Cardiff University School of Computer Science

And Informatics

A requirements analysis with feasibility study for an abstract design of a pervasive kitchen designed for a student demographic.

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Credits:	40

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Abstract

With approximately 1.4 million full-time students and 400,000 part time students in the UK in 2012/2013 there is a large market for student letting companies and private landlords.[1] With such a large market, this will inevitably beget competition. With technology advancing rapidly and being introduced more and more into homes, coupled with hundreds of thousands of new students arriving at universities across the UK every year, it is only a matter of time before student houses start keeping pace with the technological progress of regular houses. Moore's law states that every two years the number of transistors in a microchip doubles. Computing and information systems are becoming smaller and smaller and everyday homes are ever increasingly enjoying the benefits embedded computer systems. If the student houses start falling too far behind standards of living expected in the future they will find themselves losing competitively in the market.

[1] HESA - Higher Education Statistics Agency - Free Online Statistics - Students & qualifiers. 2014. *HESA - Higher Education Statistics Agency - Free Online Statistics - Students & qualifiers*. [ONLINE] Available at:http://www.hesa.ac.uk/content/view/1897/239/. [Accessed 30 April 2014].

Purpose

The purpose of this project is to outline and demonstrate an abstract, conceptual design of a pervasive kitchen in student homes. This will be done through the use of requirements, coupled with an investigation into new and emerging technology and other factors that would have an effect on the completion of this project.

Scope

This project will be tackled looking at the early stages of an iterative/spiral system design method developed by Winston W Royce, later labelled the 'Waterfall Method'.

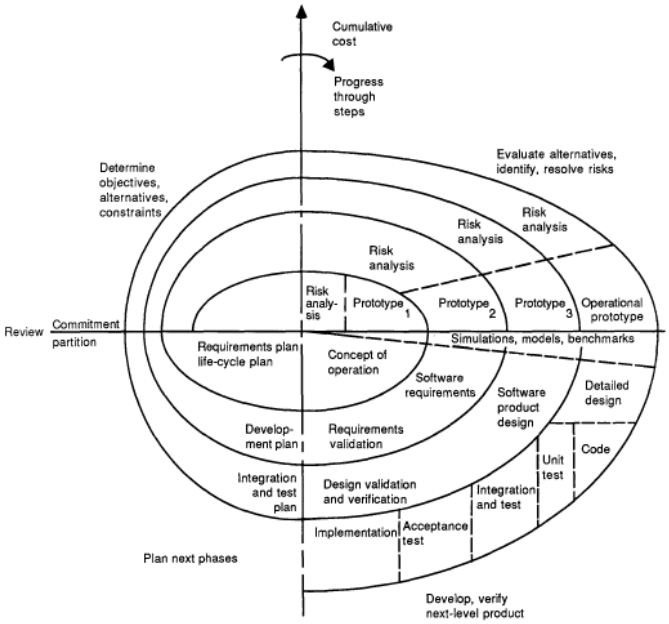

Figure 1 – Spiral model of the software process[2]

As you can see from *Figure 1,* Requirements are visited multiple times on the 'spiral'. The subsequent investigation will mainly focus on the first iteration through requirements section – researching and designing the *functional requirements.* Although it is likely that the project will progress slightly further and some non-functional requirements will be touched upon with the beginnings of a second iteration of the spiral.

The project is specific to student kitchens due to the large potential sample size available. With this project being undertaken in the heart of Cardiff, research can be easily performed and reach a large number of different students. Different demographics also have very different needs when it comes to kitchen areas so it was deemed it important to focus on one group in order to tackle the problems in a kitchen with better precision.

[2] Barry W. Boehm, 1988. *A Spiral Model of Software Development and Enhancement*. . [ONLINE] Available at: http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=59 pp. 64 [Accessed 30 April 2014].

1. Method

In solving this problem extensive investigation will be undertaken. Both qualitative and quantitative data will be collected to discover, solve and analyse the problems and solutions of current student kitchens.

In order to complete the initial research, exploration into the different methods of eliciting (drawing out or evoking) requirements to solve these problems will be completed. Once the preliminary research has been completed and analysed, a primary set of requirements will be elicited.

