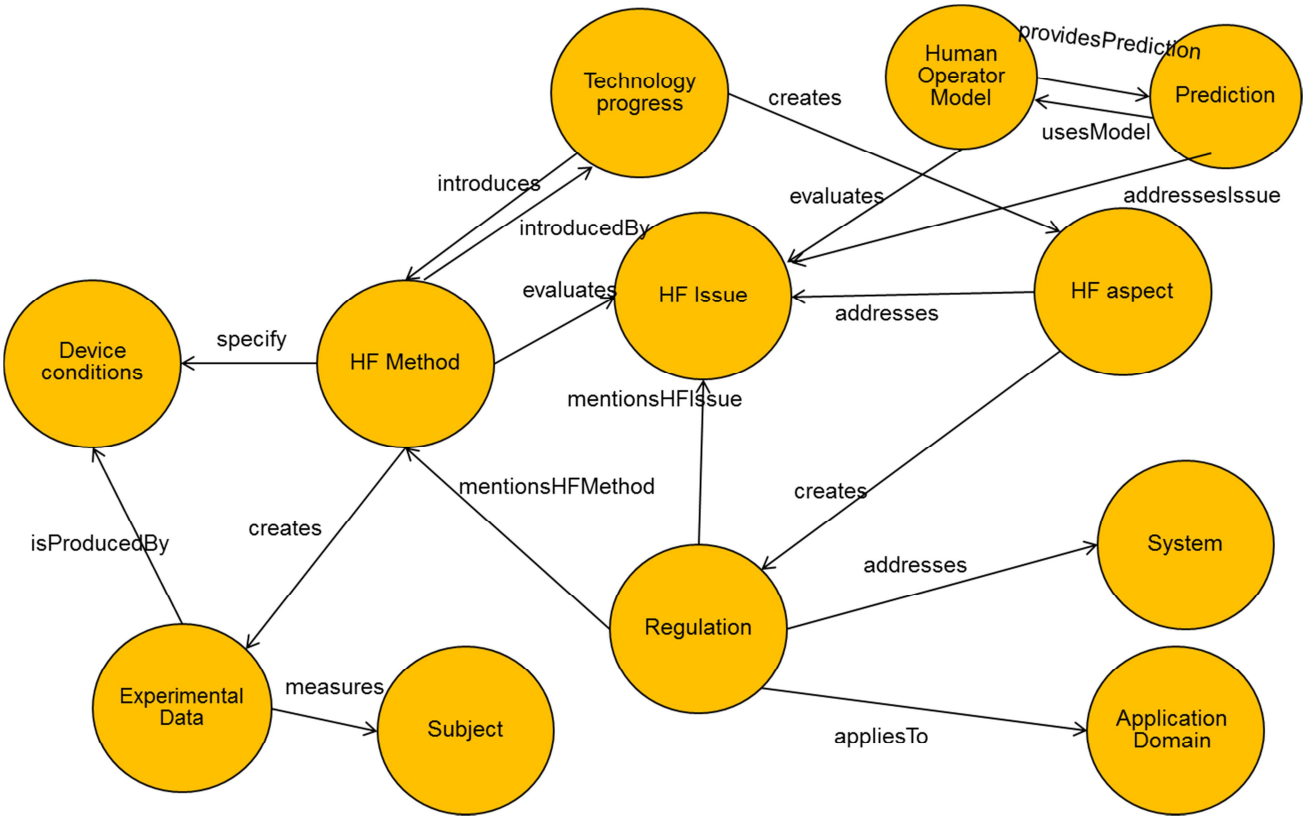


Figure 1: General schema of the HF ontology

In version 1 of the ontology described in D1.5, the following concepts and their attributes were explained:

- **HFMethod**. It categorises or describes a HFMethod using a set of descriptors such as id, summary, type, application domain, V-phase, measurement source, time of data collection, effort, costs, etc.
- **HFIssue**. It describes a Human Factor Issue and its different states. Examples are: distraction, situation awareness, usability, workload, fatigue, cognitive capacity limits, trust in automation, technology acceptance, satisfaction, desire for control and perceived risk. Although not all HF issues are at the same level or category, the ontology considers them as a list as the purpose is to link each issue to relevant HF methods and regulations.
- **Regulation**. It represents a HF Integration Concept or regulation.
- **HumanEfficiencyEvaluation**. It evaluates human efficiency by measuring reaction times, attention allocation, workload and task performance of the operator.

