IoT Coffee Maker

Project Plan

Introduction
The idea of the project is to make coffee maker more "intelligent" and connect it to the internet. The future of the internet of things (IoT) will connect more and more normal home devices to the internet. This project experiments what possibilities IoT brings to the coffee maker and how they could be implemented.

Project team members are: Markus Komu, Johnny Boxström, Lauri Paukkunen, Mikko Paloniemi and Roope Aho.

Starting point
The current status of the project is that the project plan is done.

The primary targets of IoT Coffee Maker are:
- Ability to make coffee
- The device is connected to the internet
- Automatic water and coffee grounds dispensers

The secondary targets are:
- Ability to choose between coffee, hot water and third option (hot chocolate, another sort of coffee etc.)
- Controlling the coffee maker via internet
- Collecting user statistics and showing them in the internet user interface
- Adding and editing user profiles in the internet user interface
- Identifying user with Near Field Communication (NFC) -technology
- Automatic filter change/cleaning or no filter at all
- Choosing how many cups to make coffee

Some of the secondary targets are alternatives, so they can't all be implemented in the same device. The choice between these alternatives have to be done already in conceptual design. Two main alternatives are to make the coffee to the large coffee pot or to single coffee cup at the time. Some of the secondary targets are additional features, that can be added to the device, if there is enough resources to implement them.

Preliminary idea for implementation is to use water boiling system from a existing coffee maker and build everything else around it. Electronics will be controlled by Arduino with WiFi Shield. The water will probably be apportioned from bigger tank to existing coffee maker's tank. Other dispensers could be implemented with small stepper motor attached to gear wheel that drops the grounds when it's turning. One solution to automatic filter is to use permanent filter and sweep used coffee grounds away after every use. Another is to use quick coffee grounds that doesn't need filter.

Our project team has enough resources to implement primary targets and at least some of the secondary targets. We have some know-how about designing and building a mechatronic device and more knowledge can be acquired. We have time until mechatronic circus to complete the project. Time can be the most limiting resource. Some of the components we have already and we have money to buy the rest. We have for example existing coffee maker, Arduino Uno and 3D-printer which might be used in project.

Realisation

Tasks
After project plan, next step will be to conceptual design and component selection of the critical components with long delivery time. In conceptual design, main operating principles are decided, so critical components can be ordered. The detailed design begins with disassembling existing coffee maker. After that, rough 3D-model of the device will be done. More detailed models are needed for example dispensers. Coding can be divided to two main parts: internet user interface and Arduino. Especially user interface coding can be started while detailed design isn't ready. After detailed design is ready building of electronics and mechanics can be started. Testing of subsystems can be done simultaneously with coding and building and whole device can be tested at the end of the project.

Schedule
Documentation

- Project plan is done at the beginning of the project.
- Conceptual design will produce some kind of concept document of the device.
- Detailed design will produce rough 3D-model of whole device, more detailed models of critical parts, some manufacturing drawings and part list.
- Coding will be well documented and commented.
- Final report will include some of previous documentation and additionally more description about what was done and what was the result.
- Part of the documentation is also shown in projects Wikipage.

Budget

More accurate budget can be done after component selection, but rough estimation to budget is around 100€.

Conceptual Design

Context Diagram

Figure 1 presents a context diagram of the IoT coffee maker. In the middle is the microcontroller and around it are the input devices and actuators. The arrowheads present that is the device for input or output, or is it communicating via serial port.
Statechart

Figure 2 presents a statechart of IoT coffee maker. It describes the structure of microcontroller's program code.
Building process

The project plan’s schedule was followed quite accurately. During the conceptual design, almost all of the components were ordered from China (DealeXtreme). The Chinese New Year made the delivery time quite long, so we got the components after four weeks from ordering. It was good that we ordered them so quickly, so we could start the mechanical building during those four weeks. The mechanical structure was decided during the conceptual design to be round with wooden levels and aluminum shell.
The plywooden levels were made with NC-milling machine. The round turntable was taken from broken microwave oven. Also the turntable motor was considered to take from it, but we found out that its AC motor’s turning direction changed randomly. The heating element to boil the water was taken from the old coffee maker (as the power cable).

After we got the components, it was only three weeks to get the project done. So we started to assemble electronics with hurry. At the same time, the coding was started and WiFi and NFC modules tested. Biggest problems was faced with water components. There was many connections from water containers to pipes, and we had some leakages. We also ordered accidentally water valve, which needed a little pressure to work. So the water got through it only drop by drop. We changed it to a bigger pneumatic valve, but still it took two minutes to get the water through it. The whole system got ready the day before the mechatronics circus, so final test was made then. The heating element turned out to be broken (it leaked) but luckily we got working one from the lab. Also, the WiFi module had weird problems working Arduino Mega. All the problems was sorted out and the device had its final touch with pink rubber paint.

