Rishov R. Sarkar

Project Advisor: Jennifer Hasler

Team 33 – AutoQuads

Single-Board Computers for Autonomous Quadcopters

Introduction

No matter its application, any autonomous quadcopter must be capable of processing large amounts of visual or sensor data in real time to make decisions about where and how to move. To make this possible, the quadcopter will require a single-board computer that can interface with its motors and sensors and run real-time computer vision applications. This paper is a review of commercially available single-board computers and their applications, along with a summary of the technology of these single-board computers and how they might be implemented in an autonomous quadcopter.

Commercially Available Single-Board Computers and Applications

One of the most popular single-board computers is the Raspberry Pi, which is the third best-selling general purpose computer after the Mac and PC [1]. The latest model, the Raspberry Pi 4 Model B, includes a quad-core 1.5 GHz 64-bit ARM processor and a selection of 1 GB, 2 GB, or 4 GB of RAM; it also has a CSI camera port and a VideoCore VI 3D GPU with support for hardware video decoding [2]. The model with 1 GB of RAM costs $35 [3]. While originally intended to help children learn computer science [4], the Raspberry Pi now finds applications in home automation [5] and industrial automation [6]. One commercial application of the Raspberry Pi is OTTO, a customizable camera that can perform image processing [7]. Additionally, the Raspberry Pi has been used successfully for an application in robotics for tracking of a visual target [8]. These applications are similar to the computer vision applications that may be needed for an autonomous quadcopter.

The Raspberry Pi Zero is also available, a smaller but less powerful version of the Raspberry Pi that is significantly cheaper. This board has a single-core 1 GHz CPU, 512 MB of RAM, VideoCore IV 3D GPU, and CSI camera connector [9] – [11]. This model is 65 mm by 30 mm [12], which is much smaller than the Raspberry Pi 4's form factor of 85 mm by 56 mm [13]. The model without wireless connectivity costs only $5 [14], but the model with WiFi and Bluetooth connectivity costs $10 [15]. This board is used in various hobby projects that make use of the small form factor [16], such as a motion-activated security camera [17], which runs computer vision software on the Raspberry Pi Zero.

Another commercially available single-board computer is the BeagleBone Black. This includes a tri-core 1 GHz 32-bit ARM processor with an SGX530 3D graphics engine and 512 MB of RAM [18] –

[20]. At 3.4 in. by 2.1 in. (i.e. 86 mm by 53 mm) [21], its form factor is comparable to the Raspberry Pi 4. The BeagleBone Black costs $55 [21]. Similar to the Raspberry Pi family of single-board computers, the BeagleBone Black is used in various hobby projects [22]. However, it is typically not suited for graphics-heavy applications [23].

Technology of Single-Board Computers

A single-board computer is a fully integrated computer, including a processor, RAM, and graphics acceleration, all on a single printed circuit board [23]. They often provide slots for interfacing with other devices [24], like the GPIO pins on the Raspberry Pi family of devices [2], [9] and on the BeagleBone Black [18]. Single-board computers are typically used in embedded applications and process control applications, thanks to their light weight, small size, high reliability, and power efficiency [24].

Single-board computers lie in the category of embedded computers alongside microcontroller units, which similarly incorporate a processor, memory, storage, and programmable I/O pins [25]. In contrast with single-board computers, microcontroller units are much less powerful and not easily reprogrammable, but their lower cost at scale and lower power consumption make them ideal for applications where a single-board computer, which runs an operating system and multi-tasks between multiple programs, would be impractical [25]. Single-board computers are more suited to running applications for systems such as ATMs, virtual slot machines, jukeboxes, and automated checkout systems; on the other hand, microcontrollers exist in devices such as television remotes, which do not need to be as powerful or run software as complex [25].

Implementation in Autonomous Quadcopters

An autonomous quadcopter will require a single-board computer to interpret sensor data and/or video from a camera so that it can understand its environment and make decisions about what actions to perform based on its surroundings. Of the choices for single-board computers, a single-board computer from the Raspberry Pi family is likely most suited to this application, since these devices include a GPU [2], [10], [11] that will enable real-time computer vision applications, as demonstrated by existing hobby projects [8], [17] and commercial products [7]. The specific device chosen will likely depend on the processing power demands of the software.

The single-board computer will provide the hardware platform for the software that will drive the autonomous quadcopter. Computer vision software will need to be written using a library like OpenCV [8], [17]. Software must also be written to determine how to drive the quadcopter based on input from the camera or sensors.

Hardware changes will be necessary to allow for the single-board computer to drive the autonomous quadcopter. The quadcopter will need to supply power to the single-board computer from its own battery, which will require changes to the hardware of the quadcopter, or a separate battery must be installed for the single-board computer. A custom or off-the-shelf case will likely be necessary to prevent damage to the single-board computer and mount it to the quadcopter. The single-board computer will need to interface with the quadcopter motors, camera, and sensors. If the quadcopter has no camera or sensors, these may need to be installed externally.

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