Felix Paper Title*

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***Abstract*—To solve the problem of different interfaces for different robots a data connector is developed. It creates a interoperable, decentralized Network for a robot system using the Open Platform Communication Unified Architecture (OPC-UA) standard. Creating a flexible digital twin in Isaac Sim to visualize the data of the robot system. Remote access to the data connectors (and the digital twin) to monitor the robot system from everywhere.**

***Index Terms*—OPC-UA, interoperable, decentralized, digital Twin, Isaac Sim, remote access**

I. Introduction

Every robot manufacturer develops uses their own way of communication with their robot. This leads to problems when trying to build a robot system with multiple robots from different brands. In this example two robot arms from Kinova are to be mounted on a Husky mobile robot platform from Clearpath. The Husky uses Robot Operating System (ROS) to communicate internally while the robot arms use the Kortex api from Kinova. To combine them into one digital twin they should be on one standard. For this a data connector is developed on the Open Platform Communication Unified Architecture (OPC-UA) standard. Its purpose is to act as a layer between the robot specific language and the outside world, in this example the digital twin. To add flexibility the robot data isn't collected on one server but every robot has its own server. Because of this decentralized approach every client can choose to connect only to the servers it wants to. For example if only one of the robot arms is mounted on the husky the digital twin can connect to only this one while the other robot arm con be used otherwise.

II. Advantages of OPC-UA

was ist opcua? [1] warum opcua sprich semantische Interoperabilität, Ressourcenschonung (Subscribe und Publish statt Polling), . . . das wäre Kap. 3.1

III. Development of the data connector

Depending on the robot it might be possible to install software onto it. If this is the case there is no need for additional Hardware . On the Husky PC runs ROS, so it is possible to create an ROS package with a OPC-UA Server. On the Kinova robot arms on the other Hand it is not possible to install software, so an Raspberry Pi is used which gets the data from the robot and makes them accessible via an OPC-UA server. To simplify the development the OPC-UA Server code is implemented as a stand-alone class, so it can be reused for different robots.

A. As a ROS package

B. As a stand-alone device

As Hardware for the stand-alone device a Raspberry PI 3B+ is used because it is very versatile. It could connect to robots via Ethernet, USB or with the GPIO pin nearly every other connection standard. Furthermore it is powerful enough to handle an OPC-UA server and talk to an robot at the same time. The Code is split into three main parts (Fig. 1). One part is the communication to the robot via the Kortex api, the second part is the OPC-UA server with the open62541 library. The main code part in the middle starts a thread for the connection to the robot and a thread for the OPC-UA Server. It also connects the data from from the robot class to the OPC-UA Server class. So if the connector is used with another robot, it is enough to just write a new connection to the robot. It is also possible to prepare the connection to a robot from a different manufacturer and let the main code detect what robot is connected. This increases the flexibility of the data connector.

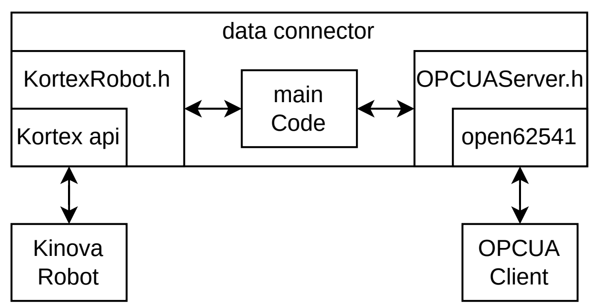

Fig. 1. Code structure of the data connector

IV. Performance Tests

To ensure the data doesn't take to long from the robot to a client a series of performance tests are conducted. These

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can be separate in two parts. First getting the data from the robot to the data connector and second get the data from the data connector to the client. Every test is made with 5 samples. Every sample is the average speed of the first 1000 data requests.