In version 2 of the ontology classes to model predictions and human operator models were included. A Human Operator Model is a mathematical model that is used to predict or classify the state of the operator, i.e. fatigued or not fatigued, fully distracted, partially distracted and not distracted, etc.

Finally, in version 3 of the ontology classes were included to represent the process and results of a HF evaluation project.

1.1 HF issues, methods and regulations

This chapter describes the concepts and properties related with HF issues, methods, and metrics derived from Human Factors Integration Concepts and Regulations.

1.1.1 HFMethod

Categorises or describes an HFMethod using a set of descriptors.

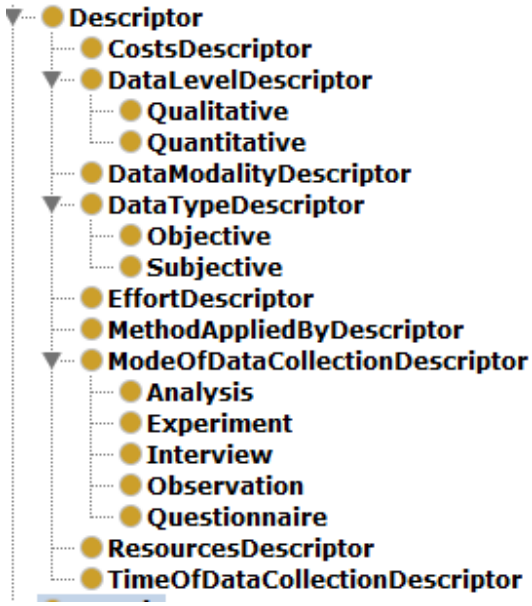


Figure 2: Descriptors for HF methods

The HFMethod concept has the following properties:

Table 1: HF ontology - HFMethod properties

Property	Description	Range
terms:title	Identifier or name of the method	string
terms:abstract	Short summary of the method	string
reference	Reference	string
appliedInPhase	Phase within the system development process in which the method is applied	VModelPhase Certification Conceptualisation Deployment Design Evaluation RequirementsEngineering SystemImplementation
appliesTo	Application domain to which this HF method	ApplicationDomain

	applies	◆ Aeronautics ◆ Automotive ◆ ControlRoom ◆ Health
measurementSource	Type of data recorded: subjective vs objective	MeasurementSourceDescriptor • Subjective ◆ Actor ◆ Observer • Objective ◆ Performance ◆ Psychophysiological
empiricalMethodType	Process used to collect the data	EmpiricalMethodTypeDescriptor ◆ Experiment ◆ ExpertInspection ◆ Interview ◆ Observation ◆ Questionnaire
timeOfDataCollection	Time of data collected	TimeOfDataCollectionDescriptor ◆ Prospective ◆ Realtime ◆ Retrospective
methodApliedBy	Skills needed to apply the method	MethodApliedByDescriptor ◆ DomainExperts ◆ HFExpert ◆ NonExpert
outcomeResult	Text description for specifying mandatory requirements for interpretation of results	string
effortTime	Time effort needed to apply the method	EffortDescriptor ◆ HighEffort ◆ LowEffort
costs	Costs needed to apply the method	CostsDescriptor ◆ HighCosts ◆ LowCosts
resources	Checklist defining the	ResourcesDescriptor

	technical and human resources needed to apply the method	◆ **Computer** ◆ **EEG** ◆ **ExperimentalLab** ◆ **EyeTracker** ◆ **PaperAndPencil** ◆ **Participants** ◆ **SimulationEnvironment**
evaluates	Human issues evaluated by this method	HFIssue
creates	Links experimental data with the HF Method used to obtain it.	ExperimentalData
introducedBy	The technology progress that introduced this HF method. Inverse property of "introduces" property.	TecnologyProgress
specify	Specification of the device conditions that are necessary to apply this HF method	DeviceConditions

