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CLOUD ROBOTICS MODEL

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ABSTRACT

Cloud Robotics was born from the merger of service robotics and cloud technologies. It allows robots to benefit from the powerful computational, storage, and communications resources of modern data centres. Cloud robotics allows robots to take advantage of the rapid increase in data transfer rates to offload tasks without hard real time requirements. Cloud Robotics has rapidly gained momentum with initiatives by companies such as Google, Willow Garage and Gostai as well as more than a dozen active research projects around the world. The presentation summarizes the main idea, the definition, the cloud model composed of essential characteristics, service models and deployment models, planning task execution and beyond. Finally some cloud robotics projects are discussed.

KEY WORDS

service robotics, cloud technologies, robotics, cloud robotics, service models

CLASSIFICATION

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WHAT IS CLOUD ROBOTICS?

Cloud Robotics (CR) was born from the merger of cloud technologies and service robotics [1], which was preceded by a change in paradigm in both domains [2]. It allows robots to benefit from the powerful computational, storage, and communications resources of modern data centres.

Cloud robotics allows robots to take advantage of the rapid increase in data transfer rates to offload tasks without hard real time requirements.

The term "cloud-enabled robotics" was presented by James Kuffner for the first time at the IEEE RAS Int. Conference on Humanoid Robotics in 2010. He was first to point out the potential of distributed networks combined with robotics, primarily to enhance the robot [3].

Cloud Robotics has rapidly gained momentum with initiatives by companies such as Google, Willow Garage and Gostai as well as more than a dozen active research projects around the world. The increasing number of robots with up to date knowledge will become a true helping hand for humans. In 2011, at the Google I/O developer Conference, Google and Willow Garage introduced their theory and foreseen application of Cloud Robotics [4].

Cloud Robotics is currently driving interest in both academia and industry, combines robot technology with network and Cloud-computing infrastructure that connects amount of robots, sensors, portable devices and most important a data-centre (Figure 1).

Driven by advances in mobile communication technologies, more and more robotics applications can be executed in the cloud [5].

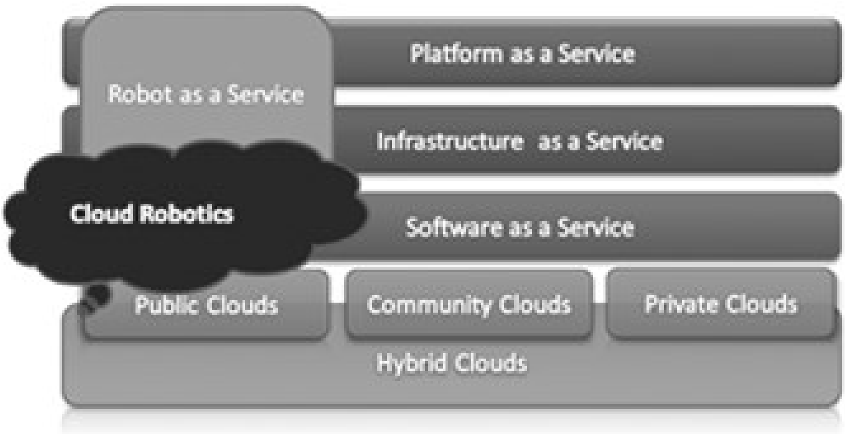

Figure 1. Cloud computing service models, the concept of Robot as a Service and Cloud Robotics.

ROBOTICS SCHOOL AND CLOUD ROBOTICS

The robotics school and cloud robotics complement each other. The increasing number of robots with up to date knowledge will become a true helping hand for humans. Cloud robotics is the use of a cloud computing to share resources and learning among robots through the internet [6]. The robotics cloud needs the robotics school to provide a standard coding system, knowledge structures and resources, and a method by which robots can be certified to serve in various fields [7, 8].

A robotics school is a collection of data pools, resources pools and service clusters for robots with advanced intelligence, it also has a knowledge coding standard together with an authentication standard for robots.

A robotics school is based on the concept of the robotics cloud; it is also the key element for building the robotics cloud. The concept of a robotics school mainly includes three aspects:

- admittance,
- teaching, learning,
- testing and graduating.

Hardware functionality must meet the hardware requirements for specific activity areas without too much encoding in software. A model of a robotics school is shown in Figure 2.

ROBOT WEB TOOLS

Robot Web Tools is designed to enable Web developers, roboticists, and even students to start building a robot Web application quickly [9-13]. A variety of routes are available for architecting a robot web application. A common route is building web technologies on an existing robot framework.

The Robot Operating System (ROS) is one of the more popular robot middle wares to build upon. Currently available tutorials include interfaces for navigation a quadrotor (Figure 3).

