Topic #1

Context

In a partially automated industrial context of automobile production, a state-of-the-art humanoid robot, named H-54, is integrated into the assembly line to perform the task of assembling car doors. Equipped with an anthropomorphic and articulated structure, H-54 is outfitted with a wide range of advanced sensors (two cameras, tactile sensors, proprioception sensors, IMU) and actuators, as well as sophisticated computing and control capabilities (specifically, part of the computation is cloud-based, while part is on-premises on the robot).

At the beginning of its shift, H-54 autonomously positions itself at the warehouse to retrieve the components necessary for door assembly. Utilising its stereoscopic vision sensors and real-time environment mapping, the humanoid robot plans the most efficient route for transporting materials to the assembly line, avoiding obstacles, and ensuring the safety of surrounding operators.

Once on the assembly line, H-54 places the door components on a worktable and uses its advanced manipulation abilities to perform precision assembly operations. Thanks to its articulated structure and controlled strength, H-54 can handle delicate components with high precision, such as assembling the electric window regulator, applying the right amount of force according to component specifications. Its force and tactile sensors constantly monitor material interaction, ensuring accurate execution of operations.

During its shift, H-54 communicates and collaborates with human operators on the assembly line. Thanks to its advanced communication interface, based on gestures and vocal dialogue, H-54 exchanges real-time information with other human operators and receives instructions to optimise workflow and resolve any operational issues.

We want to focus on the following situation:

1. While H-54 works on the assembly line, it performs a certain sequence of basic actions to assemble door components, such as the electric window regulator. H-54 must correctly perceive these components, verify that they are the correct components to be assembled, determine their position in the workspace, and manipulate them appropriately, including using tools; for this purpose, H-54 uses a data structure containing the correct sequences of tasks to be performed.

2. Occasionally, while H-54 performs these assembly operations, it must interact with a human operator to receive assistance or perform an operation together. An example is the cooperative transport of the assembled door to a predefined area of the assembly line. H-54 must then decide based on the estimated weight of the door whether to proceed alone or interact with a human operator; the robot must also decide which human operator to approach.

Problem

Using points 1/ and 2/ as general rules that H-54 must follow, design a cognitive architecture based on a series of software modules capable of ensuring H-54's overall behaviour given these normative rules.

In particular:

A. Use UML formalism to describe the cognitive architecture of H-54, identifying reasonable software components.
B. Develop the component diagram of the cognitive architecture, highlighting the cloud-based cognitive components and the on-premises ones.
C. Selecting a software module from those provided, describe its state machine explicitly specifying states, events, transitions, and any sub-states.
D. Describe the activity diagram of the cognitive architecture.
E. Highlight the software components that are "adapters."
F. Highlight the software components that are "computational."
G. Highlight where the "publish-subscribe" communication mode is used.

Topic #2

Context

In a context of space exploration on the planet Mars, a next-generation autonomous rover, named M-12, is tasked with conducting terrain analysis operations to collect scientific data. Equipped with a series of advanced sensors (including spectrometers, multispectral cameras, and radar for analysis activities, and stereoscopic cameras and IMU for navigation and attitude control) and sophisticated data processing capabilities, M-12 is designed to explore Martian terrain and gather crucial mission information.

At the beginning of an exploration task, M-12 activates and prepares to execute terrain analysis operations. Using its sensors and satellite maps provided by the Earth base, the rover plans an optimal route to explore a specific area, avoiding obstacles, and identifying points of scientific interest.

Once in the area of interest, M-12 begins to perform terrain analysis using its scientific instruments. It must be able to identify and classify soil samples, evaluate chemical and mineral composition, and detect any anomalies or geological features of scientific interest.

During its mission, M-12 may encounter situations where it must make decisions based on predefined normative rules. These rules guide the rover's behaviour and influence its actions during the exploration of Martian terrain. We want to focus on the following situation:

1. While M-12 explores the terrain, it must decide whether to analyse a surface soil sample it has identified to evaluate its chemical composition or descend into a nearby crevice to examine thin layers of rock; this decision is based on a preliminary and inconclusive analysis of the sample.