Follow-up research will then be performed to analyse and obtain feedback on the primary set of requirements written.

The analysis on the initial set of requirements will aim to provide feedback to; determine the extent of the importance of each requirement, show if any requirements have been missed out and if any problems have not been solved. This research will be opposite in nature to the initial research. For example, if the initial research were to provide quantitative results, then the follow up research would provide qualitative results by using a method designed to obtain such results, like a focus group.

To take this further, extensive research will be completed on current and emerging technologies that will allow the system to be designed and implemented. This will involve looking at research papers outlining the theoretical possibilities and capabilities of different emerging technologies while looking at electronics companies and what they are currently doing to develop relevant technology and hardware that is readily available on the market. With the results from this, a completed requirement specification that addresses all the problems found in a student kitchen will be created. Standards for requirements by recognised bodies (ISO, IEEE) will be followed, to provide a high quality requirements analysis.

This requirements analysis will then be coupled with a feasibility analysis that will study the factors that will affect the production of pervasive systems.

1.1 Workflow and Deliverables

With the above method in mind the following deliverables will be created. Its order will also demonstrate the workflow of the project.

1. Introduction
2. Primary Research
3. Elicitation Of Requirements
4. Follow-up Research
5. Emerging Technology Investigation
6. Requirements Specification
7. Requirement Specification Analysis
8. Feasibility Analysis
9. Future Work & Conclusion

1.2 External Groups Used

As the problem is beginning to get explored it is important to understand and address the groups who will have an influence on any stage of the project, from the initial research stage to the final rollout stages of production of the system.

1.2.1 Stakeholders

PRINCE2 defines a stakeholder as:

"Stakeholders are people, groups or organisations that have an interest in or might be affected by the outcome of a project."[3]

The first step of any requirements analysis is to identify the key stakeholders of any proposed system. Understanding stakeholders is vital to any project. As they have an interest in a project these are the people who stand to lose or gain from it. It is important to identify and include these groups for the following reasons:[4]

- Puts more ideas on the table

[3]PRINCE2. *How to Identify stakeholders* [ONLINE] Available at:http://www.prince2.com/blog/how-identify-stakeholders. [Accessed 30 April 2014].
[4] Community Tool Box. *Section 8. Identifying and Analyzing Stakeholders and Their Interests*. [ONLINE] Available at: http://ctb.ku.edu/en/table-of-contents/participation/encouraging-involvement/identify-stakeholders/main. [Accessed 30 April 2014].

    - The more stakeholders involved the higher the accuracy and precision of the research carried out
- Provides a wider perspective
    - If stakeholders are not properly identified they can easily become forgotten. This will lead to a lack of consideration to their needs and can result in pressure and opposition
- Increases credibility of the project
    - A closed minded approach can result in an opinion of either bias or incompetence and will prevent people from working to provide a fair and transparent system.
- Research can be relevant and correct.
    - With no explicitly highlighted stakeholder group feedback from external sources can be irrelevant, incorrect and unhelpful.

The next stage is to identify the stakeholders of the system.[5] These have been grouped into three different categories:

1. **Stakeholders within a university**.

    - **Students**.

      These are the most important stakeholders in this project. They are the ones who are the most affected by the proposed system, being the target demographic. If the proposed system gets created, these will be the users of the system on a daily basis. This is the only demographic that can accurately highlight problems in current student kitchens as these are the only users.
    - **The University**.

      It can be argued that the university have a direct stake in the quality of the student houses occupied by their students. Student experience is greatly affected by living conditions and a greater student experience will directly affect results of the university in the National Student Survey, improving the competitiveness of the establishment.

[5] Sharp, H. et al. *Stakeholder Identification in the Requirements Engineering Process, University College London:* [ONLINE] Avaliable at: http://eprints.ucl.ac.uk/744/1/1.7_stake.pdf. [Accessed 30 April 2014]

2. **Real estate personnel for a university's student population.**

    - **Landlords**.

