A Low-Cost Autonomous Robot and Educational Platform for Intelligent Automation Experiments

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Abstract. In this paper, we present a low-cost (less than $10) real-time mobile-robot platform: Aicar, for educational experiments in Intelligent Automation and related disciplines such as Artificial Intelligence and Robot Engineering. The Aicar platform uses Arduino open-source hardware and supports various programming interfaces including C/C++, Python and Matlab. With its attached android mobile phone, Aicar can support image capturing and video streaming for computer vision applications. With Aicar, various Intelligent Automation and Artificial Intelligence algorithms can be practiced, including rule based system, reinforcement learning and deep learning algorithms. Aicar platform is open sourced and the hardware design and software startup code for Aicar project is available for public access through the free online service.

Introduction

Research suggested that for students, attaining knowledge in Intelligent Automation and related disciplines such as Artificial Intelligence and Robot Engineering, through experiential and student-directed projects was likely to lead to greater achievement [1]. Mobile robots have high potential to become an ideal tool for education in engineering fields [2].

Educational mobile robots have seen a lot of development recently. For example, The K-Team has developed the Khepera III, an extensible and efficient platform suitable for many purposes. They provide software toolbox containing a collection of scripts, programs and code modules [3]. The TurtleBot, made by Clearpath Company, is a low-cost, personal robot kit with open-source software based on Robot Operating System (ROS) and open source hardware [4]. The low-cost iRobot Create, manufactured by iRobot and designed for robotics development [5], is a simple platform with small processors, USB ports and 25 pin ports. However, designs above are still too expensive to be widely adopted in class teaching. We present a low-cost (less than $10) real-time mobile-robot platform: Aicar, for educational experiments in Intelligent Automation and related disciplines such as Artificial Intelligence and Robot Engineering.

Moreover, we apply additional factors of class research project management that ensure sustainable project development across different class grades. The key factors include project governance, resource re-allocation and post-project donation. Some approaches are incorporated into the running of projects to encourage resource sharing and project sustainable development. Class projects are arranged in groups and bonus points are given to the research groups who are willing to donate their hardware resources to the junior grade classmates. These additional factors ensure the class projects can be enhanced grade by grade.

In the remainder of this paper the design of Aicar autonomous robot will be discussed, which is based on a completely open-source technology in hardware (Arduino) and software. In the next section, electronic hardware and the main components will be explained. In the following part of this paper, design principals of the robot and the information flow of Aicar will be explained. In the next part, the algorithms which can be practiced with Aicar will be described. Finally, the conclusion and ongoing work of this research is presented.
Aica Platform

In this part, we describe the overall design of Aicar platform. The pricing of the main components of Aicar platform will also be discussed.

Overall Design

We use Arduino boards (Arduino Uno [6]) to read sensor inputs and turn it into an output - activating a DC motor. We can tell Aicar what to do by sending a set of instructions to the microcontroller on the board. To do so we use the Arduino programming language and the Arduino Software (IDE). The overall design of Aicar platform is illustrated in Fig. 1 below.

![Aicar Platform Diagram](image)

Figure 1. The overall design of Aicar platform.

Aicar Pricing

Table 1 lists the components of the Aicar autonomous vehicle platform and the cost for each at the time the paper was written. The hyperlinks of these components vendors on Taobao.com are also provided in Source column (note: the price may change over time).

Table 1. Components of the Aicar Autonomous Vehicle Platform.

<table>
<thead>
<tr>
<th>Component</th>
<th>Price (¥)</th>
<th>Price ($)</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>2WD Smart Robot Car Chassis Kit</td>
<td>9</td>
<td>1.38</td>
<td>Taobao.com</td>
</tr>
<tr>
<td>Arduino Uno Compatible(with USB cable)</td>
<td>11.7</td>
<td>1.80</td>
<td>Taobao.com</td>
</tr>
<tr>
<td>HC-SR04 Ultrasonic Sensor</td>
<td>2.2</td>
<td>0.34</td>
<td>Taobao.com</td>
</tr>
<tr>
<td>BT06 Bluetooth Module</td>
<td>8.7</td>
<td>1.34</td>
<td>Taobao.com</td>
</tr>
<tr>
<td>L293D Motor Drive Shield</td>
<td>7.8</td>
<td>1.20</td>
<td>Taobao.com</td>
</tr>
<tr>
<td>Model power battery(3.7V 780mAh) x2</td>
<td>20</td>
<td>3.08</td>
<td>Taobao.com</td>
</tr>
<tr>
<td><strong>Total Price</strong></td>
<td><strong>59.4</strong></td>
<td><strong>9.14</strong></td>
<td></td>
</tr>
</tbody>
</table>
Aicar Workflow

In this section, we discuss in detail about the workflow in Aicar platform. Fig. 2 describes the main workflow and information flow in the platform.