A. Getting data from the robot

The Raspberry Pi 3B+ is directly connected to the Kinova robot via a ethernet cable. With UDP as communication standard the Raspberry Pi can get the up to 1400 datasets per second from the Kinova robot (Fig. 2). That is even more than the 1000 datasets per second, that Kinova claims [2]. A

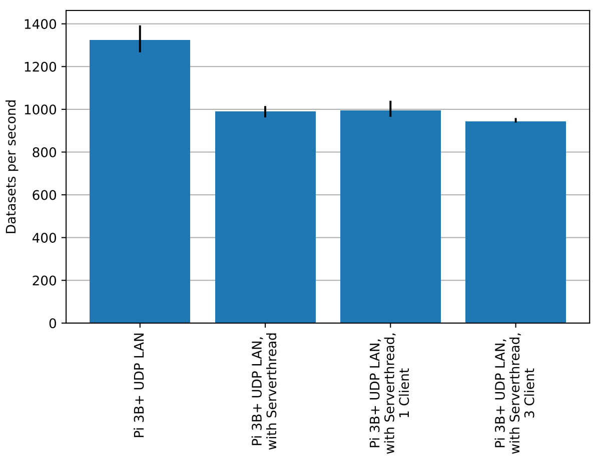

Fig. 2. Frequency with which the Raspberry Pi 3B+ can get data from the Kinova arm

dataset consists of all the data the robot has to offer. Thats over 50 data points. Is the OPC-UA server is running parallel on the Raspberry Pi the frequency is lower, around 1kHz. If one client is simultaneously requesting data from the OPC-UA server the frequency isn't really affected. But if there are more clients then the frequency begins to drop slowly.

B. Getting Data from the data connector

To get the data from the data connector two different PCs are used. One midrange Laptop (Intel 11.Gen Core i7-1165G7, Realtek Semiconductor RTL8152 Fast Ethernet Adapter) and an high end Tower PC (Intel 13.Gen Core i9-13900KF, Realtek Gaming R2.5GbE Family Controller). The PCs and the data connector are all connected to a Router (tp-link Archer C80 AC1900 MU-MiMO).

In Fig. 3 different libraries are used for the client to request one Value from the data connector. On the Laptop the c-library open62541 is faster than the python library freeopcua. On the Tower PC the python library is even faster than the c library on the Laptop. If these results are compared to the ping between these PCs and the data connector (Fig. 4) it can be concluded that the python library on the Tower PC is running close to the actual limit of the network.

If multiple clients are started in parallel on the Tower PC there is a slight decrease in the frequency with which the data can be requested from the data connector (Fig. 3). In the last test

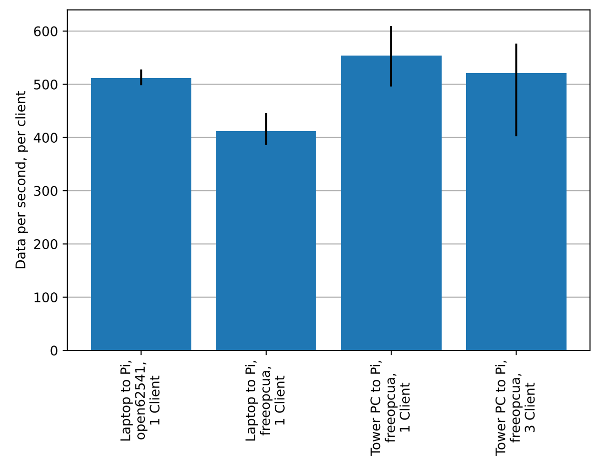

Fig. 3. Frequency with which data can be requested from the OPC-UA server

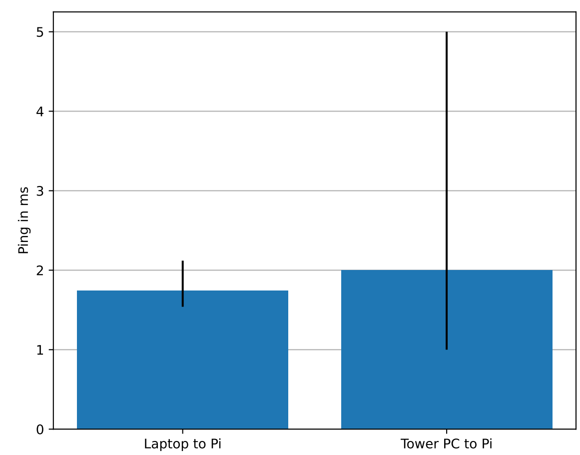

Fig. 4. Ping to the data connector

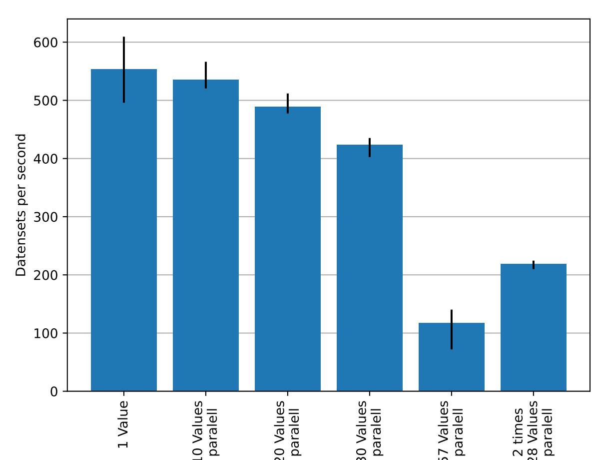

Fig. 5. Frequency with which different datasets can be requested from the OPC-UA server

(Fig. 5) datasets with different amounts of values are requested from the data connector via the Tower PC using the python library.

