Fusion Engineering and Design xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

Fusion Engineering and Design

journal homepage: www.elsevier.com/locate/fusengdes

Open software architecture for east articulated maintenance arm

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HIGHLIGHTS

- A software requirement of serial-articulated robot for EAST assembly and maintains is presented.
- A open software architecture of the robot is developed.
- A component-based model distribution system with real-time communication of the robot is constructed.

ARTICLE INFO

Article history:
Received 31 August 2015
Received in revised form 13 February 2016
Accepted 22 February 2016
Available online xxx

Keywords:
EAST
EAMA
Maintenance
Software architecture
Real-time control
OROCOS

ABSTRACT

For the inside inspection and the maintenance of vacuum vessel in the EAST, an articulated maintenance arm is developed. In this article, an open software architecture developed for the EAST articulated maintenance arm (EAMA) is described, which offers a robust and proper performance and easy-going experience based on standard open robotic platform OROCOS. The paper presents a component-based model software architecture using multi-layer structure: end layer, up layer, middle, and down layer. In the end layer the components are defined off-line in the task planner manner. The components in up layer complete the function of trajectory plan. The CORBA, as a communication framework, is adopted to exchange the data between the distributed components. The contributors use Real-Time Workshop from the MATLAB/Simulink to generate the components in the middle layer. Real-time Toolkit guarantees control applications running in the hard real-time mode. Ethernets and the CAN bus are used for data transfer in the down layer, where the components implement the hardware functions. The distributed architecture of control system associates each processing node with each joint, which is mapped to a component with all functioning features of the framework.

1. Introduction

The Institute of Plasma Physics Chinese Academy of Sciences has been running the EAST (Experimental Advanced Superconducting Tokamak) project since 2000, which targets on the development of a small non-circular cross-section superconductor tokamak and its subsystems. The EAST articulated maintenance arm (EAMA) subsystem project began from 2013, which is aimed to implement the remote handling operations in the EAST for the routine inspection and maintenance. To date, some sorts of teleoperation manipulator applications, for example the ITER Articulated Inspection Arm (AIA) [1], the Planar Articulated Arm (PAA), the ITER Mobile Parallel Robot [2] and the Articulated Teleoperated Manipulator (ATM) [3], had been developed. Many of them run on the commercial software platforms or the research software prototypes [4], and various applications have been derived from the development, in course of these applications [5], covered the topics of reliable real time control system design, graphical supervisor, and robot localization realistic etc.

The physical EAMA system is shown in Fig. 1, it mainly consists of 3 parts: cask, shuttle, and manipulator, and for each part there are several peripherals. Fig. 2 shows the structure of the EAMA, each subsystem elementary technologies are composited individually and integrated into EAMA system model, which makes compatibility and portability the major concerns in software design. The EAMA software is designed based on an open source architecture that favors the capacity and portability demands, and it also offers massive models and algorithms especially pertaining to the long dimension, joint-reductant, structure-flexible manipulator for the purpose of easy approach and long term research.

This paper is focused on software design for the robot represented by the hexagon in Fig. 2 and the paper is structured as

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http://dx.doi.org/10.1016/j.fusengdes.2016.02.074
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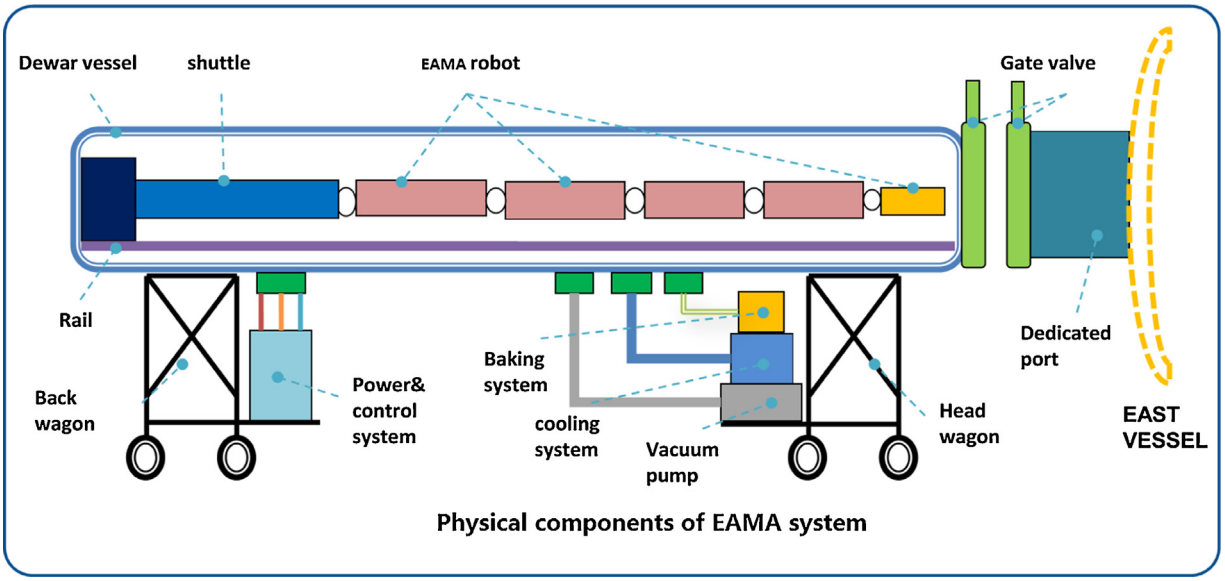