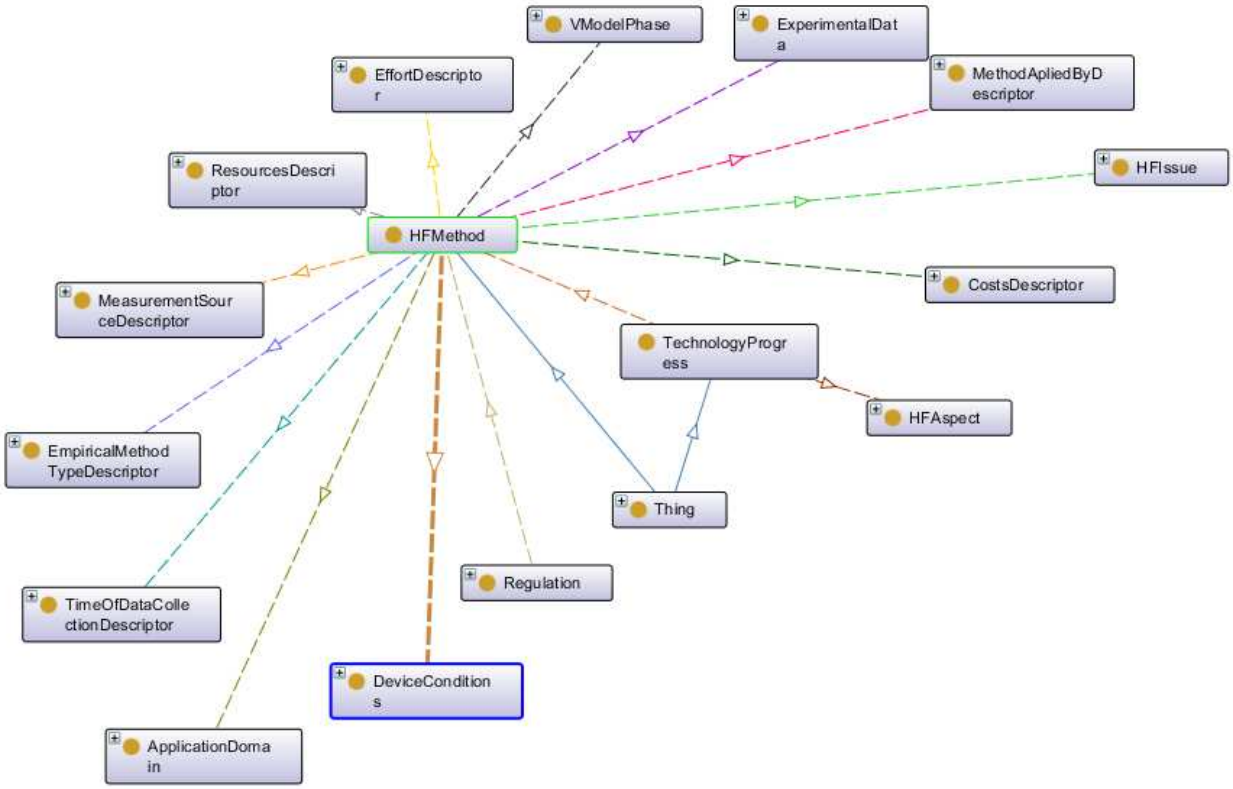


Figure 3: HF Method properties

1.1.2 HFIssue

This concept describes a Human Factor Issue and its different states. For the moment the following HF issues are considered: attention, behaviour, cognitive capacity limits, desire for control, distraction, fatigue, perceived risk, safety, satisfaction, situation awareness, task performance, technology acceptance, trust in automation, usability and workload. Although not all HF issues are at the same level or category, the ontology considers them as a list as the purpose is to link each issue to relevant HF methods and regulations.

