LENS

# Definitions:

1. Author: Silvia

**PEMS**: general

**Motivation**: missing definition

**Proposal**: Add the definition of the following terms used in LENS

* Task
* Mission
* Environment
* Physical environment
* Human environment
* Parameter
* Component
* Agents

1. Author: GSSI

**PEMS**: general

**Motivation**: missing distinction between environment and patient or medical operators in the description of the levels.

**Proposal**: Add some text to distinguish between **environment** and **patient** in the description of the levels.

When we find “[working|local|operating|static] environment” we specify if patient, medical staff/operator, environment (external) in this way we distinguish between:  
**environment:** includes everything (external, patients ….)  
**physical environment:** physical spaces and equipment where the PEMS works (working or operating environment is a synonymous)

**human environment:** humans (patients and medical staff) - a synonym is “user” (both patient that uses the device and medical staff)

**Status**: DONE

1. Author: GSSI

**PEMS**: smart ECG - insulin pumps

**Motivation:**

**Proposal:**

* Define what’s a smart ECG system. It can be a single device ECG, or a system composed of a (wearable, wireless, mobile) component (e.g. t-shirt) plus an ECG or smartphone, or can be an IoT platform where various patients can be connected and monitored (e.g. composed of user interfaces, IoT servers, and Sensor and Actuator Nodes (SAN)): <https://arpi.unipi.it/bitstream/11568/804990/2/Spano_ECG_IEEE_Sensors_preprint_finale.pdf>.
* We can classify insulin pumps as in the doc LENS\_INSULIN\_PUMP\_GSSI, namely conventional, disposable pumps, SAP, automated.

# Configurability

The ability of the system to be configured to perform a task or reconfigured to perform different tasks.

This includes the capability to re-program the system by changing a configuration setting and the ability to alter the physical structure of the system (e.g. by changing a tool).

| **Level** | **Level name** | **Description** |
| --- | --- | --- |
| 0 | Static  Configuration | The configuration is set prior to installation and cannot be altered by the user. |
| 1 | Start-up  Configuration | The configuration can be altered by the user prior to each task in order to customize the system before its use. |
| 2 | User Run-time Configuration | The configuration can be altered by the user during the system use.. |
| 3 | Run-time Self Configuration | The system can alter its own configuration within a pre-determined set of alternative configurations designed into the system. |
| 4 | Autonomous Configuration | The system can alter its own configuration in response to external factors, for example altering its morphology in response to the failure of a sensor or actuator. Note that altering configuration must be carefully distinguished from actions taken as a part of the normal autonomous operation of the system. |

1. *Author*: ANGELO

**PEMS**: Pillbox - insulin pump - sterilizer

**Motivation***: The current description* “This may range **from** the ability to re-program the system **to** be able to alter the physical structure of the system (e.g. by changing a tool)”. *The trigger of reconfiguration can be caused by users or the system itself and both at design-time and run-time.*

**Proposal***: (Ability description):* This includes the capability to re-program the system by changing a configuration setting and the ability to alter the physical structure of the system (e.g. by changing a tool).

**Status**: DONE

1. Author: Silvia

**PEMS**: general

**Motivation**: Level 0 description

**Proposal**: Replace: “configuration files (software) or mechatronic configuration” with “software or mechatronic configuration” (CHANGED: Replaced with “configuration”)

**Status**: DONE

1. Author: Silvia

**PEMS**: general

**Motivation**: Level 1 description, there is a repetition “prior to each task” and then “in advance of each cycle of operation”

**Proposal**: Remove: “in advance of each cycle of operation”

**Status**: DONE

# Adaptability

The ability of the system to adapt itself to different work scenarios, different environments, and conditions. Adaptation may take place over long or short time scales. Adaptability is divided into two sub-abilities, namely adaptation trigger and adaptation object.

## Adaptation trigger

The focus of this sub-ability concerns the trigger of the adaptation, i.e. the parts of the system or history of collected data that cause an adaptation. Indeed, the system will observe the environment, both physical environment and human environment, and the system itself (e.g. a malfunction of the system).

| Level | Level name | Description |
| --- | --- | --- |
| 0 | No adaptation | The system does not alter its operating behavior in response to experience gained over time. |
| 1 | Human-triggered adaptation | The adaptation of the system is triggered by humans. |
| 2 | Adaptation triggered by a single part of the system | The adaptation is triggered by individual components, parameters or tasks. |
| 3 | Adaptation triggered by various parts of the system | The adaptation is triggered by a set of interconnected or closely coupled parts of the system. |
| 4 | Adaptation triggered by collected data, trends on data, history | The adaptation is triggered by analyzing collected data or data history, or by identifying trends on data. |

## Adaptation Object

The focus of this subability concerns the objects of the adaptation and how the system alters its behavior or structure (parameters, components, modes, or tasks) after the adaptation.

| **Level** | **Level name** | **Description** |
| --- | --- | --- |
| 0 | No adaptation | The system does not alter its operating behavior. |
|  |  |  |
| 1 | Adaptation of a single part of the system | When an adaptation is triggered, the system alters individual parameters, components, tasks or changes mode in a specific part of the system or component. . |
| 2 | Adaptation of various parts of the system | When an adaptation is triggered, the system alters several parameters, components, tasks, or a required mode transition causes, in turn, to change modes in various components or system parts. |
| 3 | Collective adaptation | When an adaptation is triggered, the process of adaptation is carried out between multiple independent agents. The adaptation is communicated between agents and applied individually within each agent. Agents can be both real and simulated and of different types. |

1. Author: Silvia

**PEMS**: general

**Motivation**: Level 2 description, we talk about “alters individual parameters/components/tasks” but then we write “performance local to the module on which the parameter operates”, but if we alter components/tasks how can we identify the module on which parameter it operates?

