Intelligent Tea Sensor

In this article you are going to know how teachnology, the team formed by students from department of industrial design and engineering, created Intelligent Tea Sensor which won the Merit Award in 2016 MobileHero competition hold by government and MediaTek, to bring a brand new vision for customers who like to drink tea. I am going to give a deep explanations of Intelligent Tea Sensor as the leader of teachnology.

Introduction

Tea sensor caught our team on eye while looking for the concept of creating a beneficial, revolutionary, and useful human device. There are three main reasons which initiate teachnology to begin the tea sensor project. First of all, identifying the exact concentration level while brewing tea can be hard to measure, sensor should be created to assist users of aware over-brewing in the fast-pace and busy life. Secondly, customers always desire the highest quality of taste including drinking a cup of tea. Leftover tea can be harmful to one's health. At last, the durability of the newly invented device is guaranteed. After several key points are concerned, teachology produces this innovative product. In addition, teachnology designed Its app, an application connected to Intelligent Tea Sensor, which provides the function of saving and sharing the tastes. By sharing tea recipe, people will be able to creating their own community and build up their preferable social network.

UX Design

In this section, focus group is conducted with the participation of our target audience for our device. Methods include: questionnaires, focus group discussion, task analysis, online surveys and persona creation. We target the age of the focus group from 20 to 40, which was often called young adult. From the online surveys and analysis, we knew some main points which customers care.

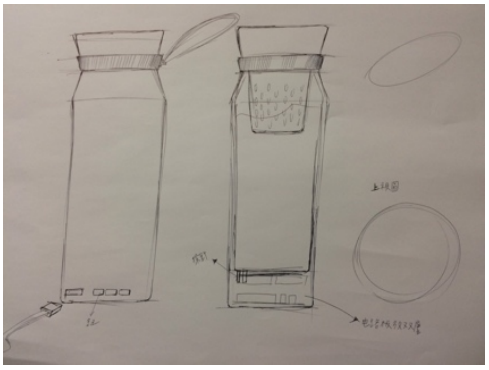
1, Instead of the traditional brewing tools, customers want a device which can assist them to brew a good quality of tea with no efforts.
2, The customers prefer the device is portable. It meets the need of brewing tea everywhere.

Design

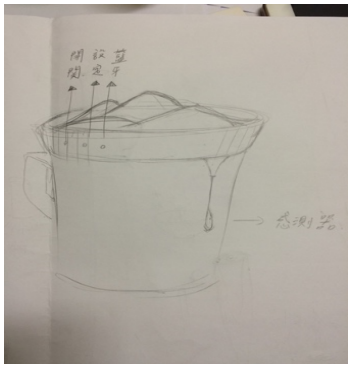
After we considered the objectives which the customer's needs, it is imperative to set the main purpose of producing Intelligent Tea Sensor. The main purpose of making a product is the core of the whole process. It is common for some projects distracted from their initial main purpose when the project is finished. Therefore, the main purpose of Intelligent Tea Sensor is to assist the customers to brewing a high and stable quality of tea which based on their preference.

1, Appearance Design

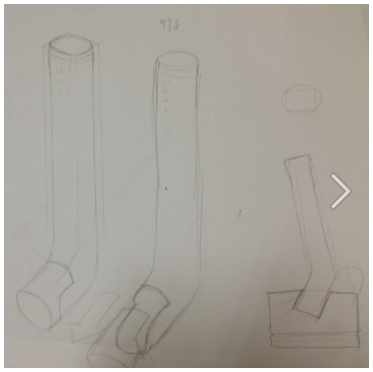
After setting the main objective of our product, we started to draft some designs took the demands of customers into account. We have three main design which solve the customer's needs. However, each has some disadvantages and advantages.



The first draft of Intelligent Tea Sensor is like a bottle. We figure out that the best way to deal with being portable and having a high quality of tea everywhere is to design a device like a bottle. Moreover, it is a container which users do not need to find another container to fill in the water to brewing tea. Nonetheless, a bottle design is not flexible. If the customers want to brewing tea at a cup, this design cannot meet the need. This design is also lacking of be creative and innovative as the result of common design in the market. A bottle can do everything. It is easy t



Second design we have is a lid design. This design settles the problem of different container. Users can use diversity of container to brewing tea. In addition, it is portable too. The lid design seems suitable in many ways. However, it is hard to determine the circumference of the cup. If we cannot determine the circumference of the cup, Intelligent Tea Sensor is unstable when user is brewing the tea.