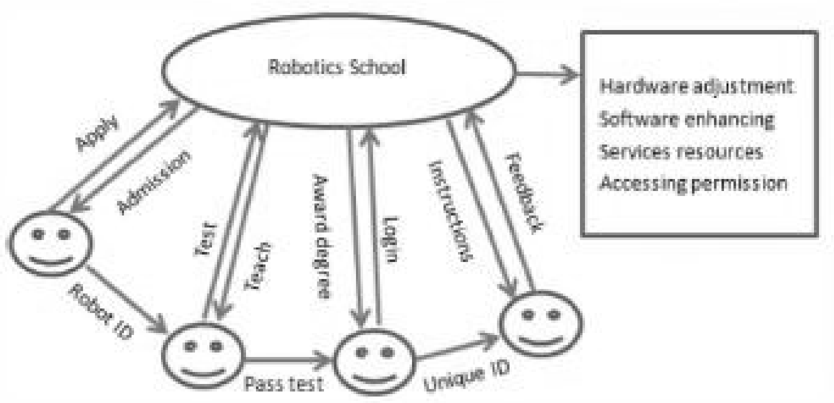

Figure 2. A model of a robotics school.

Figure 3. Tutorial interface for quad-rotor navigation.

ROS (Robot Operating System) provides libraries and tools to help software developers create robot applications. It provides hardware abstraction, device drivers, libraries, visualizers, message-passing, package management, and more. ROS is licensed under an open source, BSD license [9-10].

GPS NAVIGATION OF QUAD-ROTOR

The four rotor flying robot – a quad-rotor is a four rotor helicopter. A quad-rotor helicopter is controlled by varying the rotors speed, thereby changing the lift forces. It is an under-actuated dynamic vehicle with four input forces and six outputs coordinates.

One of the advantages of using a multi-rotor helicopter is the increased payload capacity. The quad-rotors are highly maneuverable, which enables vertical take-off/landing, as well as flying into hard to reach areas [14-17]. The quad - rotor is installed a GPS sensor is used to detect the present position. Quad-rotor is requested to track the imposed trajectory between the particular points ($j = 1, \ldots, n$) with satisfactory precision keeping the desired attitude and height of flight. Quad-rotor checks for the current position (X and Y) by use of a GPS sensor and/or electronic compass. Trajectory of quad-rotor can be introduced by GPS coordinates, e.g. $P_{GPS}(j)$ as shown in Figure 4.

Quad-rotor checks for the current position (X and Y) by use of a GPS sensor and/or electronic compass. Also, the altitude is measured by a barometric sensor. On-board microcontroller calculates the actual position deviation from the imposed trajectory given by successive GPS positions $\underline{P}_{GPS}(j)$. It localizes itself with respect to the nearest trajectory segment (by calculation of the distances δ1 or δ2). Using the gyroscope, quad-rotor determines desired azimuth of flight α (Figure 4) and keeps the desired direction of flight. Height of flight is also controlled to enable performance of the imposed mission (task). The corresponding Google Earth map is utilized to provide corresponding GPS coordinates of the quad-rotor trajectory as presented in Figure 5. GPS coordinates: longitude, latitude and altitude, defined in the map and given in the Figure 6, are used to calculate quad-rotor trajectory in the earth frame.

Corresponding model of the trajectory given in earth frame is presented in Figure 7.

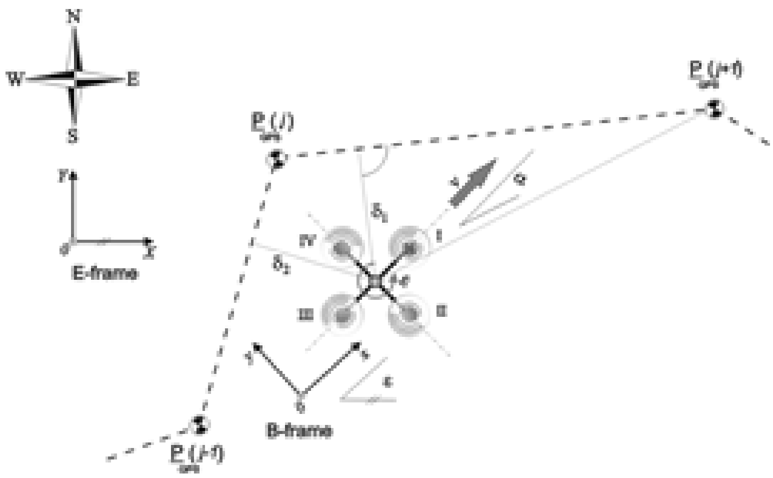

Figure 4. Quad-rotor localization and navigation with respect to the imposed GPS coordinates.