2. On some occasions, M-12 may encounter a hazardous terrain area, characterised by steep cliffs or unstable ground. In this case, the rover must decide whether to proceed with exploration, risking damage, or change course and seek an alternative route; this decision can be made autonomously, using terrain traversability algorithms that assess terrain characteristics, or with support from the technical team on Earth, which can receive information from the rover and decide what to do.

Problem

Using points 1/ and 2/ as general rules that M-12 must follow, design a cognitive architecture based on a series of software modules capable of ensuring M-12's overall behaviour given these normative rules.

In particular:

A. Use UML formalism to describe the cognitive architecture of M-12, identifying reasonable software components.
B. Develop the component diagram of the cognitive architecture, highlighting the cloud-based cognitive components (executed on a high-performance computing system on Earth) and the on-premise ones (executed partly on a computer on board M-12, partly on a fixed computing station on Mars).
C. Selecting a software module from those provided, describe its state machine explicitly specifying states, events, transitions, and any sub-states.
D. Describe the activity diagram of the cognitive architecture.
E. Highlight the software components that are "adapters."
F. Highlight the software components that are "computational."
G. Highlight where the "request-process-reply" communication mode is used.

Topic #3

Context

In a context of home assistance for elderly people, a next-generation domestic assistant robot, named A-19, is designed to perform a series of household tasks, including cleaning the house and meal preparation. Equipped with a flexible structure and a wide range of advanced sensors (including cameras, tactile and pressure sensors, temperature sensors), A-19 can operate partially autonomously within the home environment, of which it has a 3D mapping obtained during an initial calibration phase.

At the beginning of its daily activity, A-19 evaluates the surrounding environment by integrating the initial static 3D map with current perceptions, using its visual sensors, and plans the optimal route to perform the assigned tasks, such as floor cleaning. Using path planning algorithms and environment mapping, the robot determines the most efficient and safe path to carry out the assigned activities, minimising the likelihood of interfering with the activities of the assisted person.

Once the house cleaning task has begun, for example, A-19 uses its sensors to detect the presence of dirt and dust on the floors. The robot autonomously decides which areas to clean (using surface characterisation algorithms) and selects the appropriate tools to clean effectively and efficiently; for cleaning, A-19 uses standard tools such as vacuum cleaners, brooms, and cleaning cloths, which it must retrieve and store when finished.

During meal preparation in the kitchen, A-19 uses its arms to manipulate kitchen utensils and ingredients, following pre-set recipes or vocal instructions provided by the person being assisted. The robot can perform cutting, mixing, and cooking operations with precision and safety.

Occasionally, during the execution of household tasks, A-19 may need to interact with the elderly person being assisted. For example, it may receive specific instructions regarding food preferences or the arrangement of objects in the home. We want to focus on the following situation:

1. While A-19 is preparing meals in the kitchen, it must decide whether to prepare a complex variant of a complex recipe that requires the use of additional appliances, or to opt for a simpler dish that can be prepared manually with fewer resources and in less time; to do this, it may interrupt the preparation and request the intervention of the assisted person; the presence of these recipe variants is described in a recipe script, which the robot has access to.

2. During house cleaning, A-19 detects a fragile object on the floor that should not be moved or handled; the fragility of the object is detected by appropriate algorithms. The robot must decide whether to ignore the object and continue cleaning, risking damage to it, or to report the situation to the elderly person and await instructions on how to proceed.

Problem

Using points 1/ and 2/ as general rules that A-19 must follow, design a cognitive architecture based on a series of software modules capable of ensuring A-19's overall behaviour given these normative rules.

A. Use UML formalism to describe the cognitive architecture of A-19, identifying reasonable software components.
B. Develop the component diagram of the cognitive architecture, highlighting the cloud-based cognitive components and the on-premises ones.
C. Selecting a software module from those provided, describe its state machine explicitly specifying states, events, transitions, and any sub-states.
D. Describe the activity diagram of the cognitive architecture.
E. Highlight the software components that are "adapters."
F. Highlight the software components that are "computational."
G. Highlight where the "publish-subscribe" communication mode is used.