Therefore, in order to conquer those design issues from the past design, we created this final design, spoon design. This design changes the way we think about brewing tea and meet all the demands which customers need. The design is easy to carry and unlimited to every container. A flashing light indicates what Intelligent Tea Sensor is doing now. A button on the front gives user an easy way to save their taste. Furthermore, instead of traditional tea bag, tea leaf can be included into the design. The customers first fill some tea leaf into the bottom of the Intelligent Tea Sensor. Next, user put Intelligent Tea Sensor into the hot water. When the green flashing light is sparking, it is ready to drink. Several steps turn every user into a tea expert.

2, Interaction Design

Our team wants to provide customers a simple usage of Intelligent Tea Sensor. The instruction below is how we define the usage of Intelligent Tea Sensor. We separate Intelligent Tea Sensor into two modes, saving mode and brewing mode.

• Saving mode

The purpose of saving mode is to save the taste which user likes.

Switching the power on, and the light on the front of Intelligent Tea Sensor lights up blue.

⬇

Pressing the gray button on the front of Intelligent Tea Sensor in 2 seconds, and the light turns from blue to green indicating switching to saving mode.

⬇

Putting tea leaf into the bottom of Intelligent Tea Sensor, and the cup is inserted by hot water and Intelligent Tea Sensor.

⬇

When the tea is the taste you like the most, pressing the gray button on the front of Intelligent Tea Sensor in 2 seconds, and the green light is flashing in 4 times indicating it is saving the taste currently.

⬇

When user connects Intelligent Tea Sensor to Its app, the application saves the taste for user.

• Brewing mode

The purpose of brewing mode is to brewing tea which based on the taste user like.

Switching the power on, and the light on the front of Intelligent Tea Sensor lights up blue.

⬇

Uploading the taste user like from Its app to Intelligent Tea Sensor.

⬇

Putting tea leaf into the bottom of Intelligent Tea Sensor, and when Intelligent Tea Sensor is inserted into the hot water, the light turns from blue to green.

⬇

When green light is flashing in every 2 seconds, it means that the tea based on user’s taste is ready to drink.

3, Engineering

To give the core purpose for customers, teachnology utilized the techniques of TDS, Total Dissolved Solids, and temperature detection to provide accuracy for customers when saving taste and brewing tea. I am going to give a further explanations of engineering technique in three part, theory, hardware and software.

•Theory

TDS, Total Dissolved Solids, is a method used to define tea concentration. In order to measure the tea ingredients in the solution. TDS is the proper way to determine the concentration of the solution whether it is the customer 's preference or not. In reality, we knew that TDS can provide a solution for our goal is due to the theory of water TDS probe. This theory utilize the conductivity of the material in the water to measure what the concentration of this solution is. Therefore, we base on this theory to make further expansion for our tea sensor probe.

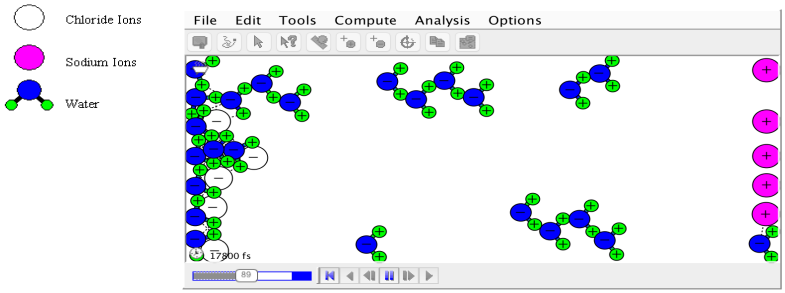
It seems like TDS and conductivity have a close relationship, however, it actually aren't the same thing. TDS is a method to measure the materials in the solution. In fact, it's to weight the residue in the water after the water has evaporated. It has to be done and observed in the lab. And how is it related to conductivity? There is no exact relationship between conductivity as µS/cm and TDS as ppm. Nonetheless, We can estimate TDS levels based on the conductivity of the water since the hydrogen and oxygen molecules of the H_2O carry almost no electrical charge. It has been discovered experimentally that for particular types of water there is an approximate relationship. Taking NACL in the water as a example, to get the ppm of the water with a higher proportion of sodium chloride. We multiply the µS/cm reading by 0.5.

The chart below is the common conversing factor chart.

