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A LOW-COST CABLE-SUSPENDED PARALLEL MANIPULATOR FOR TESTING 3D OLFACTION ALGORITHMS

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1. Introduction

Cable-suspended parallel manipulators have been a topic of research for multiple decades and called special attention in the fields of simulations [1]. However, they are also well-suited for the simple evaluation of aerial-based mobile robot olfaction (MRO) algorithms, such as gas source localization and gas distribution mapping. Based on an open source framework for 3D printers, we designed a low-cost underconstrained, cable-suspended parallel manipulator. Computations are carried out purely on an Atmel ATmega2560 microcontroller.

2. Testbed Setup

The testbed built at BAM (see Fig. 1) consists of four stepper motors connected to an aluminum metal frame with four cables leading to the end-effector. The robot is operated by an 8-bit Atmel ATmega2560 microcontroller running at 16 MHz and connected to the Rumba[1] electronics board, from which the motors are being controlled. An LCD-display is attached to the board to display further information during operation such as the end-effector's position. Furthermore, commands can be send to the device via serial connection.

The robot is designed to work as an underconstrained parallel manipulator allowing for spatial movements using gravity (see Fig. 1). Since the end-effector tends to lean towards the side with the shortest cables due to the distribution of mass, we found a pointwise connection of the cables at the end-effector to be of best use to keep the end-effector most stable. Alternatively, a gimbal can be equipped to level out the end-effector. Microstepping greatly enhances smoothness of operation and offers precise positioning within the range of millimeters. Using TMC2100 (TRINAMIC Motion Control GmbH & Co. KG) stepper drivers in stealth-chop mode, the robot runs extremely silent.

Fig. 1. Construction of an underconstrained, cable-suspended parallel manipulator with four cables for spatial positioning of an end-effector using gravity.

The robot can be operated through on-board memory or SD card to manoeuver the end-effector along predefined trajectories. Via serial connection, a host system such as a PC can communicate with the robot to control the end-effector's position and in turn react on information received from it.

A 2.4 GHz XBee module connected to a microcontroller board (Arduino Leonardo) serves as basis for the end-effector's payload. The bidirectional wireless data link enables sending measurement data to and controlling the payload from the PC. Furthermore, a 2 DoF robot arm with gripper and servos have been attached to the end-effector for test purposes.

2.1 Limitations

The Atmel ATmega2560 microcontroller is a well-known processor among communities such as Arduino. But despite its relatively low pricing, it lacks useful features such as DMA (Direct Memory Access), which help to reduce processor load significantly. Especially in situations, in which an interrupt might overpower the serial interface, information loss can occur, thus bringing communication to a halt. Therefore, switching to more powerful processors might be necessary de-

[1] See https://reprap.org/wiki/RUMBA

pending on the application. Furthermore, the proposed parallel manipulator acts as an open-loop-controller, meaning, that no information about the state of the parallel manipulator in the real world, i.e., cable lengths and end-effector's position, are propagated back to the system. Thus, the software must rely on the accountability of the hardware in terms of precision, since it cannot filter its own state using feedback from outside. This also means, the system is not able to self-calibrate its end-effector's position or cable lengths. Each deviation from the model is irrecoverably lost. Though, during tests this has not been an issue, since the motors have proven to work with reliable precision.

To overcome the limitations, additional sensors, such as an IMU or a camera, could be attached to the end-effector's payload, providing necessary information for position filtering, which could be carried out on the host system and then fed back to the robot. Force sensors installed at the cables of the robot could additionally support self-calibration of cable lengths.

3. Plume Characterization

Evaluating algorithms in the field of MRO can quickly become cumbersome due to the challenges of creating a controlled test environment, both indoors and outdoors. Simulations have therefore become a common tool to evaluate algorithms regarding chemical plume tracking [2]. However, to evaluate performance quality, real-world tests are inevitable. For this reason, the testbed has been equipped with an artificial gas source located within the workspace of the robot to form a basis for evaluating algorithms under controlled conditions.

3.1 Plume Generation

A carbon dioxide (CO_2) gas cylinder connected via a small tube to a fan is installed at a fixed location within the workspace. The 12V fan is operated by an adjustable power supply to allow for variable air flow during experiments. The payload of the cable-suspended parallel manipulator is equipped with a SprintIR infrared CO_2 sensor (GSS Ltd.[2]) with a sampling rate of 20 Hz. The sensor has a measurement range of 0 to 100 $\%_{vol}$ with an accuracy of ±5% per reading.

3.2 Experimental Results

The plume depicted in Fig. 2 has been obtained via measurements by the robot's payload following a cubic grid with a total of 405 points. The gas source emitted CO_2 with 8 liters per minute, while the fan was operated at 12V, creating a relative smooth dispersion in all three dimensions. By adjusting the emission rate and power voltage, the plume can be controlled to represent different scenarios, which may reveal different aspects of an algorithm, when compared to another.

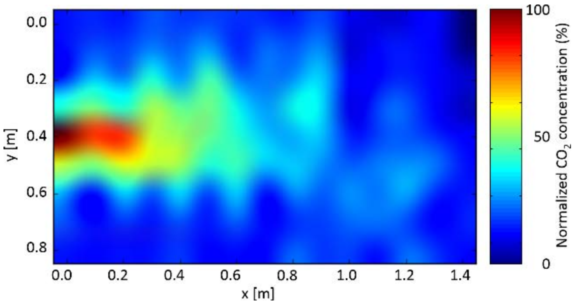

Fig. 2. Bilinear interpolation of the gas distribution measured by the robot's payload during experiments. Air flow from left to right with source located at the left mid-section.

4. Summary and Conclusions

We present a low-cost cable-suspended parallel manipulator based on a single Atmel ATmega2560 microcontroller. Through serial and wireless connection, a host system can communicate with both the robot and the processing unit installed at the end-effector, making the system suitable for robotic applications.

In a first test, we successfully characterized the plume showing the applicability of the system for testing and evaluating algorithms in the field of 3D mobile robot olfaction.

References

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[2] www.gassensing.co.uk