Introducing Classroom Cloudlet: a mobile, tangible, and transparent approach to Internet of Things education

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Providing a good understanding to children and educators on the Internet of Things (IoT) means to make them aware about where the data goes, how it is stored, and what it is stored on. In this perspective many commercial IoT systems have been shown to be unsuitable for this purpose especially when used in an educational context. They do not create user centric data collection opportunities; many of their IoT sensors that send data offsite to an online cloud create gaps in knowledge; the sensors themselves are not transparent: it's not clear what data they are collecting and how, and they are not easily compatible with school networks. Classroom Cloudlet addresses this issue. This demonstration presents an end-to-end IoT like system that includes a mobile, tangible, and transparent classroom cloudlet. Classroom Cloudlet aims to allow data from multiple devices to be easily shared, collated and analysed without using the Internet, but while still educating students about IoT and cloud concepts. The classroom cloudlet aims to be a physical representation of a cloud in an IoT system; visualise the movement of data around the system; provide a web front-end for students to view and create custom visualisations of their data. Classroom Cloudlet aims to gives the educator and the children full control and ownership of their data.

CCS CONCEPTS Applied computing~Education~Interactive learning environments•Applied computing~Education~Collaborative learning•Computer systems organization~Embedded and cyber-physical systems~Sensors and actuators

Additional Keywords and Phrases: Internet of Things, Cloud

1 Introduction

The Internet of Things (IoT) describes an interconnected network of physical objects including sensors that exchange data with other devices over the Internet or any network [1] . The Internet of Things is utilised in many industries for example medical care: health monitoring devices to enable emergency notification systems and

home automation: smart doorbells that detect and record movement. As these new technologies grow in numbers and use, it's important we educate future generations on what they are, what they do, how they work and their associated risks. The IoT is an important part of everyday life. What the IoT is and how it works is an important area for students to explore. Important questions like where the data goes, understanding how it is stored, what it is stored on, need to be answered by both educators and students. Using the IoTs to gather, disseminate and display information gives educators cross curricular opportunities. Physical Computing is the ideal technology to enable learning of the IoT due to its technological similarity to IoT equipment.

Our aims are to create an easy to setup end-to-end IoT system for education that includes a classroom cloudlet; create custom human centric input devices; create a cloudlet that can receive, sculpt and output data and; create multiple opportunities for transparency when dealing with data and technology.

2 Related work

This project leverages on a previous UK national project, Energy in Schools [2], that has the purpose to help multiple schools to create their own Internet of Things to measure environmental data in their buildings. Children programmed some of the sensors to gather data around their schools. This data was sent online to a custom data store and shared with the school's administrative staff as part of an initiative to reduce energy spending in schools. There were technical problems with setting up some of the commercial IoT sensors; an app was needed to set them up, they needed constant internet access to work and had to be given special access to the Internet via the school's network. The data storage was created and managed by outside agencies. The IoT was difficult to create and maintain without external export help, and even then, they can present multiple problems regarding security and privacy of data when it leaves the school. Other national projects have built IoTs with sensors for schools [3], again a lot of infrastructure is managed outside of the school, storing their data on the Internet.

In a survey of eight local and regional projects that involve data gathering and schools we gathered information about how the projects were run under the topics: data gathering, data storage and outputs. No one project had a seamless error-free journey from students gathering data to analysing it. In one case an educator was manually typing up the students' results so the students could analyse them later. In another, all the data for the project was stored on the individual sensors and again needed manual extraction. Our research aims to alleviate these difficulties. This demo describes the input device and cloudlet for our IoT system.

3 The classroom cloudlet system

The Classroom Cloudlet when gathering the data, we want students to code their own sensors that are visible and tangible to them. In the demo we are initially trialing with the BBC micro:bit as it enables a low friction, transparent way for children and teachers to engage. In the future we also envisage supporting a wider range of devices. The BBC micro:bit is a programmable piece of hardware, it has several built in sensors like its temperature sensor, light sensor, accelerometer, and magnetometer as well as a grid of 5 by 5 LED lights that acts as a small screen. Over 7 million micro:bits have been distributed in more than 50 countries around the world [4]. Many countries have updated their national curriculum to use micro:bit as part of their computing lessons. There is a well-developed eco system around the micro:bit including programming languages, add-on modules and learning resources. We feel the micro:bit is perfectly placed to act as the IoT sensor in our system given its number of sensors, ease of use and availability in schools.