**Proposal**: Rephrase to be consistent “individual parameters/components/tasks” or only “parameters” (CHANGED: we have modified the description level 2: The system alters individual parameters/components/tasks in any part of the system)

**Status**: DONE

1. Author: Unibg

**PEMS**: general

**Motivation**: The description “The ability of the system to adapt itself to different work scenarios, different environments, and conditions (may also include the patient). Adaptation may take place over long or short time scales.” is ambiguous.

**Proposal**: Remove ambiguities

**Status**: DONE

1. Author: GSSI

**PEMS**: insuline pumps - general

**Motivation**: Adaptability makes only a difference in the complexity of actions to be done. We might extend adaptation with a new sub-activity concerning the sensing aspect. In fact, sensing can refer to a unique parameter, multiple parameters, or even trends in the collected data.

**Proposal**:

* split adaptability in two sub-abilities: one called **Adaptation Object** and corresponding to the revised previous adaptation ability and its levels (see above), the new one called **Adaptation Trigger**, which can be made as proposed below..
* Another possible sub-activity might concern **adaptability dedicated to modes**. It seems that modes are always present in PEMS; it can make sense to evaluate PEMS also under this lens. The evaluation for instance can refer to the abstraction level at which modes are defined, also looking on how the various levels are connected. Or, whether modes relate to safety aspects, or how the transition from modes is specified and managed, for instance looking at quiescent states, etc. We added modes adaptation in the Adaptation object.

**Status**: DONE

# Dependability

The ability of the system to perform its given task(s) without systematic errors. Dependability specifies the level of trust that can be placed on the system to perform.

| **Level** | **Level name** | **Description** |
| --- | --- | --- |
|  |  |  |
| 0 | Mean failure dependability | The dependability of the system is based on the mean time to failure of its components. The dependability is based on the design of the system. The system is not able to increase its dependability autonomously. For Failure Dependability, this relates to the failure of all component parts of the system including software components. For Functional dependability, this relates to the frequency of failure of the system functions with respect to the task being undertaken, and for environmental dependability, it relates to the failure of the system to correctly interpret the environment. For Interaction dependability, it relates to the failure of the system to interact with a human in a functional or intuitive manner that is appropriate to the task. |
| 1 | Fails Safe | The system design is such that there are fail-safe mechanisms built into the system that will halt the operation responsible of the failure and place the system into a safe mode when failures are detected. This includes any failures caused by in-field updates. Dependability is reduced to the ability to fail safely in a proportion of failure modes. Fail-safe dependability relies on being able to detect failure. |
| 2 | Failure Recovery | The system is able to recover from a proportion of failures by restarting or resuming its operation. |
| 3 | Graceful  Degradation | The system is able to recognize the impact of a proportion of failures on its function and operation and is able to compensate for the effect of the failure to maintain dependable operation. Function effectiveness or the ability to achieve optimal working may be impacted. |
| 4 | Task dependability | The system is able to recognize the impact of a failure on the overall task it is undertaking and it is able to replan activities in order to minimize the impact of the failure on the task. This may also include self-repair as an alternative task. |
| 5 | Mission dependability | The system is able to recognize the impact of a failure on the overall objectives of a mission and communicate the nature of the failure to other systems to minimize the impact on the mission objectives. In turn, the system is able to receive and interpret mission failures from other systems and re-task its actions to compensate. |
| 6 | Predictive dependability | The system is able to predict that a planned future action may result in a loss of dependability, or that the effect of the partial failure of a component can be mitigated by altering future actions. Thus, the system is able to extend its dependability by exploiting predictive mechanisms that permit taking an action before a failure is observed. |
| 7 | Prescriptive dependability | The system is able to make a more advanced use of predictive analysis that forecasts system dependability in the future. Prescriptive dependability analysis goes beyond simply predicting options in the predictive model. It actually evaluates a range of prescribed actions and the potential outcomes of each action, and it is able to choose the best actions that guarantee the highest dependability and mitigate future risks and take into account the potential outcomes of each decision option. |

1. Author: Silvia

**PEMS**: Pillbox, Insulin pump

**Motivation**: prescriptive dependability missed

**Proposal**: Add new level (level 8): prescriptive dependability (<https://insightsoftware.com/blog/comparing-descriptive-predictive-prescriptive-and-diagnostic-analytics/>)