      These are important stakeholders. These will be the people responsible for implementing the system in their houses should they choose to. Essentially they are the 'customers'. It is likely the will have to perform a cost/benefit analysis on the proposed system to determine if it is a sound investment.
    - **Letting Agents.**

      These are the people who rent the properties for the landlords. They have a direct interest in this project as it can affect the overall saleability of their stock (student houses) by gaining or ignoring the competitive advantage this system offers.

3. **External.**

    - **Technology companies**.

      If the project is completed, these will be the stakeholders responsible for providing hardware and software for the system, or adapting the system design for other demographics.
    - **Developers**

      These roles could include analysts, programmers, testers, project managers and so on. Should the project be continued, these will be the personnel involved with continuing the project to completion. The developers are an important stakeholder group to consider while writing a report such as this because they are the ones who will be reading it to continue the work.

My investigation results will come from the Students. To improve processes within a kitchen and solve their issues, these issues must be highlighted first. Students are the only stakeholders with first hand primary knowledge of these, where the other stakeholders would only be speculating. There is a vast demographic readily available so the research results will be an accurate representation of the opinions of students. It is important to

remember that there is no silver bullet for a problem like this; every student will have a slightly different opinion and need. The aim is to find a solution that best fits everyone. The design inevitably will not completely satisfy everybody's problems, as everybody's problems are different. The aim is to create a requirements analysis for a system that improves and eases processes for every student while keeping in mind that some problems are impossible to completely eradicate, they can only be improved.

1.2.2 Sample population

Sample population are a vital part of the data and information gathering process. As it is obviously extremely unrealistic to expect to obtain research from every member of a population, it is necessary to choose a sample that will most accurately represent the views of the population as a whole. Research can then be carried out on this sample.

It is implausible to use all ~1.8 million students in the UK as a sample population as it will be extremely difficult to collect enough research data to accurately represent the views and opinions of the majority of students. The Cathay's borough of Cardiff will be used as the population size. This is the largest concentrated student area in Cardiff, and as this project is being completed in Cardiff, this population of students is easily accessible to be the subject of research. According to the 2011 Census, Cathay's has an estimated population of 10,623 20-24 year olds. It has a high population density, boasting 244% of the Cardiff average.[6] This suggests that the vast majority of these 10,623 are students. There are other boroughs in Cardiff that contain a small amount of students and this will compensate for the small percentage of 20-24 year olds in Cathay's who are not students, meaning the original 10,623 is an acceptable population size.

After the actors and stakeholders have been identified, according to the IEEE Computer Society the next step is to elicit requirements[7].

Elicitation of Requirements is defined as "the practice of collecting the requirements of a system from users, customers and other stakeholders."[8]

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[6] UK Census. 2011. 2011 *Census - Population & Occupied Household Spaces – Cathays.* Cardiff Research Centre.
[7] IEEE Computer Society, 'SWEBOK' (2004) *Guide to the Software Engineering Body of Knowledge v3.0. Journal*. [ONLINE]. Avaliable at: http://www.computer.org/portal/web/swebok/swebokv3. pp. 1-5 [Accessed 30 April 2014].

2. Elicitation of requirements

Before research is started it is important to explore the different methods of collating relevant data and information that will allow requirements to be elicited. The following is an exploration into the different types of primary research used which will allow a decision to be made on the method of eliciting an initial set of requirements. There are five basic methods of performing market research to elicit requirements.[9]

2.1 Elicitation Methods

2.1.1 Survey

A survey involves drawing representative and unbiased opinions from a subject group. This is done by asking a number of people in a population a number of questions, over the phone, face to face, or through a questionnaire which can be administered online, through social media, email or by physical hand-outs to people.

A survey is a paramount tool when conducting any primary research due to its inexpensive nature and ability to reach a large number of the population quickly. It offers direct control over the groups of users answering its questions, and the questions themselves can easily be tailored to a specific demographic or stakeholder group. It is the easiest way of compiling quantitative data as results can easily be visualised through the use of graphs and charts. They can quickly be compared to previous research to easily measure a change in results to assess the success of a project. A disadvantage of a survey is that some responses will inevitably be unusable due to recipients not answering truthfully, or deliberately soiling their results.