**Final device**

**Mechanical and electrical design**

The coffee maker was divided in to layers with wooden plates that were packed together with threaded rod and steel sheet cover. The bottom layer contains most of the electronic components excluding coffee maker resistor and two stepper motors. The control panel is also located in the bottom level of the device. The control panel has buttons and switches for different options that include: strong of mild coffee, strong or mild coffee with strong or mild milk and hot water for tea.
The next layer contains a plate that is rotated with a stepper motor. The rotating plate rotates the cup so that all ingredients can be distributed to the cup separately. A switch was used to determine the position of the plate. Wires going to the upper levels of the coffee maker were hidden inside hollow aluminum tubes.

The third layer contains two screw conveyors that are rotated with stepper motors and a valve that the water passes through when it is poured to the cup. The screw conveyors are used to distribute coffee and milk powder to the cup. The third layer also contains the resistor that heats the water as it passes through it.
Figure 7  Layers 1, 2 and 3
The top layer of the coffee maker has containers for coffee and milk powders and two containers for water. The water goes from the first container to the resistor and the hot water goes to the second container. The top level has also a float switch that is used to open the valve when the hot water level is high enough in the second container. Finally the layers were covered with folded metal sheet and wooden cover plate. Paint was applied for a better finished look.

**User identification: NFC**

The coffee maker was designed to have an identification system to prevent unauthorized use and to collect user data. For identification method, NFC was chosen. This could be implemented relatively easy with Arduino micro-controller by using MFRC522 NFC shield. The original idea was to use HSL bus cards for identification but the NFC shield had problems reading them and MIFARE classic NFC tags were used instead. The code for the identification was made and tested using separate Arduino Uno and added to the main code later. As the coffee maker used Arduino Mega, some changes to the wiring had to be made. Furthermore, on the final device the NFC antenna located away from the Arduino and jumper wires had to be used for the connection. The NFC shield has to be connected via 5V even though the NFC module uses 3.3V. In the final device the module and Arduino communicated via SPI6 port and the power was provided by an external power source. The wiring can be seen in Table 1.

<table>
<thead>
<tr>
<th>NFC Shield</th>
<th>Arduino Mega</th>
</tr>
</thead>
<tbody>
<tr>
<td>MISO</td>
<td>MISO</td>
</tr>
<tr>
<td>SCK</td>
<td>SCK</td>
</tr>
<tr>
<td>MOSI</td>
<td>MOSI</td>
</tr>
<tr>
<td>RESET</td>
<td>34</td>
</tr>
</tbody>
</table>

Table 1. Wiring
**IoT: WIFI**

To make the coffee maker a real Internet of Things device, WIFI was added. This was done by an ESP8266 WIFI-module for Arduino. ESP8266 is very small, cheap and simple add-on that works great in IoT projects. It requires 3.3V power and even though it is not recommended, it can be powered directly from the Arduino 3.3V pin. The power consumption of module can be high and problems may occur while powering multiple modules simultaneously with the ESP8266 as was noticed in the component testing phase of this project. Likewise the NFC, the code and operation of the module was tested on separate Arduino Uno and later added to the main assembly. The wiring can be seen in Figure 9.

![Figure 9. Connecting ESP8266 to Arduino Mega.](image)

**IoT: Collecting and uploading data to internet**

In this project the data chosen to be uploaded to Internet was the user specific counter for beverages made. The user data was written to the permanent EEPROM memory of the Arduino to prevent losing data because of WIFI problems or power cuts. This method works well with simple counter data but might not work while having sensor data.

An IoT web service, ThingSpeak, was used for gathering and visualizing the data sent from the device. ThingSpeak uses channels for the devices to collect and present the data. The data from the device can be sent to a specific field in the channel by using simple commands and a channel specific API key. Multiple fields can also be updated simultaneously, which is helpful while using many parameters. The coffee maker updated all the user counts after a successful task of making coffee and when turning on the device.
Final Budget and Part list