**Status** DONE

1. Author: GSSI

**PEMS**: general

**Motivation**: does it make sense level 0 for PEMS? It is not clear why we need this for completeness.

**Proposal**: Remove level 0 of dependability

**Status**: DONE

# Autonomy

The ability of the system to act autonomously. Nearly all systems have a degree of autonomy. It ranges from a simple autonomous task (e.g., when it reacts to sensor reading) to the ability to be self-sufficient in a complex environment.

| **Level** | **Level name** | **Description** |
| --- | --- | --- |
|  |  |  |
| 0 | Basic action | A system that executes a pre-defined sequence of actions that are unaffected by the environment and makes decisions based on its current state to proceed to the next action step. |
| 1 | Basic decisional autonomy | The system makes decisions based on basic perceptions and user input and chooses its behavior from predefined alternatives. |
| 2 | Continuous basic decisional autonomy | The system alters the parameters of behavior in response to continuous input from perceptions or based on input control from a user interacting continuously with the system. The system may be able to override or ignore user input when certain criteria are encountered. |
| 3 | Simple autonomy without environment model | The system uses perception to make moment-to-moment decisions about the environment and so controls interaction with the environment in order to achieve a predefined task. |
| 4 | Simple autonomy with environment model | The system uses perception to make moment-to-moment decisions about the environment and controls interaction with the environment to achieve a predefined task. The decisions made take into account an internal model of the environment. |
| 5 | Task autonomy | The system utilizes its perception of the environment to sequence different sub-tasks to achieve a higher-level task or mission. The events that cause behavioral changes are external and often unpredictable. |
| 6 | Constrained task autonomy | The system adapts its behavior to accommodate task constraints. These might be negative impacts in terms of failed sensors, or the need to optimize power utilization or other physical resources the process depends on, (water, chemical agents, etc). Alternatively, these might be constraints imposed by sensing ability, the physical environment, or the human environment. |
| 7 | Multiple task autonomy | The system chooses between multiple high-level tasks and can alter its strategy as it gathers new knowledge about the environment. The system will also take into account resource limitations and attempts to overcome them. |
| 8 | Dynamic autonomy | The system is able to alter its decisions about actions (sub-tasks) within the time frame of dynamic events that occur in the environment so that the execution of the task remains optimal to some degree. |
| 9 | Mission oriented autonomy | The system is able to dynamically alter its mission both within and between several high-level tasks in response to dynamic real-time events in the environment. |
| 10 | Distributed autonomy | The source for task and mission decisions can originate from outside the system. The system is able to balance requests for action with its own tasking and mission priorities, and can similarly communicate requests for action. |

1. Author: GSSI

**PEMS**: general

**Motivation**: Do we need to keep level 0? Similar to dependability

**Proposal**: remove level 0

**Status**: DONE

# Interaction

The ability of a system to interact physically, cognitively and socially either with users, operators or other systems around it. The ability to interact may be as simple as the use of a communication protocol, or as advanced as holding an interactive conversation in a social context. The ability to interact is critical to many areas of application. Interaction depends on both the medium of interaction and the context and flow of the interaction. The ability to interact takes place in three distinct ways: physical interaction, cognitive interaction and social interaction. The Interaction Ability consists of the following three types of interaction.

## Human-System Interaction

The following set of levels relate to the interaction between users and the system. This set of ability levels are distinct from the cognitive human-system interaction levels, as they define the method of interaction independently of the cognitive context.

| **Level** | **Level name** | **Description** |
| --- | --- | --- |
| 0 | No interaction | It is possible that the system will effectively have no operational interaction with a user. |
| 1 | Direct control | The user provides control of the system moment to moment. The system can translate, alter, or block these controls within parameters set by the user or system. The user controls are in the form of parameters that alter the control of the system. These parameters may be continuous quantities, or binary controls. |
| 2 | Direct physical interaction | The user controls the system by physically interacting with it. The system reacts to the user interaction by feeding back physical information to the user via the contact point. |
| 3 | Task selection | The system is able to execute pre-defined sequence of actions (tasks) autonomously. The user selects the subsequent action at the completion of the sequence of actions. |
| 4 | Traded autonomy | The system is able to operate autonomously during some parts of a task or in some tasks. Once this task or sub-task is complete, the user will either select the subsequent task or intervene to control the system by direct interaction to carry out a task. This results in alternating sequences of autonomous and direct control of the system by the user. |
| 5 | Task sequence control | The system is able to execute sub-tasks autonomously, these sub-tasks will involve a higher level of decisional autonomy than a predefined sequence of actions. On completion of the sub-task, user interaction is required to select the next sub-task resulting in a sequence of actions that make up a completed task. |
| 6 | Supervised autonomy | The system is able to execute a task autonomously in most operating conditions. The system is able to recognize when it is unable to proceed or when it requires user input to select alternative strategies or courses of action. These alternatives may involve periods of direct control. |
| 7 | Task alternatives selection | The system is able to autonomously execute tasks, but requires the user to select between strategic task alternatives in order to execute a mission. |
| 8 | Mission Goal setting | The system is able to execute tasks to achieve a mission. The user is able to interact with the system to direct the overall objectives of the mission. |

## Human-System Interaction Feedback

The ability to command a system depends on the user’s perception of the state of the system. This set of levels defines how this state information can be fed back to a user who is operating the system.