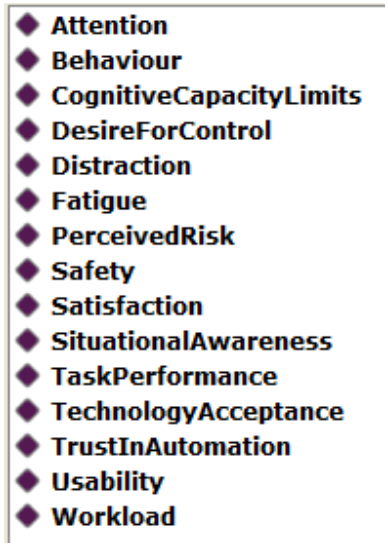


Figure 4: HF Issue instances

Some HF issues can be predicted using mathematical models. E.g. in the case of fatigue, a two state classifier could be proposed: fatigued or not fatigued. In the case of visual distraction 3 possible states could be defined: fully distracted, partially distracted and not distracted. This relationship is explained in section "1.2 Human Operator Models and Predictions".

1.1.3 Regulation

This term represents a Human Factors Integration Concept or Regulation for any of the four HoliDes application domains. These concepts and regulations were identified in *deliverable D1.2*.

The Regulation term has the following properties:

Table 2: HF ontology - Regulation properties

Property	Description	Range
appliesTo	The domain to which the HF integration concept or regulation applies	ApplicationDomain
addresses	The system addressed	System

	by the HF integration concept or regulation.	• ATM • EFB • Cockpit • Etc
mentionsHFIssue	The HF issues that are mentioned in the HF integration concept or regulation	HFIssue
mentionsHFMethod	The HF methods that are mentioned in the HF integration concept or regulation	HFMethod

1.1.4 ApplicationDomain

This concept describes each of the application domains covered in HoliDes project: aeronautics, control rooms, automotive and health care. The instance domain independent is used to refer to any domain.

Figure 5: Application Domain instances

1.2 Human Operator Models and Predictions

This chapter describes the concepts and properties related with Human Operator Models, the measurement output provided by the model and the associated prediction that usually corresponds to a label of one of the classes of a classifier.

1.2.1 Prediction

The Prediction class connects an input data set with a Human Operator Model and with the measurement output provided by the model as shown in the next figure.