<table>
<thead>
<tr>
<th>Component</th>
<th>Qty</th>
<th>Price</th>
<th>Where?</th>
<th>Why?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stepper Motor with ULN2003 Driver - Silver (DC 5V)</td>
<td>4</td>
<td>€10.76</td>
<td>China</td>
<td>For dispensers (x3), spare part (x1)</td>
</tr>
<tr>
<td>Mega 2560 R3 Atmega2560-16AU Board</td>
<td>1</td>
<td>€14.93</td>
<td>China</td>
<td>For controlling (Chinese version)</td>
</tr>
<tr>
<td>ESP-01 ESP8266 Serial Wi-Fi Wireless Module + Adapter for Arduino</td>
<td>1</td>
<td>€9.23</td>
<td>China</td>
<td>For IoT connection</td>
</tr>
<tr>
<td>2 Channel Relay Shield Module for Arduino</td>
<td>2</td>
<td>€5.84</td>
<td>China</td>
<td>For connecting thermal resistance and water valve by Arduino</td>
</tr>
<tr>
<td>5V 10A Switching Power Supply</td>
<td>1</td>
<td>€14.88</td>
<td>China</td>
<td>Converter from 220V to 5V</td>
</tr>
<tr>
<td>NFC Shield RFID RC522 IC Card Sensor Kit for Arduino UNO / Mega2560</td>
<td>1</td>
<td>€8.28</td>
<td>China</td>
<td>For authentication (IoT)</td>
</tr>
<tr>
<td>2015S Electronics Microswitch w/ Lever Roller</td>
<td>10</td>
<td>€4.14</td>
<td>China</td>
<td>Limit switch (10pcs/box)</td>
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<tr>
<td>Electrical Power Control 3-Pin Toggle Switch</td>
<td>5</td>
<td>€3.88</td>
<td>China</td>
<td>Toggle switch (5pcs/box)</td>
</tr>
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<td>1/2-3201K Copper Water-Air Oil Solenoid Valve - Golden</td>
<td>1</td>
<td>€11.59</td>
<td>China</td>
<td>For water dosing</td>
</tr>
<tr>
<td>6A PA98 Selflatching Push Button Switches, Red (PCB 125-250V)</td>
<td>4</td>
<td>€3.58</td>
<td>China</td>
<td>Push button (25pcs/box)</td>
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<tr>
<td>LSON XL6099 XL6099E 1 DC-DC Boost Power Module</td>
<td>2</td>
<td>€5.82</td>
<td>China</td>
<td>Voltage regulator (x2)</td>
</tr>
<tr>
<td>Microwave (broken)</td>
<td>1</td>
<td>€3.00</td>
<td>Recycling center</td>
<td>For turning the cup</td>
</tr>
<tr>
<td>Coffee maker</td>
<td>1</td>
<td>€5.00</td>
<td>Recycling center</td>
<td>For water heating</td>
</tr>
<tr>
<td>HVAC products</td>
<td></td>
<td>€49.00</td>
<td>Sigma</td>
<td></td>
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<tr>
<td>Paint</td>
<td>2</td>
<td>€30.00</td>
<td>Sigma</td>
<td></td>
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<tr>
<td>Coffee and milk</td>
<td></td>
<td>€15.00</td>
<td>Sigma</td>
<td></td>
</tr>
<tr>
<td>Building materials (aluminum physique, wiring, etc)</td>
<td></td>
<td>€30.00</td>
<td>Auto University</td>
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<td><strong>Total</strong></td>
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<td><strong>€306.59</strong></td>
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</tr>
</tbody>
</table>

Software

The software for the IoT coffee maker is programmed in C language and an Arduino Mega microcontroller is used for control. The source code can be found in the source.txt file.

source.txt

User instructions

1. To use the IoT coffee maker, user identification is needed. Identification is done with Near Field Communication (NFC).
2. When the user has been identified the prefered beverage is chosen by pressing the red buttons. The first button is for coffee, the second is for hot water and the third one is for cappuccino. The switches above the buttons are used to determine the strength of the beverage, left for normal and right for strong.
3. When the desired beverage has been chosen, the green led under the button will light up and the coffee making process is started. When the beverage is ready, the cup will return to the front of the machine.
4. Every time a beverage has been made, the information is uploaded through the WiFi connection to the Thingspeak web page.

Coffee making process
1. WiFi connection is established for communication to Thingspeak
2. User identification through registered NFC tag (green led blinks if user is found, red if access is denied)
3. When a red button is pressed, the corresponding green led will light up. At the same time the heating element will be turned on.
4. The cup is moved to the right location, depending on what beverage has been chosen. E.g., for coffee the cup will move by the table \( \frac{1}{4} \) of a full rotation.
5. The corresponding feeding screw will be enabled, and the powder will be dispensed into the cup.
6. The cup will move to the next location, to wait for the next powder or for the water.
7. When the water level has reached its limit, the valve will open and let the water into the cup.
8. The cup containing the hot beverage will return back to its starting point, as the table is rotated \( \frac{1}{4} \) of a full rotation.
9. Stats are uploaded through WiFi to Thingspeak

**Coffee process:** NFC Coffee button, heating element on table \( \frac{1}{4} \) rotation coffee screw enabled (2 rotations for normal, 4 rotations for strong) table rotate \( \frac{1}{2} \) rotation water valve will open when correct water level is reached, heater element off table \( \frac{1}{4} \) rotation Stats are uploaded through WiFi to Thingspeak

**Tea process:** NFC Tea button, heating element on table \( \frac{3}{4} \) rotation water valve will open when correct level is reached, heater element off table \( \frac{1}{4} \) rotation Stats are uploaded through WiFi to Thingspeak

**Cappuccino process:** NFC Cappuccino button, heating element on table \( \frac{1}{4} \) rotation coffee screw enabled (2 rotations for normal, 4 rotations for strong) table rotate \( \frac{1}{4} \) rotation milk screw enabled (2 rotations for normal, 4 rotations for strong) water valve will open when correct water level is reached, heater element off table \( \frac{1}{4} \) rotation Stats are uploaded through WiFi to Thingspeak

**Outcome**

![The final device.](image-url)
The final device with stylish paintwork can be seen in Figure 11. The device works as we wanted. Maybe it is a bit slow for outdoor use and supported NFC standards are limited, but otherwise we are very pleasant. The coffee tastes delicious. The device could be used for example in workplaces to monitor who is drinking how many coffees. Also the amount could be limited easily, so noone could drink too much. Other application could be to make paying automatic process via internet.