First, the Arduino board reads in the distance signals from HC-SR04 sensor and the (optional) commands from BT06 Bluetooth module. Then, it controls the DC motor by sending the PWM (Pulse Width Modulation) signals to the L293D motor drive shield board. The Bluetooth commands and debug information are sent through Arduino Uno board’s #0 (RX) and #1 (TX) serial port. Aicar can be operated in two modes: manual mode and automation mode. In manual mode, the operation commands are sent in through Bluetooth channel. Aicar can execute eight commands in this mode: Forward, Backward, Turn Left, Turn Right, Stop, Turn Random, Increase Speed Ratio and Decrease Speed Ratio. In automation Mode, Aicar can run autonomously and turn a random angle when there are obstacles in front of it.

Image capturing and video streaming are supported by the attached mobile phone. The video signals are captured by the android phone and sent to the host computer under WIFI connection. We installed DroidCam\textsuperscript{1} app on the mobile phone. The DroidCam App can connect to its’ computer application and send the real-time video streams to the host computer. The host computer can use Python or Matlab interfaces to retrieve and process the captured images and video streams. The startup code for demonstration is available at https://github.com/luckh2/aiclass/tree/master/startup.

Supported Algorithms with Aicar

Project-based learning uses active learning techniques and gives students direct exposure to hardware and software. By extending the approach to incorporate Aicar, various Intelligent Automation and Artificial Intelligence algorithms can be practiced, including rule based system, reinforcement learning and deep learning algorithms. In this section, we explain in detail the supported algorithms with Aicar autonomous robot platform in educational experiments.

Rule Based Systems

Rule-based systems are used as a way to store and manipulate knowledge to interpret information in a useful way. They are often used in information automation and artificial intelligence applications and
research. Rules typically take the form of an {IF: THEN} expression, (e.g. {IF 'condition' THEN 'action'}, or as a more specific example, {IF 'distance < 40cm' THEN 'stop' AND 'turn-around'}). Algorithm 1 illustrates the rule-based control in Aicar.

### Algorithm 1. Rule-based Collision Avoidance

**Input:** Obstacle distance $d$, Parameters: constant distance $D$, Angle Range $\theta_1$, $\theta_2$

**Output:** Action $A$, Turning Angle Array $\theta[]$, Timing Array $T[]$

1. $A \leftarrow \text{RUN}$
2. $i \leftarrow 0$
3. $T[i] \leftarrow \text{CurrentTime}$
4. $0[i++] \leftarrow 0$
5. **While** true **Do**
6. **IF** ($d \leq D$) **Then**
7. $T[i] \leftarrow \text{CurrentTime}$
8. $0[i] \leftarrow \text{Random}(\theta_1, \theta_2)$
9. $A \leftarrow \text{STOP}$
10. $A \leftarrow \text{TURN}(0[i++])$
11. $A \leftarrow \text{RUN}$

### Reinforcement Learning

Reinforcement learning is concerned with how an agent ought to take actions in an environment so as to maximize some notion of long-term reward. Here we want to maximize the Aicar running time. Algorithm 2 illustrates the simple learning of parameters in Aicar.

### Algorithm 2. (Simple) Reinforcement Learning of parameters $\theta^*$

**Input:** Timing Array $T[]$, Turning Angle $\theta[]$

**Output:** Best Angle $\theta^*$ (which leads to longest Aicar Running Time)

1. $N \leftarrow \text{Length of } T[]$
2. **For** ($i \leftarrow 0; i < N-1; i++$)
3. $\text{TimeLength}[i] \leftarrow T[i+1] - T[i]$
4. $T^* \leftarrow 0$
5. **For** ($i \leftarrow 0; i < N-1; i++$)
6. **IF** ($\text{TimeLength}[i] > T^*$) **Then**
7. $T^* \leftarrow i$
8. $\theta^* \leftarrow 0[T^*]$
9. Return $\theta^*$

### Deep Learning Classification

Deep learning is based on learning data representations, as opposed to task-specific algorithms. In machine learning, a convolutional neural network (CNN, or ConvNet) is a class of deep, feed-forward artificial neural networks that has successfully been applied to analyzing visual imagery. Algorithm 3 illustrates using alexnet [7] CNN deep model to classify the image captured in Aicar.

### Algorithm 3. Deep Learning Classification of Video Capture image

**Input:** Video Camera object $\text{camera}$

**Output:** Picture Label $L$

1. $\text{nnet} \leftarrow \text{alexnet}$
2. **While** true **Do**
3. $p \leftarrow \text{camera.snapshot}$
4. $p \leftarrow \text{imresize}(p, [227,227])$ //alexnet input image size
5. $p \leftarrow \text{imrotate}(p,-90)$ //DroidCam App image tuning
6. $L \leftarrow \text{classify}(\text{nnet}, p)$
7. $\text{Image}(p)$ //show the image
8. $\text{title}(\text{char}(L))$ //show the label

### Conclusion

We describe Aicar in this paper: a low-cost (less than $10) autonomous robot platform for educational experiments in Intelligent Automation and related disciplines. The platform uses open-source
hardware and software toolkits to support various *Intelligent Automation* and *Artificial Intelligence* algorithms, including rule based system, reinforcement learning and deep learning algorithms. We are looking forward to more interesting projects using Aicar, for example, learning the music beats and making Aicar a dancing robot. Aicar platform is open sourced and the hardware design and software startup code for Aicar project is available online. (https://github.com/luckh2/aiclass).

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**References**