2.1.2 Focus Groups

Focus groups involve collecting individuals from a demographic and observing the discussions and communications on a topic and extracting information from their ideas and arguments as they arrive at a conclusion.[10] Focus groups are led by a moderator whose role it is to facilitate the interaction between members of a group to keep the correct focus of

[8] Ramos Rowel and Kurts Alfeche, John Wiley and Sons. 1997. Requirements Engineering - A good practice guide)

[9] 2014. *The Five Basic Methods of Market Research.* [ONLINE] Available at: http://www.allbusiness.com/marketing/market-research/1287-1.html. Last accessed 30 April 2014.

[10] Gibbs, A, 1997. Focus Groups . *Social Research Update, University of Surrey*, 19, pp 1

the discussion while obtaining qualitative information on different opinions and perspective of a topic.

It is a useful method of information collating as it can offer a vast array of opinions and perspectives, however it is time-consuming and can only target a very small percentage of a target population. It can also lead to a 'groupthink' mentality where members of the group 'synchronize' opinions.[11] This can mean discussions can be led by opinionated individuals, narrowing the diversity of perspectives and ultimately, the accuracy of a conclusion.

2.1.3 Personal interviews

Like Focus Groups, personal interviews are facilitated by a moderator asking open ended questions to an interviewee. As it is usually a one-on-one it will only get a single perspective of a problem. The result, although providing valuable insight, is subjective and may not accurately represent the views of a population. Interviews are time consuming and difficult to get an acceptable amount of people to participate without incentive.

2.1.4 Observation

Sometimes, responses to interviews or surveys can contradict an individual's actual behaviour, they may not be able to articulate their points effectively, or they may even forget arguments that can potentially prove valuable insights. An observation is taking information about a problem by witnessing the participant's behaviour in their 'natural habitat'. It is a useful technique for recognising common real world issues and problems and gives an accurate picture of the scenario you are trying to assess. Although it is an accurate tool for identifying problems in the scenario, it does have a few drawbacks. It is extremely difficult to gather enough information for a thorough investigation. There is no accurate representation of all year round issues or patterns unless you observe all year round – impossible with the nature of this project. It is also intrusive to the participant, having somebody watching and note-taking an aspect of everyday life. It is unpractical with the project to gather enough data from enough to make the results from the sample group accurate and representative of the target population as a whole.

[11] Janis, I. L. (1982b). *Groupthink* (2nd ed.). Boston: Houghton Mifflin

2.1.5 Field trials

Field trials are placing a product or service into the market under real life conditions to test its saleability. This kind of research is not applicable to this project due to its infancy on the development lifecycle. We, as a population, are a long way away from having a fully pervasive kitchen available within a market.

2.2 Appropriate Solution

The technique most relevant, with the constraints of this project, to understand the key stakeholders' needs and issues, is a survey. This will enable best elicitation of an initial set of requirements and identify areas where further research is necessary to find technology to enable implementation of the elicited requirements. With the time constraints of this project, a survey is extremely applicable due to the ability to quickly disperse and collect a large amount of data to and from a population.[12]

Confidence interval is defined as 'The percentage of all possible samples that can be expected to include a true population parameter"[13]

Margin of error is defined as "The maximum expected difference between the true population parameter and a sample estimate of that parameter"[14]

To have a meaning, Margin of Error needs to be qualified by a Confidence Interval.

For example, if there were equal numbers of men and women in a 100 person population, with a 95% Confidence Interval, and 5% Margin of error, If you were to ask "Are you Male?" 95% of the time, a survey would find that between 45% and 55% would say "Yes".

[12] A Hannan, Faculty of Education, University of Plymouth, 2007. *Using Questionnaires in Education Research*. [ONLINE] Available at:http://www.edu.plymouth.ac.uk/RESINED/QUESTS/index.htm. [Accessed 30 April 2014].
[13] Stat Trek. 2014. *Confidence Level: Definition* . [ONLINE] Available at: http://stattrek.com/statistics/dictionary.aspx?definition=confidence_level. [Accessed 30 April 2014].
[14] Stat Trek. 2014. *Margin of Error: Definition* . [ONLINE] Available at: http://stattrek.com/statistics/dictionary.aspx?definition=margin_of_error. [Accessed 30 April 2014].