Figure 5. Google-Earth map of the lake used to define desired GPS trajectory of the quad-rotor flying robot.

	LONGITUDE			LATITUDE			ATTITUDE
point	*degrees*	*minutes'*	*seconds"*	*degrees*	*minutes'*	*seconds"*	*feet*
0	44	17	20.88	20	28	24.19	970
0'	44	17	20.88	20	28	24.19	970
1	44	17	21.44	20	28	36.04	963
2	44	17	27.11	20	28	50.67	964
3	44	17	40.87	20	29	4.07	970
4	44	17	51.45	20	29	17.09	968
5	44	17	39.87	20	29	11.14	987
6	44	17	29.61	20	29	0.2	980
7	44	17	20.63	20	29	10.35	970
8	44	17	19.05	20	29	23.15	991
9	44	17	14.02	20	29	7.53	1049
10	44	17	20.72	20	28	59.15	985
11	44	17	13.12	20	28	48.47	1045
12	44	17	14.54	20	28	31.86	983
13	44	17	11.05	20	28	26.98	987
14	44	17	3.83	20	28	32.98	970
15	44	16	50.71	20	28	39.13	1007
16	44	16	41.90	20	28	54.12	970
17	44	16	46.05	20	28	37.28	1036
18	44	16	53.58	20	28	31.58	1016
19	44	17	9.90	20	28	16.59	983
20	44	17	14.95	20	28	22.6	943
20'	44	17	14.95	20	28	22.6	943

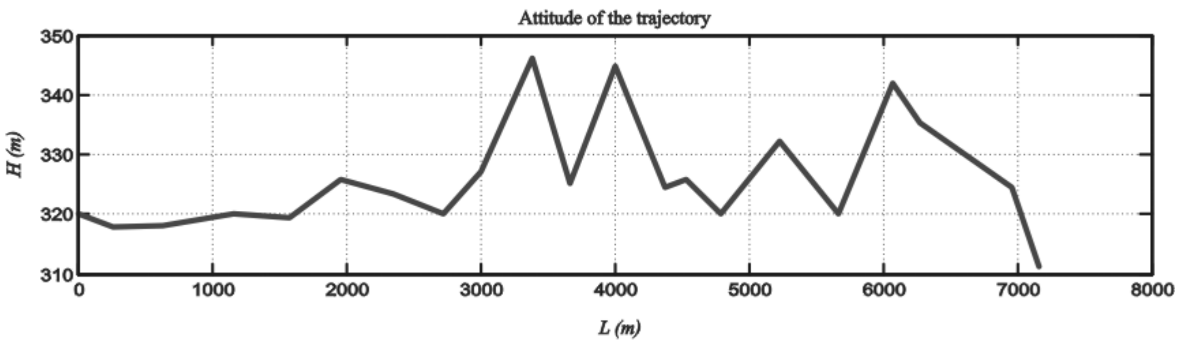

Figure 6. GPS coordinates acquired from the Google Earth map and used for determination of the desired quad-rotor trajectory.

