Evaluation of Microcontroller Wireless Technology to Enable a Smart Connected Intensive Care Units (ICU)

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1. Background

Intensive Care Unit (ICU) is a complex environment.
- The users usually experience high cognitive workload and stress.
- Interoperability between equipment and the complexity of tasks lead to performance degeneration.
- Patients can suffer from the latent errors of poor ICU system design.
- Mitigation of interoperability issues can lead to a better quality of the working environment, and patient treatment.
- Microcontroller and Single Board Computers (SBCs) are readily available to design cost-effective tools that can target specific needs.

What are microcontrollers and Single Board Computers (SBC)?
- Microcontrollers and SBCs are small but powerful computers that are capable of controlling multiple outputs.
- Can aid with interoperability between tools

Recent emergence of wearable devices (e.g., communication tools, smartphones, smartwatches) and wireless electronic equipment make microcontrollers and SBCs a good candidate to improve interconnectivity and interoperability among different subsystems in an ICU

Critical Need: to investigate the efficacy of microcontrollers and SBCs to improve interoperability in ICUs

2. Research Aims

Aim 1: Investigate the efficacy of microcontrollers to improve interoperability among devices in the ICU
Aim 2: Compare microcontroller capabilities to improve a wireless Task Severity Awareness Tool (TAT)

3. Case Study: Development of a Task Severity Awareness Tool (TAT)

3.1 TAT Background

- Developed to enable nurses to inform others when a high-severity task such as medication administration is being conducted
- Tool was implemented in a cardiovascular intensive care unit (CVICU) of a Canadian teaching hospital.
- This tool consists of three actuators (two buttons and one pedal) located at the bedside, and a scrolling LED display outside the CVICU room connected to a microcontroller (Arduino Uno).
- When any of the actuators are pressed, the microcontroller detects the input, and as an output the scrolling LED display lights up with a “do not disturb” message.

3.2 TAT Improvement

- While the tool showed promise in mitigating unnecessary interruptions during high-severity tasks, usage required an extra step (pushing a button).
- Automated actuation of the display and wireless connection between wearable tools may mitigate these limitations.

3.3 Methodology for Choosing a Microcontroller or SBC and Tool design

Several ICU-specific criteria were identified using a review of literature and subject matter expert interview.
- The two dominant microcontrollers (Arduino and Raspberry Pi) were compared against these criteria using a decision matrix.
- Compared to Arduino Uno, Raspberry Pi 3 was deemed superior in terms of memory space, processing power, input/output, and connectivity.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Arduino Uno</th>
<th>Raspberry Pi 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analog Input</td>
<td>6</td>
<td>Not included, can be added</td>
</tr>
<tr>
<td>Digital Input/output Pins and PWM Outputs</td>
<td>14, 6 pins can be PWM</td>
<td>40 GPIO Pins</td>
</tr>
<tr>
<td>Memory</td>
<td>32 KB Flash Memory</td>
<td>SD Card</td>
</tr>
<tr>
<td>Processor</td>
<td>ATmega328P</td>
<td>Quad Core ARMv8</td>
</tr>
<tr>
<td>CPU Speed</td>
<td>16 MHz</td>
<td>1.2 GHz</td>
</tr>
<tr>
<td>USB Ports</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Price</td>
<td>$24.95</td>
<td>$39.95</td>
</tr>
<tr>
<td>Connectivity</td>
<td>Needs attachments for Bluetooth, Wi-Fi, IR, and RF</td>
<td>Bluetooth and Wi-Fi connectivity included. Attachments for IR or RF needed.</td>
</tr>
</tbody>
</table>

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<tr>
<th>Criteria</th>
<th>Arduino Uno</th>
<th>Raspberry Pi 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analog Input</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Digital Input/output pins</td>
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<td></td>
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<tr>
<td>Memory</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Processor</td>
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<td>CPU Speed</td>
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<tr>
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<td>Connectivity</td>
<td>2</td>
<td>4</td>
</tr>
</tbody>
</table>

4. Future Work

- Development of tools to connect a specific set of tools (e.g., pumps, displays, phones)
- There is a wide range of sensors and devices that can be used with microcontrollers or SBCs.
- Customization of tool to target a particular problem (e.g., interruption mitigation).
- Reduce interoperability problems
- Centralize information from multiple devices into one
- Reduce the complexity of medical tasks to improve performance
- Human-centered designed tools to aid diminish the complexity of tasks healthcare practitioners conduct
- Benefits range from the reduction of medical errors and improvement of the quality of working environment.

5. Sources


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