| **Level** | **Level name** | **Description** |
| --- | --- | --- |
| 0 | No feedback | The system does not provide any feedback to the user |
| 1 | Basic feedback | The user is able to assess the state of the system by direct perception (by watching or listening). The system does not provide any means of feeding back information to the user. |
| 2 | Data feedback | The system feedbacks visual information (visual or audio) about the state of the environment around the system based on data captured by the system. The user must interpret this information (visual imagery or audio signals) to assess the state of the system or its environment. |
| 3 | Haptic feedback | The system is able to feedback on a physical force that represents the forces at the end effector of the system. The force feedback is delivered to the user via a single point of contact, for example a joystick. |
| 4 | Multi-modal feedback | The system is able to provide multi-modal feedback to the operators by means of synchronized different feedback channels. |

1. Author: Unibg

**PEMS**: Pillbox, Insulin pump, in general

**Motivation**: missed sound feedback

**Proposal**: integrate also audio information in the levels and remove “visual” in the level names. Changed name from “tele-presence” to multi-modal” and removed “telepresence”

**Status**: DONE

## System to System Interaction

The following set of levels relate to the interaction between systems in carrying out a task or mission. No distinction needs to be made between separate systems that communicate and dependent systems that carry out a task. However, there is a distinction between systems that rely on a central controller and those that use distributed decision-making.

| **Level** | **Level name** | **Description** |
| --- | --- | --- |
| 0 | No interaction | The system operates on its own without communication with another system. |
| 1 | Communication of own status | Two or more systems communicate basic status information and task-specific status. Status information is pre-defined for the task. The information communicated only relates to the state of the system within the task. |
| 2 | Communication of task status | Two or more systems are able to communicate information about the task they are performing in terms of task completion, time to completion, and information about task barriers, resources etc. This information is at a high level and will impact on the planning of a common task, or tasks in a common space. |
| 3 | Communication of environment information | Two or more systems share information about their environments, or share wider scale information that they have acquired or been given. The systems are able to assimilate the information and extract task-relevant knowledge from it. |
| 4 | Team communication | Two or more systems are able to communicate task-level information during the execution of the task such that it is possible to implement dynamic planning between the systems in the team. Each system carries out its own tasks with awareness of the other systems in the team. |
| 5 | Team coordination | Two or more systems are able to collaborate to achieve a task outcome that could not be achieved by either system alone, or by each system operating independently. |
| 6 | Capability  Communication | Systems are able to communicate their own task capabilities and utilize cooperative working between teams of heterogeneous systems where there is no prior knowledge of the composition of the team. |

## Human-System Interaction Safety

The following levels only apply to systems that have an inherent level of unsafety in the interaction between the human and the system. For example, if a system is safe at Level 0 then there is no need for it to reach Level 1 safety. For this reason, each successive level relates to systems that exhibit increased levels of potential harm. It is assumed that all systems meet safety criteria appropriate to their environment with respect to electrical and battery safety requirements, typically specified by European CE marking criteria. It is also expected that appropriate safety criteria have been applied with respect to consumables used by the system. For example heated liquids, liquids under pressure, or chemical agents.

| **Level** | **Level name** | **Description** |
| --- | --- | --- |
| 0 | Intrinsic safety | The mechanism of the system is safe because by design it cannot damage a person at any time during its operating cycle. The maintenance of this level of safety does not depend on software. |
| 1 | Basic safety | The system operates with a basic level of safety appropriate to the task. Maintaining safe operation may depend on the operator being able to stop operation or continuously enable the operating cycle, e.g. a red button able to stop operation. The maintenance of this level of safety does not depend on software. |
| 2 | Basic operator safety | The system is made safe for the operator by physically bounding the operating space of the system. Access gates trigger stop commands to the system. The system will not operate unless the bounding space is closed. |
| 3 | User detection | The system is informed or is able to understand when a user enters the work zone. The system operates safely, e.g. changing to a safety mode, while the user is present in the operating zone. |
| 4 | Workspace detection | The system operates within a well-defined space where a zone of safe operation is identified and programmed into the system. While the system is occupying the safe zone it operates safely. The system may also use sensing to detect that humans do not enter the unsafe zone. |
| 5 | Dynamic User detection | The system or its support systems detect humans within its operating zone and dynamically define a safe zone that envelopes the user where the system controls its operation to be safe. |

## GSSI, UniBG

**PEMS**: general

**Motivation**: Remove ambiguities.

**Proposal**: Revised descriptions of both the subability and its levels. Removed the HSIS - Context

**Status: DONE**



# Perception

The ability of the system to perceive its environment. It includes the ability to interpret information and make informed and accurate deductions about the environment based on sensory data.