The purpose of the Classroom Cloudlet is to make children aware what data is being gathered and how. If a sensor needs calibration; how is it done, who does it. Every student should know the answers to these questions before using a sensor. Our hypothesis is that giving children the opportunity to create and code their own sensors will create a sense of ownership of the data this will lead to improve a better understanding on how sensors work. The cloudlet accepts data from sensors in its environment via low-power wireless network interfaces. The system is made of two main components: the data gathering element and the data visualization element.

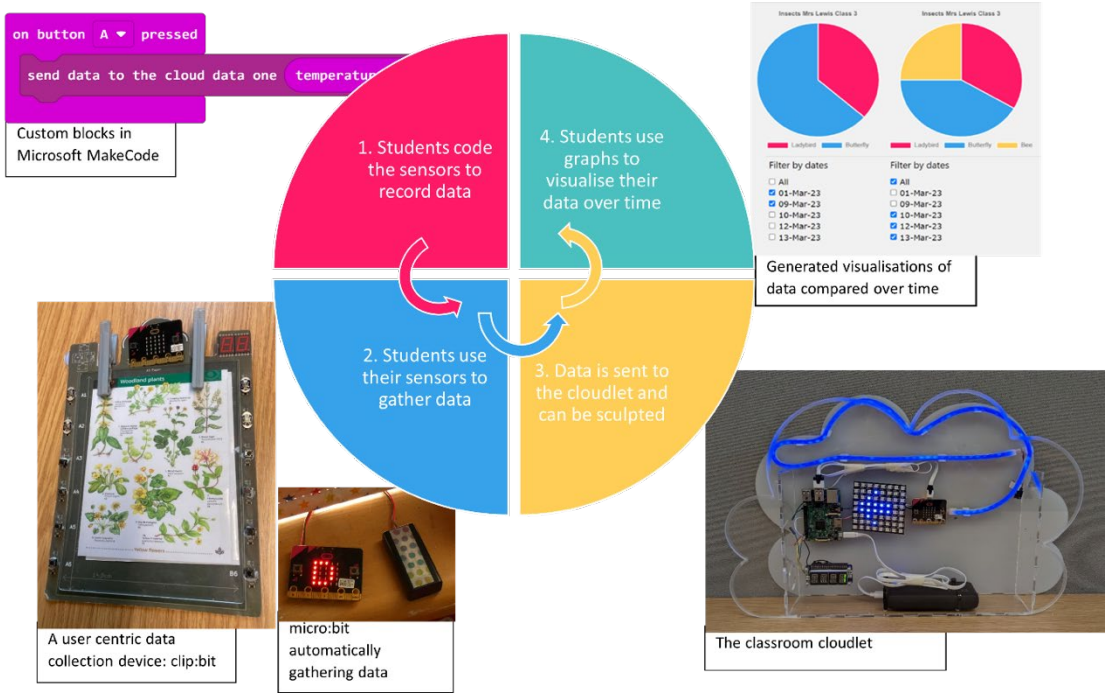

Figure 1 The journey of our IoT system

3.1 Data gathering

There are two distinct classifications of data collection we want to capture in the classroom cloudlet. The first is through the automated sensing from devices like the micro:bit that can be left in classrooms, added to doors, plants (see Figure 2C micro:bit soil sensor), etc. It has been noted there is a danger collecting data using automatic sensors will result in a drop in engagement in motivation [3]. The second classification is more hands on, done by the children using a device. For this we have developed a custom micro:bit add-on board called the Clip:bit to support the second human-in-the-loop data collection.

The Clip:bit was developed by educators working with schools on multiple projects that involved surveying. One example is recording the biodiversity in the local area using biodiversity logbooks [5]. The logbooks show a picture of a plant or animal, and students use a tally system to record the number they see in each area on a given day. The Clip:bit was designed using past experiences of gathering data outdoors with children, feedback from designers and classroom teachers. Teachers wanted a reliable piece of technology that allows students to record multiple data points easily. It needed to be durable, small, and easy to use with handouts such as the logbooks. A paper prototype was created and iterated on (see Figure 2A Clip:bit paper prototype). The first electronic prototype of the Clip:bit is a solid piece of laminate in the shape of a clipboard (see Figure 2B Clip:bit digital render). It has two 7-segment LED displays, 12 buttons and a port for the micro:bit to be mounted. It is powered by 1.5V alkaline batteries on the back.

