Artifact: Mobility Improves Accuracy: Precise Robot Manipulation with COTS RFID Systems

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I. Introduction

This artifact abstract is a guideline to GLAC[1], a real-time tracking system based on COTS RFID devices. We encapsulated the GLAC core for the convenience of users. Based on it, we extended a GLAC APP to provide some useful features about RFID tracking.

II. Quick Start

GLAC is open source on https://github.com/543202718/GLAC. The project is programmed with JDK 1.8 and organized with Apache Ant 1.10.6. To start the project, the following 4 steps are needed:

1) Clone or download the GitHub repository.
2) Enter the root directory of this project with the command `cd INSTALLATION_FOLDER/GLAC`.
3) Execute the command `ant clean jar` to package it.
4) The executable JAR is *dist/GLAC-with-dependencies.jar*. In the root directory, execute the command `java -jar dist/GLAC-with-dependencies.jar` to run it.

Moreover, to apply the online tracking feature, we need a ThingMagic M6e RFID reader, an RFID tag and four 920MHz omnidirectional antennas.

III. GLAC Core

The core code of GLAC is packaged as a class library file *lib_GLAC.jar*, exposing three classes, `Config`, `HMM` and `TagData`. Among them, `TagData` is the encapsulation of tag data, `Config` is the parameter configuration, and `HMM` is the core class whose exposed methods are shown in Fig 1.

```
void add(TagData td);
void clear();
ArrayList<Pair<Double, Double>> getTrajectory();
ArrayList<Pair<Double, Double>> getVelocity();
```

Figure 1. Exposed methods of HMM

Before tracking, we clear the information of HMM by *clear()*. Then, we continuously provide new observations to HMM and update the trajectory by *add()*. Current tracking results can be obtained by *getTrajectory()* and *getVelocity()*.

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IV. GLAC APP

On the basis of GLAC core, we developed a GLAC APP. There are several features, such as offline tracking, simulation and online tracking. Some screen shoots of GLAC APP are shown in Fig 2.

A. Config Setting

The config of GLAC includes two parts, one is the antenna setup and the other is the parameters. The config is described in the json format as the file *Config.json*. Generally, if *Config.json* is in the same directory as *GLAC-with-dependencies.jar*, it will be loaded. Otherwise, a new *Config.json* with default config will be generated and loaded.

B. Offline Tracking

As shown in Fig 2 (a), the offline tracking feature allows users to track a tag whose tag readings are recorded in a file. Firstly, click the “Select” button to select the file of tag data. Then, click the “Track” button to start tracking. Finally, the trajectory that GLAC obtained will be shown in the coordinate system below.

Tag data format: Tag readings are saved in csv format. Without table header, each line in this file represents a reading, including three numbers. The first number is the antenna index counting from 0. The second number is the timestamp in milliseconds and the third is the phase in radians.

Some experimental data is stored under the directory *data/10/TagData* and *data/40/TagData*.