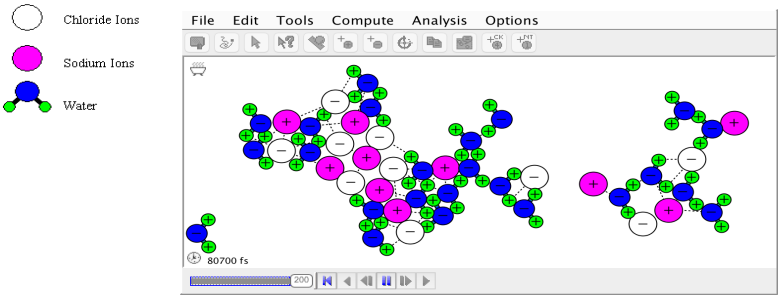
Salt (all 0.01 mol/l)	mg/l *	Conductivity μS/cm	TDS factor - mg/l / Cond
NaCl	584	1156	0.51
CaCl2	1110	2310	0.48
NaHCO3	840	865	0.97

We can see from the chart that in order to get mg/l for a NACL solution, we multiply the conductivity by 0.51 etcetera for each solution.

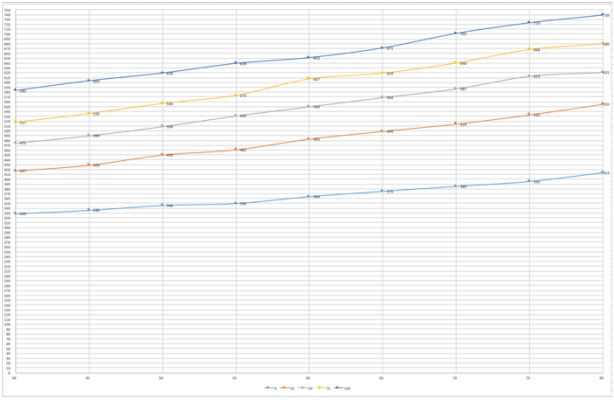
Moreover, if we are going to determine the conductivity of the water by DC current, it is going to occur some big problem.



The figure is a simulation of NACL in water in DC current .
From the figure, we can see that the molecular separate into different part. It is because of the DC current which breaks the force between molecular. Therefore, we have to avoid this situation, otherwise, the measurement won't be accurate. AC current is the alternative way to fix this problem.



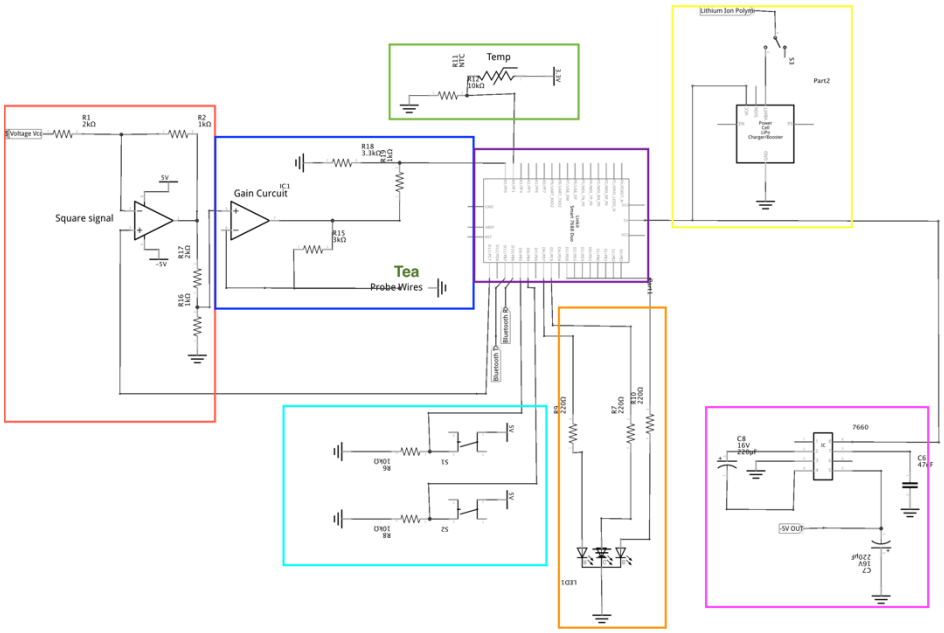
The figure shows that when we make use of AC current for our measurement. The molecular won't break apart. If the frequency of AC current is high enough, molecular don't have enough time to break apart before the opposite current is pulling them. They will look like shaking on their own position.
After I explained the basic knowledge of TDS, I am going to give a explanation of another core knowledge of TDS. The measurement of TDS is various when the temperature is increasing. It is a huge issue because when brewing tea, the temperature of the tea is increasing or decreasing. If we have to measure the TDS of the tea precisely, we need to deal with this temperature issue.