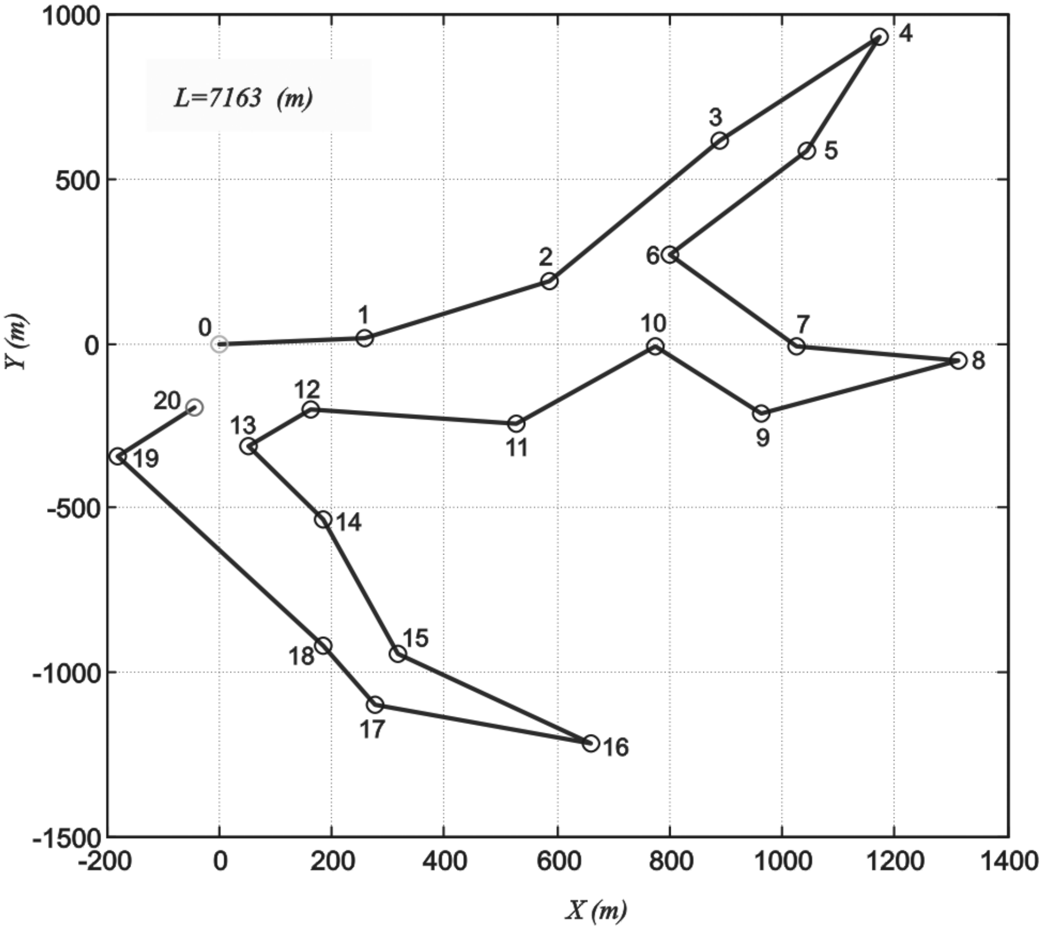

Figure 7. Multi-segment trajectory model of the quad-rotor determined in the Earth inertial frame.

CLOUD ROBOTICS PROJECTS

Finally some Cloud Robotics projects are discussed. With the *RoboEarth* Databases and its Cloud Engine, RoboEarth provides an open-source Cloud Robotics framework that allows robots to share knowledge via a www-style database and access powerful robotic cloud services [5]. Source code and documentation are available via RoboEarth's Software Components page.

Rosbridge focuses on bridging communication between a robot and single ROS environment in the cloud. Available open-source via [18]. The *RosJava* library allows to run ROS on Android phones. While not strictly a cloud robotics project, it allows ROS developers to use Android devices to connect to (human) cloud services such as Google Goggles. Available open-source via [19].

The *DAvinCi* Project showed the advantages of cloud computing by parallelizing a SLAM algorithm using a Hadoop cluster [20].

The *Cloud-Based Robot Grasping* project uses Google's Object Recognition Engine to recognize and grasp common household objects. *GostaiNet* offers to execute robot behaviors such as vision and speech algorithms on compatible robots in the cloud. GostaiNet provides seamless control of any robot, using a web browser from anywhere in the world. Gostai can host the services on the GostaiNet robotics cloud [21-23].

CONCLUSIONS

Cloud robotics allows robots to take advantage of the rapid increase in data transfer rates to offload tasks without hard real time requirements.

Cloud Robotics has rapidly gained momentum with initiatives by companies such as Google, Willow Garage, and Gostai as well as more than a dozen active research projects around the world. It allows robots to benefit from the powerful computational, storage, and communications resources of modern data centers.

The presentation summarizes the main idea, the definition. The cloud model composed of essential characteristics, service models and deployment models, planning task execution and beyond. Cloud computing can enable cheaper, lighter, smarter robots. The infrastructure exists and is rapidly evolving in terms of performance and accessibility. Finally some cloud robotics projects are discussed.

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MODEL ROBOTIKE U OBLACIMA

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SAŽETAK

Robotika u oblacima nastala je spajanjem uslužne robotike i tehnologija oblaka. Ona omogućava robotima korištenje pogodnosti poput znatnih resursa za računanje, pohranu i komunikaciju u modernim centrima podataka. Robotika u oblacima omogućava, nadalje, robotima korištenje znatnog porasta brzina prijenosa podataka da proslijede zadatke bez zahtjevnih vremenskih ograničenja. Robotika u oblacima dobila je znatni moment slijedom inicijativa tvrtki kao što su Google, Willow Garage i Gostai te kao što je veći broj aktivnih istraživačkih projekata po svijetu. Ovaj rad je sažetak glavne ideje, definicije, modela oblaka koji uključuje bitna svojstva te uslužnih i razvojnih modela, planiranja izvršavanja zadataka i drugoga. Naposljetku, razmotreni su pojedini projekti robotike u oblacima.

KLJUČNE RIJEČI

uslužna robotika, tehnologije oblaka, robotika, robotika u oblacima, uslužni modeli