## General Perception

The following levels refer to the generic ability of a system to perceive environmental state by sensor data.

| **Level** | **Level name** | **Description** |
| --- | --- | --- |
| 0 | No external perception | Some systems do not sense their environment but simply carry out sets of pre-programmed actions triggered by a starting event. Although there may be safety systems that cause the system to fail-safe these do not alter the operating cycle behaviour. |
| 1 | Direct Single and Multi-parameter sensing | A system uses sensors that provide a single, or multiple parameter output directly. The system utilises these outputs to directly alter behaviour within an operating cycle. |
| 2 | Low-level processing parameter sensing | A system may use fixed and known markers in the physical environment (e.g. Barcodes, QR codes, etc). The detection of these markers provides provides triggers to alter or switch between behaviours or sequences of behaviours. |
| 3 | Multi-Parameter Perception | A system uses multiple single-parameter sensors to create a unified model of the environment. Sense data can be collected from multiple types of sensor as well as multiple sensors of the same type. Each sensor contributes information to the model. The model is used to alter the behaviour of the system. |
| 4 | Feature-based perception | Sense data is gathered from a region of the environment such that the sense data has a spatial mapping. The richness of the sense data information content is such that it is possible to apply feature extraction to the sense data and thereby interpret the content of the sense data as a set or sets of features. The system performs a data reduction with an assumption about the expected features. The presence of features is used to alter behaviour. |
| 5 | Grouped feature detection | The sense data gathered from the environment can be processed such that features can be aggregated to capture linkages between features. A group of features may relate to the same real elementin the environment, but where the elementhas not been identified. The characteristics of the feature group can be used to alter the behaviour of the system. For example a set of features of the same colour that move in the same way may relate to a pink ball. |
| 6 | Element identification | The system can identify elements or coherent entities that it has detected in the environment through sets of grouped features and can use this identification to alter the system's behaviour. The importance of this level is that a data source or a priori element model is required. |
| 7 | Property identification | The system is able to deduce the properties of elements in the environment or environment itself and utilise those properties within system behaviour. |
| 8 | Hidden state identification | The system is able to infer properties of an element or personthat are not directly observable. The elements are not fully available in data sources ahead of time and environment interpretation and classification are required. |

## Element recognition

This ability may range from being able to recognise instances of a single element, to being able to distinguish between many different elements or even identify elements that fit a generic pattern.

| **Level** | **Level name** | **Description** |
| --- | --- | --- |
| 0 | No Recognition | The system does not need to detect or recognise elements in the environment in order to carry out its task. |
| 1 | Feature detection | Sense data is gathered from a region of the environment such that the data has a spatial component and can be mapped to a model of that region. The richness of the sense data is such that it is possible to apply a feature detection process to create a set or sets of features that persist. |
| 2 | Element detection | Multiple persistent features can be grouped to build models of distinct elements allowing elements to be differentiated from each other and from the environment. |
| 3 | Element recognition single instance | Element models created from sense data can be matched to specific known instances of an element with a reliability that is appropriate to the task. |
| 4 | Element recognition one of many | Element models created from sense data can be matched to one of a number of specific instances of known elements with a reliability that is appropriate to the task. |
| 5 | Parameterised element recognition | Element models created from sense data can be matched to a number of known, parameterised element types. The settings for the parameters (e.g. size ratio, curvature, joint position etc) can be deduced from the sensed element model. Note that in conjunction with single instance recognition ability this implies the ability to recognise a known (possibly learned) instance of a generic element. |
| 6 | Context-based recognition | The system is able to use its knowledge of context or location to improve its ability to recognise elements by reducing ambiguities through expectations based on location or context. |
| 7 | Element variable recognition | The system is able to recognise elements where there is a degree of variability in the element that approaches the scale of the element. |
| 8 | Novelty recognition | The system is able to recognise novelty in a known element, or parameterised element type. |
| 9 | Unknown element categorisation (Rigid) | The system is able to assess an unknown rigid element based on sense data and deduce properties that are relevant to the task. |
| 10 | Element property detection | It is possible to use sensed data and the derived element model to deduce the properties of an element. |
| 11 | Flexible element detection | The system is able to detect the shape and form of elements that are deformable and generate parameterised models of flexible elements. This includes articulated elements and elements with flexible and rigid components. |
| 12 | Flexible element classification | The system is able to classify flexible elements by their properties and parameters. It is able to recognise specific known elements relevant to the task with an appropriate level of reliability. |
| 13 | Animate elements | The system is able to detect animate elements and provide a classification appropriate to the task. |
| 14 | Pose estimation of animate elements | The system is able to estimate the pose of an animate element within the environment. |

1. Author: Unibg

**PEMS**: all

**Motivation**: “Object” is too much robot oriented (what about humans?). Is feature a synonym of element?

**Proposal**: use “Element” instead of “Object” + definition of element: With **elements,** we mean physical objects as well as human body parts (like an arm), actions, or emotions (like the stress by facial recognition). We distinguish between **physical elements** (objects or human body parts) and **abstract elements** (like emotions or actions). Physical elements may have a location in the space. We removed the occurrences of location when referring to general elements, which may include abstract ones. This applies to both previous subabilities.

**Status**: DONE



1. Author: GSSI

**PEMS**: Smart ECG, Hemodialysis, general

**Motivation**: Overall perception focuses much on sensing of the environment. Scene perception does not seem to fit for PEMS.

**Proposal**: Does it make sense to distinguish sensing of the environment from sensing of humans, for instance to grapes emotions, stress, or for identifying the correct user? Remove Scene perception.