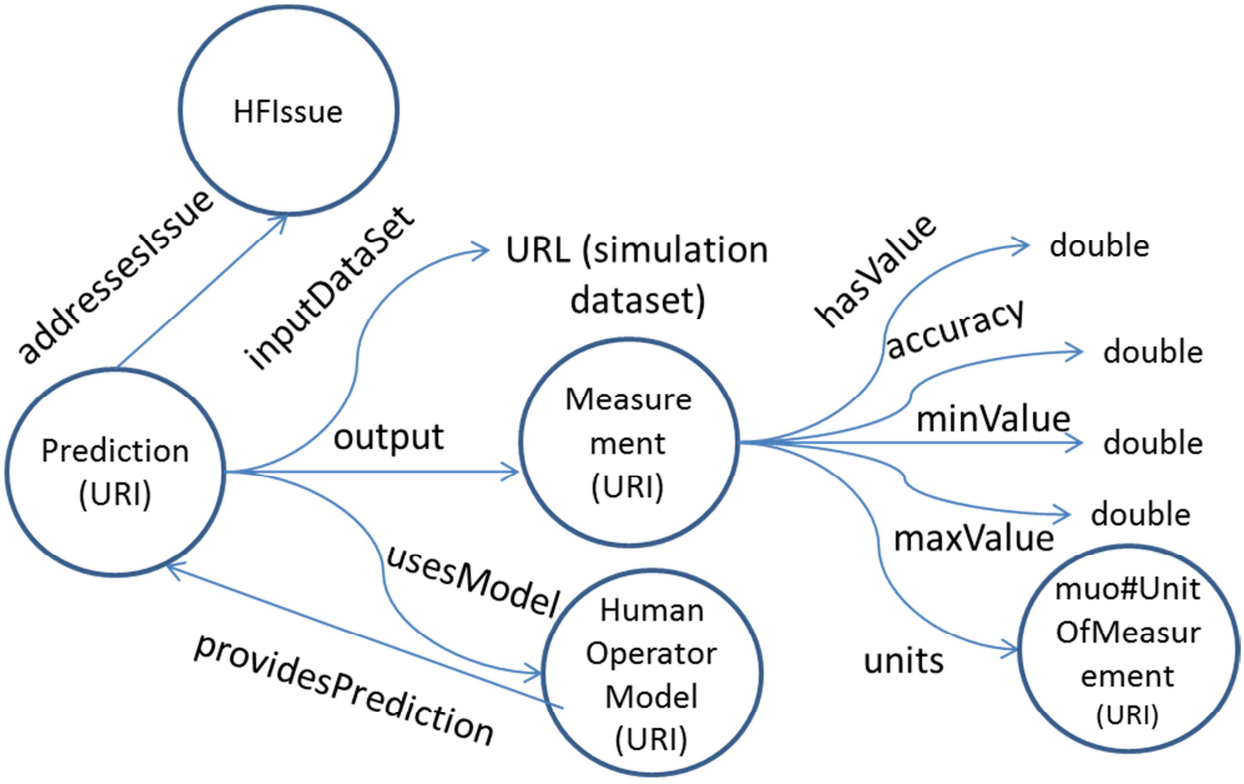


Figure 6: Connection between the prediction, the model and the measurement

Table 3: HF ontology - Prediction properties

Property	Description	Range
inputDataSet	URL or address of the file that contains the input numerical values used by the model to predict or classify the state of the operator.	String (URL)
usesModel	The precise values of the	HumanOperatorModel

Property	Description	Range
	mathematical model used to calculate the prediction, i.e. type of model, preconditions, etc.	
output	Value of the output provided by the mathematical model.	Measurement
addressesIssue	The HF Issue addressed by the prediction	HFIssue

1.2.2 Measurement

The class Measurement is related to:

- a value (i.e. quantity, double),
- accuracy (double)
- a scale (optional), i.e. a minimum and maximum possible values
- measurement units (optional) from the Measurement Units Ontology (MUO) available at http://idi.fundacionctic.org/muo/muo-vocab.html

Table 4: HF ontology - Measurement properties

Property	Description	Range
hasValue	The numerical value provided as output by the mathematical model.	double
accuracy	The accuracy of the mathematical model	double
minValue	minimum possible value of the output of the model	double
maxValue	maximum possible value of the output	Double

Property	Description	Range
	of the model	
units	Measurement units for the numerical value of the output of the model	Muo#UnitOfMeasurement

1.2.3 HumanOperatorModel

The HumanOperatorModel concept has the following properties listed in Table 5. It must be noticed that a model can be of several types. E.g. SVMs as well as Bayesian models are statistical models. Hence we can say that HumanOperatorModelA is at the same time of type SVM and of type statistical. The purpose of this property is to be able to say with what type of algorithm the experiment results have been obtained. This way, you could say that Set A of results have been obtained with a model trained using a SVM, set B with Naives Bayes, etc. It is not the intention to provide a complete list of model types as new instances can be easily added to the ontology.