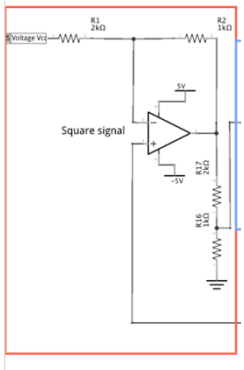
Five color curves in the figure above represent separate consentration of tea. The x-axis presents the temperature. The y-axis presents the measurement of TDS. The figure shows that when the temperature is growing, the measurement of TDS is increasing, too. Therefore, How do we solve

this problem? The answer is temperature compensation. Temperature compensation is a technique which determine the measurement of TDS correctly when temperature is increasing. If we take look at the figure again, we can realize that the slope of the consentration of tea is increasing gradually. The known data in the figure gives a prediction of slope of every consentration through caculation of interpolation method. Combining the technique of TDS and temperature compensation gives a method to determine the taste accurately.

•Hardware



Based on TDS theory, we designed the complete schematic of Intelligent Tea Sensor above. I am going to elaborate the schematic in color blocks below.

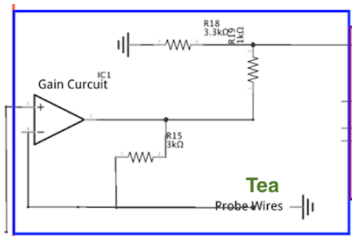


▲ Red block

As I mentioned above, it is necessary to use AC current for measurement. The red block is the circuit which offsets the square ware generated by 7688 Duo, open development board produced by MediaTek. 7688 Duo creates a PWM wave from 0V to 3.3V. In order to generate AC current, we design the schematic of using operational amplifier to achieve the goal of offset. The figure on the left shows the design of the schematic. We make use of the KCL theory, Kirchhoff's current law, to calculate the output voltage. Due to virtual ground between negative and positive pin, we can conclude that V+ equals V-. In addition, the current passed through resistance R1 remains the same as the current passed through resistance R2. Therefore, we can determine the output voltage by the formula below.

$$(Vcc - V+) / R1 = (V+ - Vo) / R2$$

,which Vo represents output voltage.
In this case, Vcc equals 5V. V+ equals square wave from 0V to 3.3V. R1 equals 2k ohm. R2 equals 1k ohm. After solving this formula, Vo equals a square wave from 2.5V to -2.5V.

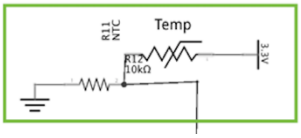


Blue block

After offsetting the PWM wave, our next step is to determine the output voltage of operational amplifier when the concentration of tea is changing. The formula of the circuit on the left can be shown as below.

$$Vo = V+ * (1 + R15/Tea)$$

In this case, V+ equals a square wave from 0.8V to -0.8V as the result of a square wave from 2.5V to -2.5V passing through resistance voltage divider. R15 equals 3k ohm. The function of the later part of resistance voltage divider is to match the range of analogRead in 7688 Duo which is range from 0 to 3.3V. The output voltage of resistance voltage divider is connected to pin A5 on 7688 Duo for the purpose of temperature compensation.

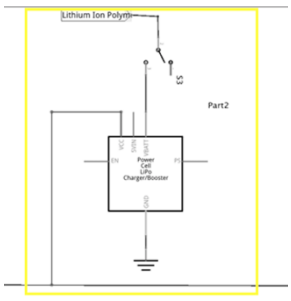


Green block

This schematic at the left presents the temperature detection by thermistor in series with 10k ohm. For more information, you can have a look at this website.

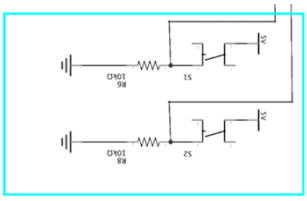
Purple block

This is the open development board we are using for Intelligent Tea Senor. 7688 Duo provides many functions for many purpose. We make good use of 7688 Duo to solve the temperature compensation issue and to deal with our whole software operation.



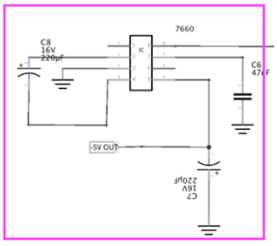
Yellow block

This schematic shows that where the power source of Intelligent Tea Sensor comes from. We use 500mAh Polymer Lithium Ion Battery to power all our system. We also design a USB charger which user can plugin USB to charge Intelligent Tea Sensor.