V. Digital twin

VI. Remote access

VII. Ease of Use

A. Maintaining the Integrity of the Specifications

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A. Abbreviations and Acronyms

Define abbreviations and acronyms the first time they are used in the text, even after they have been defined in the abstract. Abbreviations such as IEEE, SI, MKS, CGS, ac, dc, and rms do not have to be defined. Do not use abbreviations in the title or heads unless they are unavoidable.

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C. Equations

Number equations consecutively. To make your equations more compact, you may use the solidus (/), the exp function, or appropriate exponents. Italicize Roman symbols for quantities and variables, but not Greek symbols. Use a long dash rather than a hyphen for a minus sign. Punctuate equations with commas or periods when they are part of a sentence, as in:

$$a + b = \gamma \tag{1}$$

Be sure that the symbols in your equation have been defined before or immediately following the equation. Use "(1)", not "Eq. (1)" or "equation (1)", except at the beginning of a sentence: "Equation (1) is . . ."

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Please use "soft" (e.g., `\eqref{Eq}`) cross references instead of "hard" references (e.g., `(1)`). That will make it possible to combine sections, add equations, or change the order of figures or citations without having to go through the file line by line.

Please don't use the `{eqnarray}` equation environment. Use `{align}` or `{IEEEeqnarray}` instead. The `{eqnarray}` environment leaves unsightly spaces around relation symbols.

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E. Some Common Mistakes

- The word "data" is plural, not singular.
- The subscript for the permeability of vacuum μ_0, and other common scientific constants, is zero with subscript formatting, not a lowercase letter "o".
- In American English, commas, semicolons, periods, question and exclamation marks are located within quotation marks only when a complete thought or name is cited, such as a title or full quotation. When quotation marks are used, instead of a bold or italic typeface, to highlight a word or phrase, punctuation should appear outside of the quotation marks. A parenthetical phrase or statement at the end of a sentence is punctuated outside of the closing parenthesis (like this). (A parenthetical sentence is punctuated within the parentheses.)
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- In your paper title, if the words "that uses" can accurately replace the word "using", capitalize the "u"; if not, keep using lower-cased.
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- Do not confuse "imply" and "infer".
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- There is no period after the "et" in the Latin abbreviation "et al.".
- The abbreviation "i.e." means "that is", and the abbreviation "e.g." means "for example".

An excellent style manual for science writers is [9].

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a) Positioning Figures and Tables: Place figures and tables at the top and bottom of columns. Avoid placing them in the middle of columns. Large figures and tables may span across both columns. Figure captions should be below the figures; table heads should appear above the tables. Insert

TABLE I
TABLE TYPE STYLES

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	Table column subhead	***Subhead***	***Subhead***
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[a]Sample of a Table footnote.

Fig. 6. Example of a figure caption.

figures and tables after they are cited in the text. Use the abbreviation "Fig. 6", even at the beginning of a sentence.

Figure Labels: Use 8 point Times New Roman for Figure labels. Use words rather than symbols or abbreviations when writing Figure axis labels to avoid confusing the reader. As an example, write the quantity "Magnetization", or "Magnetization, M", not just "M". If including units in the label, present them within parentheses. Do not label axes only with units. In the example, write "Magnetization (A/m)" or "Magnetization {A[m(1)]}", not just "A/m". Do not label axes with a ratio of quantities and units. For example, write "Temperature (K)", not "Temperature/K".

ACKNOWLEDGMENT

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REFERENCES

Please number citations consecutively within brackets [3]. The sentence punctuation follows the bracket [4]. Refer simply to the reference number, as in [5]—do not use "Ref. [5]" or "reference [5]" except at the beginning of a sentence: "Reference [5] was the first ..."

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For papers published in translation journals, please give the English citation first, followed by the original foreign-language citation [8].

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