Table 5: HF ontology – HumanOperatorModel properties

Property	Description	Range
modelType	Type of model	ModelType Neural Bayesian Mathematical Statistical SVM BiologicallyInspiredArchitectures Cognitive ConceptualTheoretical HybridArchitectures SubsymbolicArchitectures SymbolicArchitectures
appliesTo	Application domain	ApplicationDomain

Property	Description	Range
	to which this model can be applicable	
executableModelType	Type of executable model	ExecutableModelType ◆ EventBased ◆ Executable ◆ FasterThanRealTime ◆ NonExecutable ◆ NonRealTime ◆ RealTime
typeOfPredictions	Type of predictions	PredictionType ◆ Qualitative ◆ Quantitative
providesPrediction	Available predictions	Prediction
answersQuestion	Questions that can be answered with this model	Question • abstract
hasPrecondition	Preconditions to use the model	Precondition • abstract
providesOutput	Outputs provided by the model	ModelOutput • abstract
supportsCognitiveBehaviouralFunction	Supported cognitive or behavioural functions	● CognitiveBehaviouralFunction FatigueFunction WorkloadFunction ProblemSolving DecisionMaking Learning LongTermMemory WorkingMemory SituationAwarenessFunction DistractionFunction AttentionFunction PsychomotorPerformance Perception

Property	Description	Range
requiresEffort	Effort	◆ HighExclusiveFulfillment ◆ HighInclusiveFulfillment ◆ MediumExclusiveFulfillment ◆ MediumInclusiveFulfillment ◆ SmallExclusiveFulfillment ◆ SmallInclusiveFulfillment

The CognitiveBehaviouralFunction concept has the following property:

Table 6: HF ontology - CognitiveBehaviouralFunction property

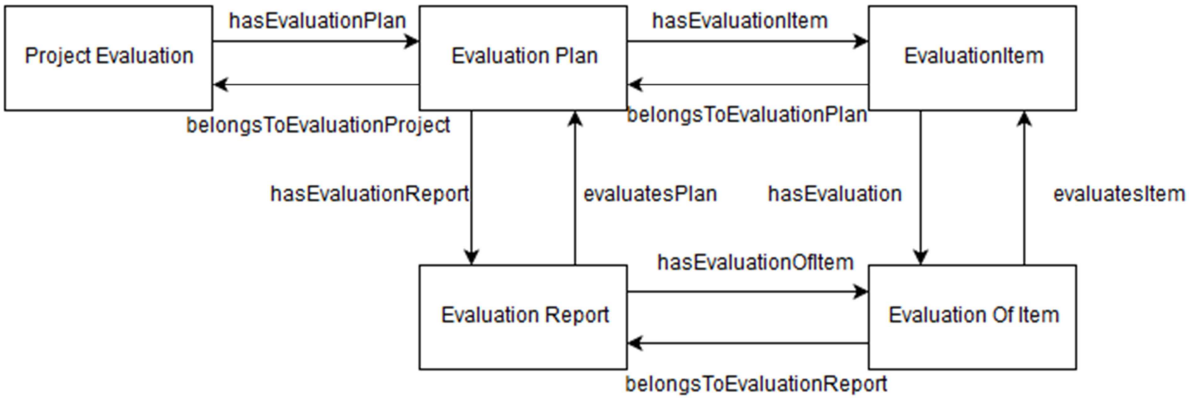
Property	Description	Range
modelsProperty	Subtype of each cognitive/behavioural function that is modelled.	CBFunctionProperty

1.3 HF evaluation results

The HF Ontology contains 5 classes to represent the process and results of a HF evaluation project:

- ProjectEvaluation
- EvaluationPlan
- EvaluationItem
- EvaluationReport
- EvaluationOfItem

The relationship between these concepts is depicted in the next figure.



In addition, it contains the class HumanEfficiencyEvaluation that evaluates human efficiency by measuring reaction times, attention allocation, workload and task performance of the operator.

1.3.1 ProjectEvaluation

This concept represents an evaluation project. It has a name, an identifier and one or several evaluation plans.