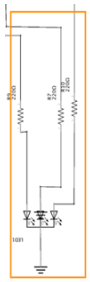
▲ Cyan block

Gray button for the purpose of saving taste and Bluetooth button for the purpose of connecting to Intelligent Tea Sensor are designed in the schematic.



▲ Magenta block

This 7660 IC circuit is the function of producing negative voltage for powering operational amplifier. Pin 8 is inserted with 5V. Negative 5V is output from pin 6.



▲ Orange lock

We use RGB led to indicate diversity of color. The schematic at the left is a RGB led in series with 220 ohm.

•Software

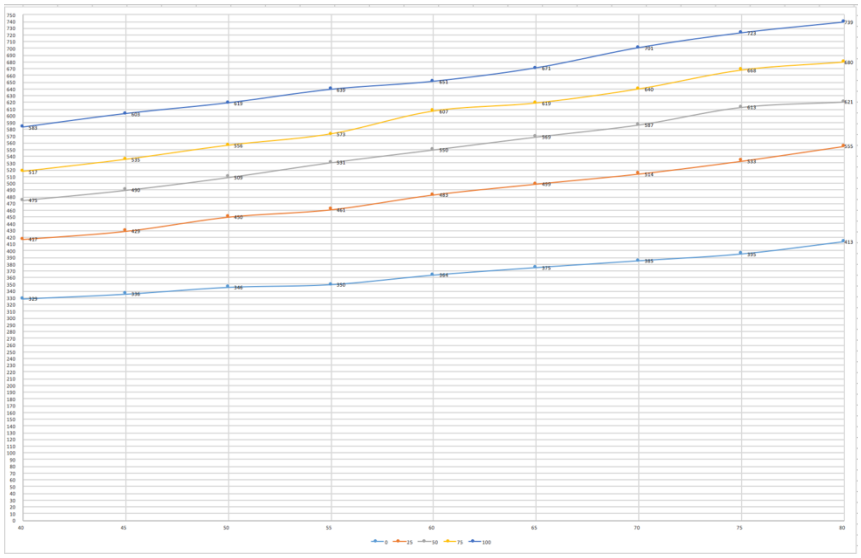
In this section I am going to account for the whole software operation of Intelligent Tea Sensor. First I will explain how to implement temperature compensation, the whole operating code for 7688 Duo, and Its App(under construction).

▲ temperature compensation

To determine the property of the slope, known data must be provided before the code started.

measure unit: analogRead	0	25	50	75	100
80	413	555	621	680	739
75	395	533	613	668	723
70	385	514	587	640	701
65	375	499	569	619	671
60	364	483	550	607	651
55	350	461	531	573	639
50	346	450	509	556	619
45	336	429	490	535	603
40	329	417	475	517	583

The x-axis of the figure above presents the concentration of the tea in percentage. For instance, 0 represents 0% of tea.(in other words, it is water) 25 represents 25% of tea. The y-axis presents the temperature ranged from 40 to 80 degrees. Those measurement is measured by the circuit I mention above. After having those data, we can move forward to the code of temperature compensation.



The description of the code
Step 1: Recording the taste of temperature and TDS.

Step 2: Determining which the temperature interval does the current temperature fall in. (<40C,40C~50C,50C~60C,60C~70C,70C~80C,80C>)

Step 3: Determining which the concentration interval does the current TDS fall in. (<0%, 0%~25%, 25%~50%, 50%~75%, 75%~100%,100%>)

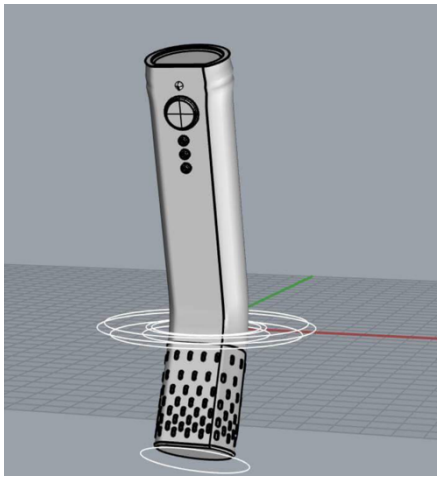
Step 4: Making use of interpolation method to calculate the slope of point (current temperature, current TDS) in the temperature interval and concentration interval which the point falls in.