The calculations for Sample size are as follows:[8,]

$$x = Z(^{c}/_{100})^{2} r(100-r)$$

$$n = {}^{N x}/_{((N-1)E^{2} + x)}$$

$$E = \mathrm{Sqrt}[{}^{(N - n)x}/_{n(N-1)}]$$

Where:

n = Sample Size

N = Population Size

E = Margin of Error

r = the fraction of responses interested in

'Z(*c*/100)' = The Critical Value for confidence level ('c') (Based on normal distribution)

In order for a survey to provide reliable results and provide an accurate representation of the population it is important to ensure that an acceptable number of returns are collated. A target number of survey responses must be outlined to provide guidance on the proactivity of results gathering.

Following these equations, with a sample size of 10,623 in the Cathays area, a Confidence Interval of 95% and Margin of Error of 10%, the aim is to obtain at least 96 responses to have acceptable results from the research.[15, 16]

Due to the nature of the project, 10% margin of error is the best that can be achieved as this project has a very limited time scope and it is unfeasible to offer incentives for people to do the survey. Had more resources been available it would have been possible to collate a lot more responses and lowered the Margin of Error. However, given the constraints in place, 10% is acceptable.

[15] Raosoft, Inc. 2014. *Sample Size Calculator by Raosoft, Inc.* [ONLINE] Available at: http://www.raosoft.com/samplesize.html. [Accessed 30 April 2014].

[16] iSix Sigma. 2014. *How To Determine Sample Size, Determining Sample Size*. [ONLINE] Available at:http://www.isixsigma.com/tools-templates/sampling-data/how-determine-sample-size-determining-sample-size/ [Accessed 30 April 2014].

2.3 Research

The purpose of the survey was to identify the issues and problems faced by students. In the questionnaire there is: a question verifying the recipient of the questionnaire is a student, a total of 15 multiple choice questions based on kitchen problems, and an option of submitting ideas of issues that were not highlighted within the survey. There are a number of subtopics within the survey. While there are other questions, the main topics included:

- Cooking issues and abilities
- Storage Issues
- Shopping habits
- Kitchen Equipment

The questionnaire was distributed completely online through social media. It was originally broadcasted with a link to the survey, requesting Cardiff students to complete it. After it had been broadcast, the survey was then sent out specifically to a range of students – mostly, but not exclusively first year students as they typically do not choose their living arrangements or who they share a kitchen with, and therefore are more likely to provide an accurate insight into the widest array of issues in a shared kitchen.

As aforementioned, the target quantity of respondents to the questionnaire was 96. In total 113 results were collected.

The questionnaire was created using 'Google Forms'. This questionnaire consisted of two parts. The front end of the survey, which was what users saw after clicking on the URL, was the survey itself. The back end of the questionnaire was a spreadsheet. The spreadsheet was populated automatically with the results of the survey once the 'user' pressed 'Submit'. This made it extremely easy to extract and analyse the data. The data was then extracted using a simple copy and paste to Microsoft Excel. As the answers were multiple choices, a 'COUNTIF' analysis was used on the answers to provide a numerical value to the quantity of selected answers for each question, allowing for easy visualisation in graphs and charts. The decision to use Google Charts was made as a result of a number of factors. Other online survey providers such as 'Kwiksurvey' and 'Surveymonkey' require registration and both formats are fairly rigid in comparison to the flexibility of Google Forms. A 'Surveymonkey'

free account only allows up to 10 questions and 100 responses.[17] The survey created on Google Forms easily surpassed both these constraints. A free account also didn't offer a feature that allowed export into Excel or PDF, which was an utilised attribute of the Google Forms results as it allowed for quick and easy data manipulation and visualising. A Screenshot of the survey can be found in Appendix 1 (Heading 1.17) along with a link to the live survey site.