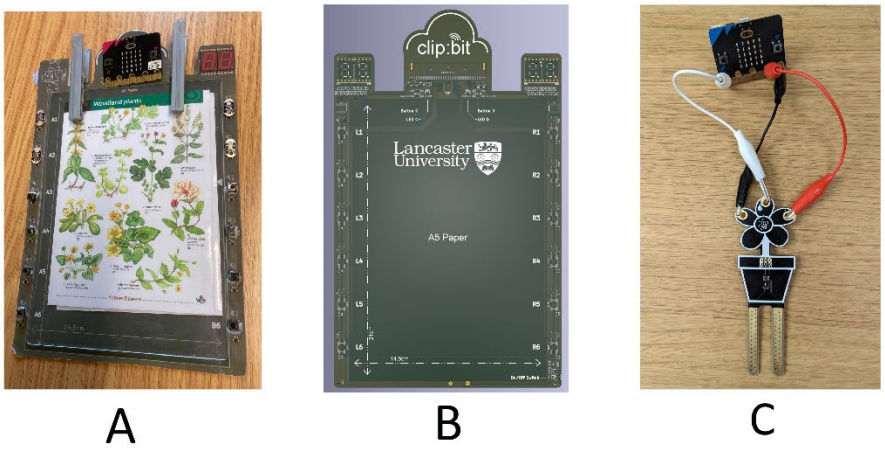

Figure 2 Clip:bit paper prototype (A), clip:bit digital render (B) and the micro:bit soil sensor (C)

The Clip:bit allows students to gather data specific to their environments. It aims to allow students to change the behaviour of it, again providing a layer of transparency to data gathering. Students can see what they're recording on the logbooks, on the 7-segment display and know how and where the data is recorded.

The Clip:bit will make use of the micro:bit's data logger, a persistent data storage tool. This allows the students to store their data on the micro:bit and retrieve it even if the micro:bit loses power. The data can be stored in the data logger then sent over radio to the cloudlet. This ensures the students have access to their own data for smaller analysis and creates a backup of the data in case the cloudlet is out of range of the micro:bit.

3.2 Data visualization

A cloudlet was initially defined as a "trusted, resource-rich computer… that's well connected to the Internet and available for us by nearby mobile devices" [6]. A cloudlet resembles a data center in a box, typically it contains cache copies of data. Our cloudlet pulls from these original definitions, this first prototype is not directly connected to the Internet nor is it a cache but we envisage a network of these devices which provide mutual back-ups to each other, connected through the school intranet. Our definition also pulls from the other definition of a cloudlet: a mini cloud [7]. An IoT cloud is a network that supports IoT devices and applications. This includes the underlying infrastructure, servers, and storage, needed for real-time operations and processing [8].

Our cloudlet is a tangible representation of a "cloud." It has the same functions of a cloud in a typical IOT system. The students can both see and touch the cloudlet. This makes it less abstract and easier to understand the principles on which the IoT operate. Using the cloudlet, educators can physically point to where the data goes from the sensors and where it is stored for later analysis. Not only is the cloudlet visible, but it is transparent in two ways. All the pieces of the cloudlet are visible to the students. They can see the computer, the micro:bit and devices in the cloud that visualize what is happening. The operation of the cloudlet is also made transparent to the audience. When data arrives from the different types of micro:bit sensors inside the cloudlet light up. A grid of LEDs animates an arrow going from the edge of the cloud to the computer in the centre. The cloudlet also has a 7-digit display that displays the number of micro:bits in range. See Figure 3 The classroom cloudlet. The cloudlet uses a micro:bit to gather data from the micro:bit sensors and a raspberry pi as its main computer and data storage. Students and educators can connect to the cloud to view the data gathered from the sensors. The cloudlet can create a Wi-Fi hotspot that any computer or device with Wi-Fi can connect to. In future versions we envisage access to the cloudlet through the school's intranet.

An important difference between our cloudlet and an IoT cloud is the data in our cloudlet is not on the Internet. The data does not leave the school. This feature raises many questions about data security, privacy and ethics in IoT systems. Again, questions educators and students need to answer before using a cloudlet.