Table 7: HF ontology - ProjectEvaluation properties

Property	Description	Range
dcterms:identifier	An unambiguous reference to the evaluation project.	String
dcterms:title	A name given to the evaluation project.	String
hasEvaluationPlan	1..n evaluation plans linked to an evaluation project. Inverse property of belongsToEvaluationproject	EvaluationPlan

1.3.2 EvaluationPlan

This concept represents the evaluation plan.

Table 8: HF ontology - EvaluationPlan properties

Property	Description	Range
dcterms:creator	Person responsible for creating the evaluation plan.	foaf:Person
designVersionIdentifier	An unambiguous reference to the design version.	String
dcterms:title	A name given to the evaluation plan.	String
dcterms:identifier	An unambiguous reference to the evaluation plan.	String
dcterms:created	Date on which the evaluation plan was created.	Date
dcterms:modified	Date on which the evaluation plan was changed.	Date
hasEvaluationReport	Link to the report that contains the evaluation results. Inverse property of evaluatesPlan	EvaluationReport
hasEvaluationItem	Link to the items that conform the evaluation plan. Inverse property of belongsToEvaluationPlan	EvaluationItem

Property	Description	Range
belongsToEvaluationProject	Reference to the project evaluation. Inverse property of hasEvaluationPlan	ProjectEvaluation

1.3.3 EvaluationItem

This concept represents each of the items in an evaluation plan.

Table 9: HF ontology - EvaluationItem properties

Property	Description	Range
dcterms:creator	Person responsible for creating the item.	foaf:Person
dcterms:identifier	An unambiguous reference to the evaluation item.	String
dcterms:description	Descriptive text about the item.	String
dcterms:modified	Date on which the item was changed.	Date
dcterms:created	Date on which the item was created.	Date
dcterms:title	A name given to the item.	String
belongsToEvaluationPlan	Reference to the evaluation plan. Inverse property of hasEvaluationItem	EvaluationPlan
hasEvaluation	Link to each of the responses or evaluations given to the item. Inverse property of evaluatesItem	EvaluationOfItem

1.3.4 EvaluationReport

This concept represents the evaluation report.

Table 10: HF ontology - EvaluationReport properties

Property	Description	Range
dcterms:creator	Person responsible for creating the report.	foaf:Person
dcterms:identifier	An unambiguous reference to the evaluation report.	String
dcterms:description	Descriptive text about the report.	String
dcterms:modified	Date on which the report was changed.	Date
dcterms:created	Date on which the report was created.	Date
evaluatesPlan	Link to the evaluation plan used to create the report. Inverse property of hasEvaluationReport	EvaluationPlan
hasEvaluationofItem	Link to the evaluation of items that conform the evaluation report. Inverse property of belongsToEvaluationReport	EvaluationOfItem

1.3.5 EvaluationOfItem

This concept represents the evaluation of an item that conforms the evaluation report.

Table 11: HF ontology - EvaluationOfItem properties

Property	Description	Range
dcterms:creator	Person responsible for creating	foaf:Person

Property	Description	Range
	the evaluation of item.	
dcterms:identifier	An unambiguous reference to the evaluation of item.	String
dcterms:description	Descriptive text about the evaluation of item.	String
dcterms:modified	Date on which the evaluation of item was changed.	Date
dcterms:created	Date on which the evaluation of item was created.	Date
belongsToEvaluationReport	Reference to the evaluation report. Inverse property of hasEvaluationOfItem	EvaluationReport
evaluatesItem	Link to the item that is evaluated. Inverse property of hasEvaluation	EvaluationItem

1.3.6 HumanEfficiencyEvaluation

This term measures the human efficiency.

Table 12: HF ontology - HumanEfficiencyEvaluation properties

Property	Description	Range
attentionAllocationValue	The value that measures the attention allocation of the operator	Measurement
operatorWorkloadValue	The value that measures the operator's workload	Measurement
reactionTimesValue	The operator's reaction times of different HMI designs	Measurement
taskPerformanceExecutionTime	The operator's task performance	Measurement