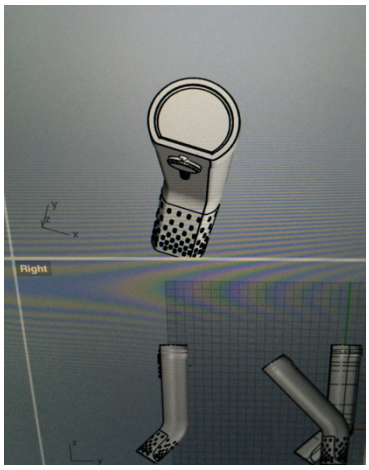
Step 5: Making use of interpolation method to calculate the slope in different temperature intervals.

Step 6: When current temperature is known, theoretical measurement of Recorded TDS in that current temperature can be determined.

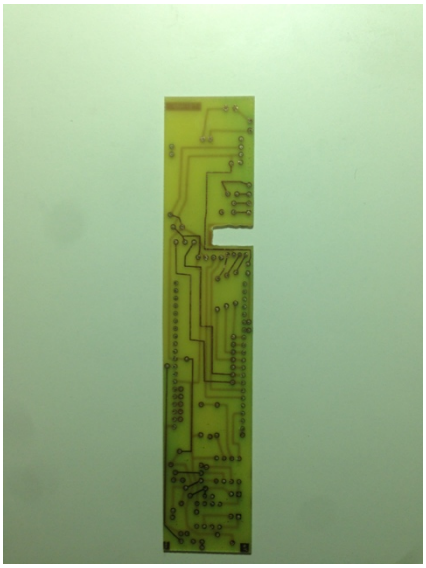
Test

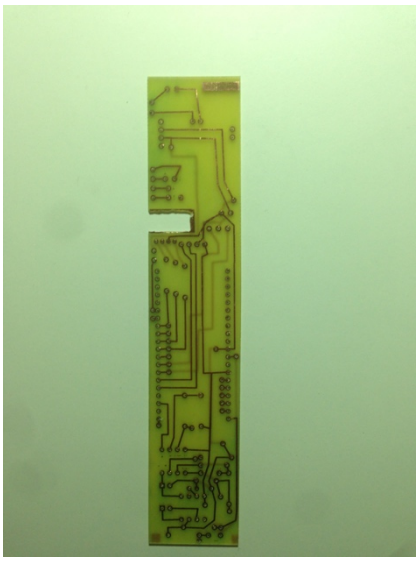
After user research and design, the next process is testing our design. Due to limited resources, we did not repeat the process of design and testing. In exterior design, we start to create the appearance of Intelligent Tea Sensor with 3D print. We create a model through Rhino, a design software for 3D print.





In hardware part, we begin to make a printed circuit board. First, we make good use of PCB software to design layout of the schematic. The second step is photo process. There are three main steps in photo process, which are exposure, developing and etching. When our layout was finished, we are going to expose the layout on the board by photo exposure machine. After the layout has been exposed to the board, we are moving to the next step, developing, which is the step for developing the layout. When developing, we will need to move the board into the developer back and forward for developing the circuit. After developing, the pure water is needed to wash the board in order to make the board clean. The third step is etching. We will put our board into a container filled with FeCl2. Finally, we have finished a printed circuit board. The final step is to solder the components on the board.





After combining exterior design and printed circuit board, it is ready to test that whether we meet the main purpose of Intelligent Tea Sensor for users. After several users have used, we organize the feedback as follow.

1, Maybe the technique which was used in Intelligent Tea Sensor can determine the taste accurately. However, can cup really brew a good tea?

2, The design is a little bit too big. It is not easy for users to take.

3, Intelligent Tea Sensor is necessary to fill in tea leaf before brewing tea. However, in many situations users do not bring their tea leaf with them when they are not at home.

4, The charging port is design as USB port which is not as popular as Micro USB.

In order to increase popularity of Intelligent Tea Sensor, we exhibit our Intelligent Tea Sensor at New Taipei Mini Maker Faire, which is an exhibition for startup to market their products. In addition, thanks to techbang, the Chinese blog, for reporting our product. Click here to see our report.

Summary

In order to make Intelligent Tea Sensor, it takes about one years from design to launch. The product we made right now is actually a prototype of our real product. However, due to the prototype we made, we gather some useful feedback from users. In the future, we are going to make good use of those feedback to create a well-designed Intelligent Tea Sensor which provides users a more usable and efficient design.