Although most of the questions were multiple choice, there was an option to add additional comments on the topic if the survey participant wished. With the results being exported into Excel it was difficult to automatically analyse these qualitative responses. They had to be read individually.

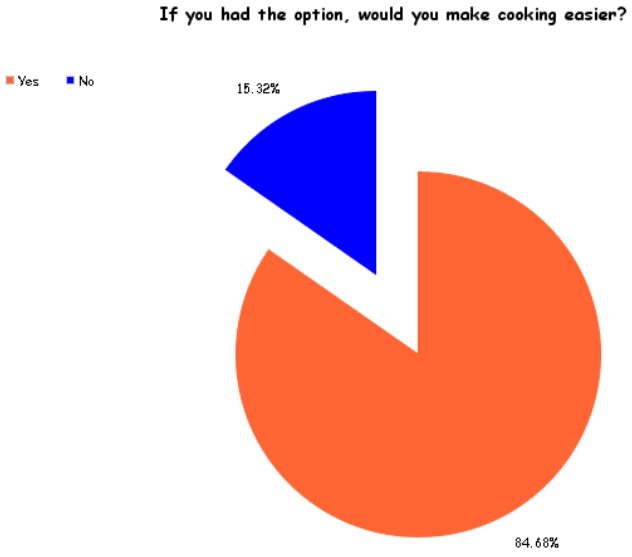
Once the survey results were collected, the next step was to begin to analyse the data in order for requirements to be elicited.

[17] Survey Monkey . 2014. *SurveyMonkey Plans and Pricing*. [ONLINE] Available at: https://www.surveymonkey.com/pricing/?ut_source=header&t=ENT_CALLOUT. [Accessed 30 April 2014].

3. Research Results

Of the 113 results collected, only 2 were soiled by unhelpful comments, meaning that the results from those two were disregarded, leaving 111 usable responses – 15 over the minimum 96 results to maintain the margin of error at 10%.

The majority of representation will be in Pie chart format as it best represents the opinion distribution of the population as a whole. An example of this is below. It allows easy viewing of the question. In this case the question is: "If you had the option, would you make cooking easier?" Although this is a fairly vague question it is clear to see that the vast majority of the population would opt to make cooking easier. This was used as evidence to support produced requirements. More specific questions were used to elicit other explicit requirements. Some of the questions in the survey needed further explanation. For example, in 'Q14 - Do you often have issues with timings in the kitchen?' (Found in Appendix 1, Heading 1.15) it was explained in the question that this could mean; overcooking, burning items or different items of food not finishing cooking at the same time.



The problems highlighted that would be solved through the following requirements analysis were:

- Bins overflowing.

- People not washing up.
- Not enough surface space.
- No easy food waste system.
- Disputes over communal items.
- Temperamental smoke alarms.
- Food going missing
- Insufficient storage space
- Wait times for appliances to become free
- Expired food
- Cost of shopping
- Forgetting shopping
- General Mess
- Cooking abilities
- Effort of cooking

A Complete set of results and graphs from the survey can be found in Appendix 1.

After the results have been collated and analysed the next stage was to begin eliciting requirements from the data for further analysis.

4. Initial Requirements

4.1 Definitions

'Requirements' are essentially rules to be determined, that any system or service has to satisfy in order to fully carry out its intended purpose for its intended users. The IEEE Computer Society defines them as:

"As its most basic, a software requirement is a property that must be exhibited by something in order to solve some problem in the real world."[18]

The IEEE defines a requirement as:

1. A condition or capability needed by a user to solve a problem or achieve an objective
2. A condition or capability that must be met or possessed by a system or system component to satisfy a contract, standard, specification, or other formally imposed document
3. A documented representation of a condition or capability as in (1) or (2)[19]

A requirements specification is defined as:

"(A) document that enlists all necessary requirements that are required for the project development."[20]

4.2 Elicited requirements

Using the survey responses a preliminary list of requirements were created. Due to the fact that it was only an initial set of requirements, it was likely that there would be a lot of change. For this reason the initial requirements were not drawn up in the initial template, they were displayed in a list listing only their functionality.