**Status:** DONE

# Cognitive

The ability to interpret the task and environment such that tasks can be effectively and efficiently executed even where there exists environmental and/or task uncertainty. The ability to interpret human commands delivered in natural language or gestures. The ability to interpret the function and interrelationships between different elements in the environment and understand how to use or manipulate them. The ability to plan and execute tasks in response to high-level commands. The ability to work interactively with people as if like a person. Currently, different aspects and faculties of the Cognitive Ability as a whole have different degrees of maturity and pose different challenges. Attempting to combine these differences into a single rating or overarching target is likely to lead to invalid or misleading conclusions. The assessment of cognitive ability is therefore divided into several components or faculties. The assumption is that the cognitive ability of a system can be assembled and described more accurately by referring to a mixture of component abilities.

## Action

It concerns the ability of the system to act purposefully within its environment and the degree to which it is able to carry out actions and plan those actions.

These abilities build on perception and decisional autonomy abilities. Action ability also co-depends on other cognitive abilities.

| **Level** | **Level name** | **Description** |
| --- | --- | --- |
|  |  |  |
| 0 | Defined action | The system executes fully pre-defined actions as a sequence of sub-actions. This sequence can repeat until stopped by an operator or other system event. |
| 1 | Decision based action | The system is able to alter its course of action based on perceptions or system events. It is able to select between a set of pre-defined actions based on its decisional autonomy ability. |
| 2 | Sense driven action | The system is able to modulate its action in proportion to parameters derived from its perceptions. The perceptions are used to drive the selection of pre-defined actions or the parameters of pre-defined actions. |
| 3 | Optimized action | The system is able to alter the sub-task sequence it applies to the execution of a task in response to perceptions or a need to optimize a defined task parameter. |
| 4 | Knowledge  driven action | The system is able to utilize knowledge gained from perceptions of the environment including elements within it, to inform actions or sequences of action. Knowledge is gained either by accumulation over time or by embedding knowledge from external sources, including user inputs that associate properties with perceptions. |
| 5 | Plan-driven action | The system is able to use accumulated information about tasks to inform its plans for action. |
| 6 | Dynamic planning | The system is able to monitor its actions and alter its plans in response to its assessment of success. |
| 7 | Task action suggestions | The system is able to suggest tasks that contribute to the goals of a specific mission. |
| 8 | Mission proposals | The system is able to propose missions that align with high-level objectives. |

## Interpretive

The interpretation of sense data is key to the ability to identify, recognise, classify and parameterize elements in the environment. It particularly refers to the ability to amalgamate multi-modal data into unified high-level element descriptions that create knowledge for tasks to draw on. The ability to interpret also engages knowledge sources to build increasingly complex interpretations of the environment and human interaction, in particular building frameworks of relationships between the environment and elements and between elements..

| **Level** | **Level name** | **Description** |
| --- | --- | --- |
| 0 | No interpretive Ability | The system does not need to interpret the environment or user interface actions. |
| 1 | Fixed sensory interpretation | The system has a fixed interpretation of the perceptions that occur because they are pre-categorized. |
| 2 | Basic environment interpretation | The system uses sensor data to interpret the environment into fixed notions of environmental data pre-categorized. |
| 3 | Elementdelineation | The system is able to disambiguate elements from an interpretation of its environment. The disambiguation of elements is based on built-in notions of elements and the environment. These notions may only be valid within a narrow operating context. |
| 4 | Element category interpretation | The system is able to interpret the shapes and forms of elements based on categories of elements that are task-relevant. It is able to interpret sense data to identify elements over a timescale appropriate to the task. Note that this ability level is particularly affected by the Cognition Ability Parameters. |
| 5 | Structural interpretation | The system is able to interpret perceptions to extract structural information from the environment. It is able to identify the structural relationships between elements in the environment. |
| 6 | Basic semantic interpretation | The system is able to apply semantic tags to elements, allowing it to plan actions based on functional objectives that depend on the semantics of elements . |
| 7 | Property interpretation | The system is able to interpret perceptions to determine the properties of elements in the environment. |
| 8 | Novelty interpretation | The system is able to interpret perceptions to identify novelty in elements . |
| 9 | Environmental affordance | The system is able to interpret the environment in terms of what it affords. |

1. Author: GSSI

**PEMS**: general

**Motivation**: This ability seems to be too much into robotics. Basically into environment and object recognition of robotics.

**Proposal**: Modify the descriptions in order to adapt them more to the medical domain.

**Status:** DONE

## Envisioning

Envisioning refers to the ability of the system to assess the impact of actions in the future. This may reduce to prediction but in the higher levels involves an assessment of the impact of observed external events.

| **Level** | **Level name** | **Description** |
| --- | --- | --- |
| 0 | No envisioning ability | The system is not able to predict subsequent states. |
| 1 | Function projection | The system is able to project the effect of its function onto the environment in order to be able to assess its effectiveness. |
| 2 | Basic environment envisioning | The system is able to observe events in the environment that relate to the task and envision their impact on the actions of the system itself. |
| 3 | Envisioning safety | The system is able to assess the safety implications on users of observed events occurring in the environment. |
| 4 | Envisioning user responses | The system is able to envision the actions of a user responding to events in the environment. |

