

Microcontrollers for Swarm of Autonomous Underwater Vehicles

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Introduction

Underwater exploration is crucial for investigating bio-marine species, monitoring pollution, and developing disaster warning system. Due to the vastness of the ocean, application of multiple Autonomous Underwater Vehicles (AUVs) in co-operative missions is gaining traction [1]. For application of AUVs in networked or swarm mode, there are several crucial issues: sensing and communication, cooperation and mission control, design of AUV platforms, autonomous behavior and aspects of simultaneously running multiple robots [2].

The embedded CPU and operating system needs to be defined as a compromise between boards, size, computational burden and power consumption. This choice is fundamental to ensuring the feasibility of required computations (data processing) and for ensuring AUV's autonomy [3]. This paper reviews factors to be considered while selecting appropriate microcontroller (MCU) to operate a swarm of AUVs; focusing on three off-the-shelf microcontrollers: Arduino, Raspberry Pi and BeagleBone.

Required Hardware Interfaces

The most important consideration while selecting an MCU is the different forms of external interfaces available. The first are communication interfaces. These include peripherals such as USB, I2C, SPI, UART, BLE and Ethernet. These interfaces greatly affect how much program space the MCU will need to support. The second type of interface includes digital inputs and outputs, analog to digital inputs and pulse width modulation (PWM). These two interface types will dictate the number of pins that will be required by the MCU. Arduino Uno comes with 6 Analog pins, 14 Digital (6 PWM) pins, while Raspberry Pi offers 8 GPIOs and no analog pins. TI's BeagleBone Black has 7 analog pins and 65 GPIOs (8 PWM).

Processor Speed

The onboard processing speed required by AUVs may differ depending on the control method employed to achieve swarming behavior. In case of Master Slave control, the Master robot requires higher computing resources and thus requires a microprocessor with high processing speed. The Slaves have simpler functions like following instructions and relaying information. For Consensus control, each robot in the swarm independently determines their action to achieve desired goal [4]. Thus, each agent in the swarm will need similar computational resources. In special cases like CoCoRo project, more than two types of controllers are needed [5]. Arduino Uno uses ATmega328 running at 16MHz, while Raspberry Pi has ARM1176JZF-S processor running at 700 MHz. BeagleBone Black has ARM Cortex-A processor and runs at 1GHz speed.

Memory needs

Flash and RAM are two very critical components of any microcontrollers. Making sure that you don't run out of program space or variable space is undoubtedly of highest priority. A factor to be considered is scalability; future updates to the program would need additional memory, so the installed MCU should have the margin already built-in [6]. Furthermore, swarms deployed to collect data need large data storage capacity; MCUs with option for external SD card will be preferred. Arduino Uno provides 32KB Flash memory and 2KB SRAM, while Raspberry Pi has 256MB of RAM and 4GB eMMC Flash. BeagleBone Black has 512MB DRAM and 2GB eMMC available.

Cost and Availability

To ensure scalability of a swarm, an inexpensive AUV design is essential. While Raspberry Pi and Arduino are comparable in at \$39.99, the BeagleBone Black at \$59.99 is more expensive. Arduino is good choice as it is the most versatile MCU on the market and is the most widely used by hobbyists. Another consideration is availability. If the goal is to design a real life product, MCU should be easily available in large quantity in future.

Power Constraints

Total power requirements for the MCU along with needs of all the onboard sensors, should be calculated. The AUV's size is constraint by the volume and weight of the battery [7]. There is a tradeoff between the low power requirements and the processing power; if both are available the cost will go up. Higher the number of sensors used, more is the power requirement. Arduino, BeagleBone Black and Raspberry Pi can all run off of a 5V power source. Moreover, power management is limited due to the fact that all peripherals are not accessible in a low power state.

Programming Language

Microcontroller selection also depends on familiarity with programming languages. The most common are Assembly and Embedded C. Arduino uses a variant of C, whereas Raspberry Pi and BeagleBone Black can support any language that is supported by a compatible Linux distribution. While it is easier to use high level languages, they will increase memory requirements. There is a tradeoff between time spent to develop and the program size efficiency.

Knowledge and Support

As microcontrollers have been available for a very long time, the selection decision in the industry is now governed by the support from chip vendor and development tools, not the price and features. Availability of documentation, manufacturer support, flexibility of the tool in supporting multiple families with ease and community examples are important factors. The debugging capabilities and an easy graphic user interface (GUI) for configuring the various peripherals of the microcontroller are added benefits [3].

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