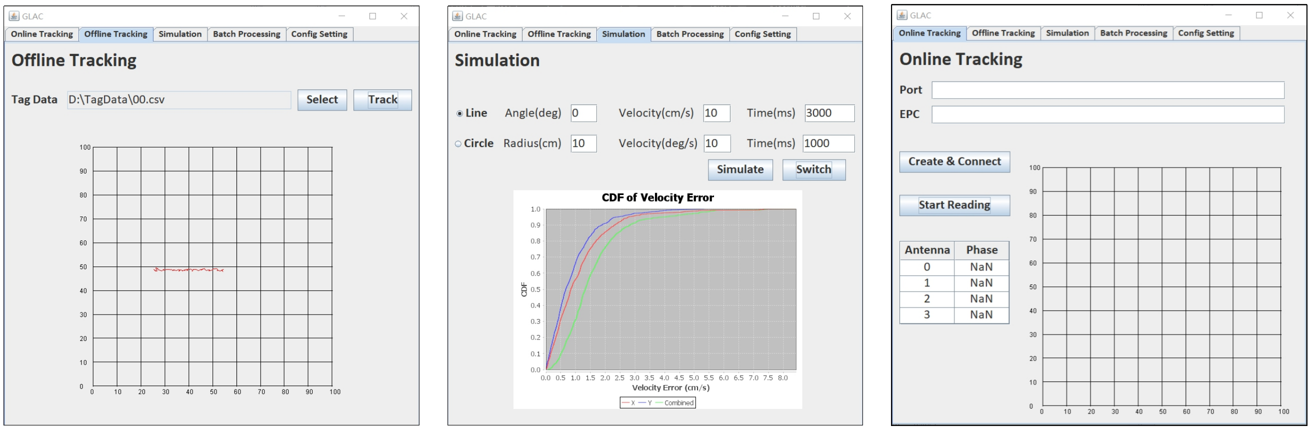
C. Simulation

Except using experimental data, as shown in Fig 2 (b), the simulation feature also allows users to track the simulated data. Firstly, choose the shape and parameters of the simulated trajectory. Then, click the “Simulate” button to begin the simulation and calculate the tracking error, which will be shown in the figure below. When clicking the “Switch” button, it’s able to switch the CDF of position error and velocity error.

D. Online Tracking

Further more, as shown in Fig 2 (c), the online tracking feature allows users to collect data themselves and track online.

Firstly, set up the antennas and connect them with the reader which is connected to the computer with USB. Secondly,



(a) Offline Tracking (b) Simulation (c) Online Tracking

Figure 2. The screen shoots of GLAC APP

attach the RFID tag on the target object. Thirdly, modify the config according to the actual antenna setup. Then, correctly fill in the port and EPC of target tag in the GUI. After that, click the "Create & Connect" button to connect the reader and click the "Start Reading" button to start. The phase reading of each antenna will be shown in the table and the trajectory obtained by GLAC will be shown in the right figure.

V. Paper Result Verification

A. Batch Processing

We developed the batch processing feature for paper result verification. This feature will track all tag data files in a directory and compare with their groundtruth in another directory, showing the CDF of position error and velocity error.

Groundtruth format: Groundtruth is saved in csv format. Without table header, each line represents a state in a moment, including four numbers, which are X coordinate, Y coordinate, X velocity and Y velocity. The unit of position is cm and the unit of velocity is cm/s. It is worth noting that the name of groundtruth file should be the same as the corresponding tag data file.

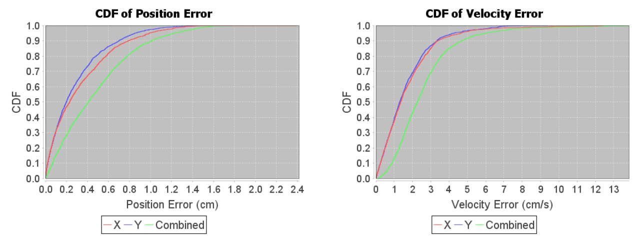
B. Verification

Part of the experimental data is stored under the directory *data*, which is collected with default antenna setup, including data on linear motion at 10 cm/s and 40 cm/s. With default parameters, the CDF of tracking errors are shown in Fig 3.

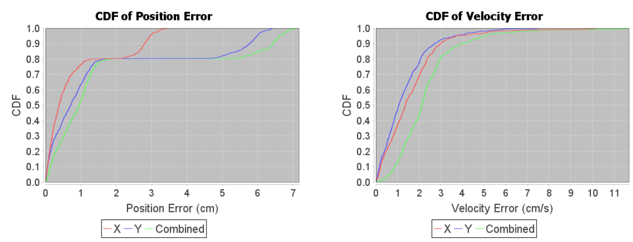
For 10cm/s and 40cm/s motion, the median position error is 0.41cm and 0.95cm. Meanwhile, the median velocity error is 2.26cm/s and 2.12cm/s, respectively. These results are consistent with those in Figure 7 of paper[1].

VI. Conclusion

The artifact of GLAC has been open source in GitHub. We promise that it will be maintained for more than 3 years. Please feel free to contact us for any questions.



(a) 10cm/s Linear Motion (b) 10cm/s Linear Motion



(c) 40cm/s Linear Motion (d) 40cm/s Linear Motion

Figure 3. The tracking errors of linear motion data

Acknowledgement

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References

[1] H. Wang, S. Chen, and W. Gong, "Mobility improves accuracy: Precise robot manipulation with COTS RFID systems," in *2021 IEEE International Conference on Pervasive Computing and Communications (PerCom)*, 2021.