1. Author: Unibg

**PEMS**: general

**Motivation**: The working environment seems fitting more to the manipulation

**Proposal**: Remove “working” according to the definition we gave at the beginning of the document

**Status:** DONE

## Acquired knowledge

environments will always contain a number of unknowns. In many proposed application areas, systems will encounter unknown situations as a normal part of task execution. The acquisition of knowledge about new situations is fundamental to the success of these new application areas.

| **Level** | **Level name** | **Description** |
| --- | --- | --- |
| 0 | No Acquired Knowledge | The system does not acquire knowledge during its operation. Required knowledge is embedded in the system. |
| 1 | Sense data and property knowledge | The system is able to acquire knowledge about its environment and properties of elements in the environment based on sense data gathered from moment to moment. |
| 2 | Persistent sense data knowledge | The system is able to accumulate knowledge about its environment based on sense data that persists during the execution of the current task. |
| 3 | Deliberate acquisition | The system is able to acquire knowledge about the composition of its environment by executing actions that are deliberately designed to increase knowledge through exploration. |
| 4 | Place knowledge | The system is able to accumulate knowledge about the location and types of physical elements within physical environment in terms of matching elements to pre-defined and known types. |
| 5 | Knowledge scaffolding | The system has the ability to integrate embedded knowledge of elements and places with related knowledge gained from the environment. |
| 6 | Requested knowledge | The system is able to recognise that it has insufficient knowledge about an element or place relevant to the task and can formulate a question to gain that knowledge either from a person or an external data source such as the internet or another system. |
| 7 | Distributed knowledge | The system is able to communicate its gained knowledge to other systems, and can receive and integrate knowledge from other systems. |
| 8 | Interaction acquisition | The system is able to acquire knowledge about its environment and elements within it through planned interactions with the environment and elements.. |
| 9 | Object function | The system is able to acquire knowledge about the function of objects in the physical environment. This knowledge may be acquired directly or indirectly through observation. |
| 10 | User knowledge | The system is able to acquire knowledge about the user by observation. |
| 11 | Critical feedback | The system is able to acquire knowledge about its actions by analysis of critical feedback that follows the completion of the action. |
| 12 | Long-term observation | The system is able to distinguish between long-term and short-term changes in the physical environment and the objects within it and in the human environment. |
| 13 | Patterns of behaviour | The system is able to acquire knowledge about the patterns of behaviour of the user that relate to the task. |
| 14 | Observation learning | The system is able to acquire knowledge indirectly from observing other systems or people carrying out tasks. |

1. Author: GSSI

## PEMS: insulin pump - general

**Motivation:** For instance, referring to level 12, it doesn’t make sense to say that the system is able to distinguish changes in the objects within the patient

## Proposal: Fix environment - patient. Fixing environment - patient may require cascading changes.

**Status:** DONE

## Reasoning

The reasoning ability is the glue that holds the cognitive structures together. Perception, knowledge acquisition, interpretation and envisioning all rely to a certain extent on the ability to reason from uncertain data. As application tasks become more complex the need to provide task and mission-level reasoning increases.

| **Level** | **Level name** | **Description** |
| --- | --- | --- |
| 0 | No Reasoning | The system does not carry out any form of reasoning but simply executes a pre-determined pattern of activity. |
| 1 | Reasoning from sense data | The system is able to make basic judgements of sense data sufficient to allow actions to be controlled. |
| 2 | Pre-defined reasoning | The system is able to use basic predefined knowledge about structures and elements in the environment to guide action and interaction. |
| 3 | Basic environment reasoning | The system is able to use knowledge of the environment gained from perception in conjunction with stored knowledge to reason about the environment. |
| 4 | Reasoning under uncertainty | The system is able to reason under uncertainty, e.g., about the environment and its elements, combining potentially conflicting or incomplete data from disparate sources. |
| 5 | Dynamic  reasoning | The system is able to reason and operate under uncertainty in a dynamic environment. |
| 6 | Safety reasoning | The system is able to reason about its safely operation in the environment. |
| 7 | Task reasoning | The system is able to reason about the appropriate courses of action to achieve a task where there are alternative actions that can be undertaken, exploiting information such as task objectives, time to completion, resource usage, or the desired performance level. |
| 8 | Mission reasoning | During the mission execution, the system is able to reason about the priorities of different tasks within the mission and propose priorities based on its knowledge of the mission,the tasks, and environment. |

1. Author: GSSI

**PEMS**: Pillbox, Insulin pump, in general

**Motivation**: This ability seems to be too much into robotics. Basically into environment and object recognition of robotics.

**Proposal:** Modify “objects” in “elements”, in a way that it is more general. With “elements” we consider both objects which can be in the environment and humans.