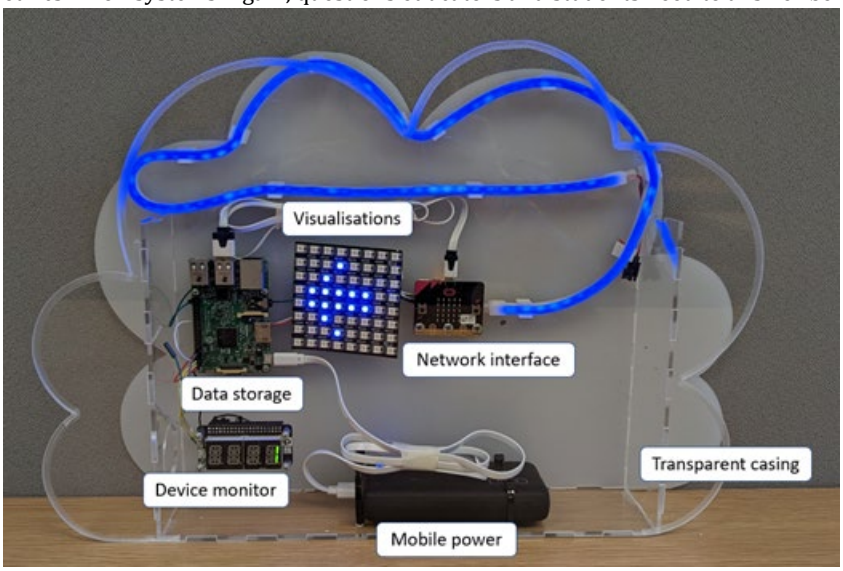

Figure 3 The classroom cloudlet

3.3 Data sculpting and analysis

Once the data is inside the cloudlet, teachers and students can begin a process we call "data sculpting." Educators can sculpt their data for their unique situations. One way of sculpting the data that commercial IoT sensors do not easily allow is fixing the data, e.g., removing multiple entries if a student accidentally pressed a button for too long. Instead of discarding all that student's data, multiple fast entries can be detected and deleted. Another scenario for sculpting is the aggregation of data sets, e.g., fifteen devices were recording the number of insects in their area, each record is recorded as Button 1:Number. An educator can use the cloudlet to aggregate Button1 and rename the field to the insect it represents. This will ensure the outputs are easy to read and analyse.

For analysis children and educators can connect to the cloudlet over a Wi-Fi hotspot or through the school intranet into a web front end. The website contains all the projects and data connected to them. Educators will have admin rights to edit the data while students can view and create graphs based on their data. Figure 4 The cloudlet's web front end analysing displays two pie charts for a classroom project around insects. The charts are comparing the insects counted on one date range to another. Underneath is the raw data gathered in the project. The webpage loads dynamically. Individual datasets can be toggled on and off using their label in the legend. The graphs animate as they change.

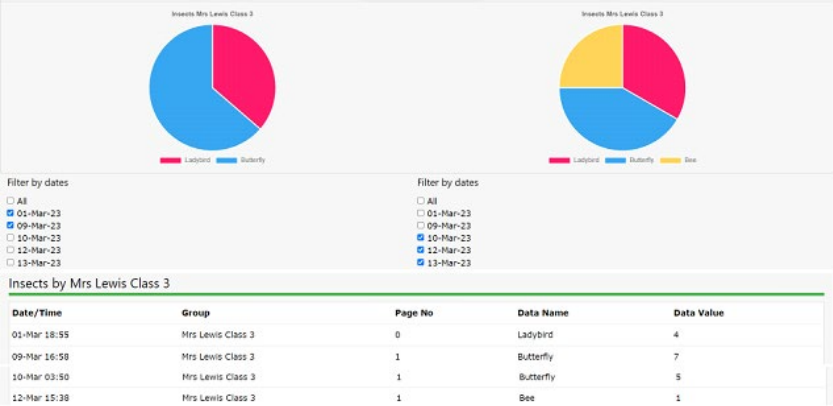

Figure 4 The cloudlet's web front end analysing data.

4 Future work

This demo is of the Clip:bit and other micro:bit sensors sending data to a cloudlet; and of the cloudlet storing, sculpting and displaying that data as digital graphs. The cloudlet has yet to be fully tested in a school environment. Setup, install and regular use needs to be observed over a period of time using both the Clip:bit, the standard micro:bit sensors and the cloudlet. We have several local projects lined up to test the system but are also open to work with other researchers to implement this project and research its impact on education. The project is not limited to the UK: the micro:bit has been sold in over 50 countries and appears in many school curriculums already.

We plan to gain educator feedback on the cloudlet particularly its web front end and iterate its design and function. We consider that this project can be implemented over different age ranges over different schools.

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