Fig. 1. Physical component of EAMA system.

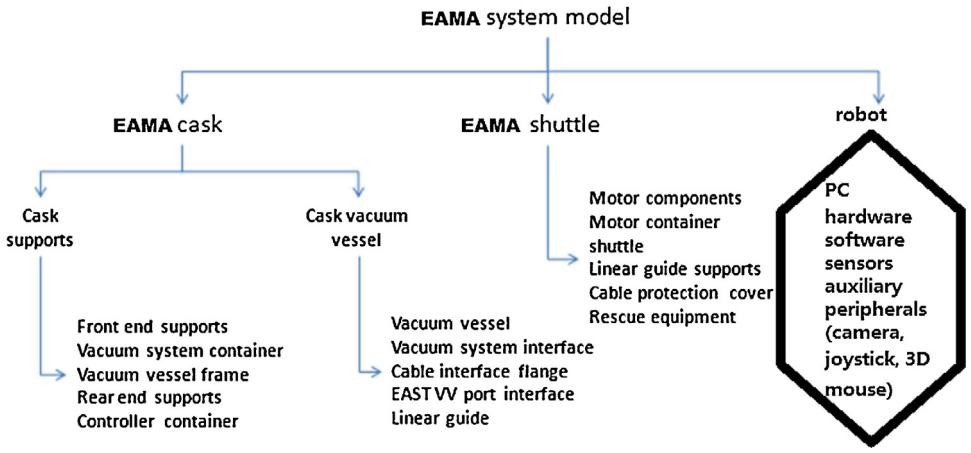

Fig. 2. EAMA system prototype development structure.

follows: Section 2 presents the related work of the robot software, control system prototype of other tokamak system and the objectives of current software solutions; Section 3 gives the overview of software attributes, software distribution system, software configuration, supervisor, visualization, layers, components distributions, communication, scheduling, hardware abstraction and low-level control. In the last section the conclusion and further work are discussed.

2. Related work

2.1. ITER robotics

The ITER Articulated Inspection Arm (AIA) robot is developed by the Institute for Magnetic Fusion Research (IRFM) [6], the CEA licensed Energid's Actin software to be the AIA robot supervision, which works in collaboration with AREVA and OPEN CASCADE, by a turnkey application layer for intuitively controlling the robot and preventing collisions dynamically. In Shanghai Jiao Tong University, the State Key Laboratory of Mechanical System and Vibration and the Research Institute of Robotics presented a remote handling robot (RHR) system that consist of three parts: an omnidirectional transfer vehicle (OTV), a Planar Articulated Arm (PAA), and an Articulated Teleoperated Manipulator (ATM) [3]. It is simulated by MATLAB and robot technology middleware (RTM) for a remote operation.

2.2. EAST FIVIR

As shown in Fig. 3, a flexible in-vessel inspection robot (FIVIR) is the outcome of a joint project between the Institute of Plasma Physics in Chinese Academy of Sciences (ASIPP) and the Shanghai Jiao Tong University (SJTU), which is used for carrying servicing facilities in EAST. A multi-body system model of the end-effector is created using ADAMS analysis [7].

2.3. Design objectives

The functions of software architecture of EAMA cover the aspects of task management, communication coordination, movement achievement, etc. The software should achieve the multiple objectivities in the development course, which includes the schedulability, the stability, the portability and the compatibility, elaborated in details as follows:

Please cite this article in press as: J. Wu, et al., Open software architecture for east articulated maintenance arm, Fusion Eng. Des. (2016), http://dx.doi.org/10.1016/j.fusengdes.2016.02.074