**Status:** DONE

1. Author: Unibg

**PEMS**: Pillbox, Insulin pump, in general

**Motivation**: missed levels - levels 4 5 6 without a clear ordering?

**Proposal**: adjust levels description and naming: **Status:** DONE

## Cognitive Human interaction

The following levels relate to different levels of human interaction with a system that has a cognitive element. They specifically relate to the interaction between a human and a single system. Where multiple systems are involved a corresponding set of levels applies.

| **Level** | **Level name** | **Description** |
| --- | --- | --- |

| 0 | No Cognitive  Human  Interaction | Many systems will be able to operate successfully without cognitive interaction with the user. |
| --- | --- | --- |
| 1 | Fixed interaction | Interaction between the user and the system follows a fixed pattern. Typically, this takes place via a user interface with well-defined inputs and outputs. Fixed interaction also includes interaction via a computer-based user interface where interactions directly control the system according to pre-defined sets of commands with specific meanings. The connection between the user and the system may involve a wireless link. Any interpretation of commands is fixed and embedded. |
| 2 | Task context interaction | The system is able to interpret commands from the user that utilize task context semantics within a domain-specific communication framework appropriate to the range of the task. The system is able to relay task status to the user using task context semantics suitable for the task. |
| 3 | Elementinteraction | The system is able to interpret user interactions that refer to elements as appropriate to the task. This includes the ability to interpret user interactions that identify elements’ as well as processing commands that reference elements relevant to the task. Dialogues are initiated by the user. |
| 4 | System-triggered interaction | The system is able to start a dialogue with the user in a socially appropriate manner relevant to its task or mission. The system has a basic understanding of the social interaction appropriate to the task/mission domain. The interaction may continue throughout the operating cycle for each task as is appropriate to the task/mission. |
| 5 | Social interaction | The system is able to maintain dialogues that cover more than one type of social interaction, or domain task. The system is able to manage the interaction provided it remains within the defined context of the task or mission. |
| 6 | Complex social interaction | Dialogues cover multiple social interactions and tasks, where the system is able to instruct the user to carry out tasks or enter into a negotiation about how a task is specified. The interaction is typified by a bi-directional exchange of commands. |
| 7 | Intuitive Interaction | The system is able to intuit the needs of a user with or without explicit command or dialogue. The user may communicate with the system without issuing explicit commands. The system will intuit from the current context and historical information the implied command. |

1. Author: Unibg

**PEMS**: Pillbox, Insulin pump, in general

**Motivation**: Which is the relation between this ability and the human-system interaction ability?

**Proposal**: renaming of the sub-ability in “cognitive” human interaction, given that the difference with human-system interaction is the cognitive ability of the system.

**Status: DONE**

1. Author: GSSI

**PEMS:** Insulin pump, in general

**Motivation:** We should consider additional abilities

**Proposal:** Add the following abilities / aspects:

* user-acceptability and user-friendliness
* legal and ethical aspects
* controllability
* Explainability (paper Patrizia “XSA: eXplainable Self-Adaptation” ASE’2022)

**Status: Add explainability dal paper di Patrizia**

# Explainability

The explainability is the ability of the system to make the entire control/adaptation process transparent and comprehensible by explicitly providing an explanation to humans. This explanation should be provided for the relevant behavioral aspects of the system’s decision making (i.e., why a control task/adaptation is requested, the reasoning behind a control task/adaptation decision, the effects/outcomes of the control task/adaptation) in a given operating condition (i.e., the observable features of the *semantic space* – environment and configuration dimensions with their own type and domain) to meet the control/adaptation goals (e.g., satisfy the system-level requirements). These include the use of interpretable models (e.g., linear models or decision trees) and of model-agnostic interpretation tools for local or global explanations.

| **Level** | **Level name** | **Description** |
| --- | --- | --- |
| 0 | No explainability | The system does not explain its behavior while it operates or adapts itself. |
| 1 | Passive recognition of the need of explainability | The system recognizes that the explanation of a particular behavioral aspect should be provided. Thus, it passively accumulates knowledge about the control/adaptation goals and the operating conditions, which could be used to increase explainability. Defined variables of the semantic space shall be observable and measurable at runtime. |
| 2 | Active recognition of the need of explainability | The system recognizes that the explanation of a particular behavioral aspect should be provided. Thus, it actively accumulates knowledge about the control/adaptation goals and the operating conditions by executing actions that are deliberately designed to increase explainability through exploration methods that extract and derive proper knowledge from the measured variables of the semantic space. |
| 3 | Local aspect explainability | The system explains a selected behavioral aspect of a control/adaptation process that occurs to satisfy the control/adaptation goals in a specific operating condition. |
| 4 | Global aspect explainability | The system explains the average behavior of a control/adaptation process with respect to the satisfaction of the control/adaptation goals under changing operating conditions. |
| 5 | Collective explainability | The process of explainability is carried out among multiple communicating control/adaptation agents in a decentralized manner. |

per MVM

level 0 : satisfied: MVM has no explainer component.

level 1: Improvable (low effort) : MVM could be endowed with a component for data and events continuous recording.

level 2: Improvable (high effort) : MVM could be endowed with a component for data and events continuous recording and machansms for exploring and deriving knowledge from collected data.

level 3: Improvable (high effort) : In addition, MVM could be endowed with an explainer mechanism that analyses control/adaptation requests to provide explanation of local control/adaptation aspects.

level 4: Improvable (high effort) : In addition, MVM could be endowed with an explainer mechanism that analyses the outcome (i.e., either success or failure) for all control/adaptation decisions as a whole to provide explanation of global control/adaptation aspects.

level 5: Unable