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[18] Azuma, M. "*Applying ISO/IEC 9126-1 Quality Model to Quality Requirements Engineering on Critical Software*". [ONLINE] Avaliable at: https://www.google.co.uk/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&cad=rja&uact=8&ved=0CDcQFjAB&url=http%3A%2F%2Fwpage.unina.it%2Fpaolo.melillo%2Ftesi%2FRiferimenti%2520Normativi%2520e%2520Legislativi%2FApplying%2520ISO_IEC%25209126-1%2520Quality%2520Model%2520to%2520Quality%2520Requirements%2520engineering%2520on%2520critical%2520software.pdf&ei=KfVkU8jzLaXJ0AXM9oHgDA&usg=AFQjCNGcfrSSekM1AKFGje2Y_p3xjE-iVQ&sig2=fhCcM1xR75jYiaOp667Ypw&bvm=bv.65788261,d.d2k [Accessed 30 April 2014].

[19] *BABOK Guide. 2009. A Guide to the Business Analysis Body of Knowledge Version 2.0*. p. 4

[20] Pressman, Roger 2010. *Software Engineering: A Practitioner's Approach*. Boston: McGraw Hill. pp. 123. ISBN 9780073375977.

Due to the fact the preliminary research provided quantifiable results, it was necessary to provide a qualitative analysis. As this would involve interaction with a potential user, the preliminary requirements only required their description; any other information could be communicated easily. Although the requirements were not completely ordered, they were grouped into different, headed, sub-systems so a reader could understand the context of any requirement.

The requirements specification was created to both solve the problem highlighted in the initial research, and to begin to introduce pervasive computing into the student kitchen. The three kinds of requirements in the original requirement specification are:

1. Functional requirements that solve highlighted issues in the student kitchen.
2. Non-functional requirements that add pervasiveness to the kitchen.
3. Functional requirements to ensure the requirements from (2) operate effectively and efficiently as possible.

An example list of the requirements for the one sub-section of the system can be found below:

STEALING FOOD REQUIREMENTS

1. *Thumbprint locks on cupboards*
2. *>1 second to log in*
3. *Key slot in case of failure/powercut*
4. *Capability to add up to 10 users per cupboard*
5. *Database for cupboard to be stored centrally*
6. *Physical Option to leave unlocked or locked*
7. *Scanner to be less than 200mm´*
8. *Capability for up to 4 'master' thumbprints*

A full copy of the list of preliminary requirements can be found in Appendix 2.

5. Follow-on Research

The next step was to decide on a method to extract qualitative information. Based on the techniques described in *2.1 Elicitation Methods*, and the relative ease of organising them, it was decided that personal interviews would be the tool used to complete the required analysis of the requirement specification.

5.1 Research Objectives and Methods

Although there is no mathematical formulae to work out how many students are suitable in an interview, in a study conducted by the 'National Centre for Research Methods', almost every one of 14 social scientists who were asked 'how many qualitative interviews were enough?' answered with 'it depends'. Essentially 1 interview could be enough wherein other cases 50+ is necessary, it is dependent on the depth of possible qualitative answers.[21]

Peter and Patricia Adler of the University of Colorado gave the advice that generally for a graduate project, between 12 and 60 interviews are sufficient.[17] With this in mind 17 students were interviewed in an unstructured, informal format with a view to finding out the following:

- To what extent has the set of preliminary requirements solved the problems that the interviewees, and other students they know of, have in a student kitchen.
- What requirements in the specification are not needed or relevant to solve the problems faced in a student kitchen.
- What the most important requirements are in the specification.
- The level of importance of each requirement with a view to addressing the problems of the student kitchen.
- What problems may be faced with while using the implemented kitchen.
- What requirements could be added to further increase the effectiveness of the proposed system.

[21] Baker, S & Edwards, R. How many qualitative interviews is enough?. *National Centre for Research Methods Review Paper*. [ONLINE] Avaliable at http://eprints.ncrm.ac.uk/2273/4/how_many_interviews.pdf . [Accessed 30 April 2014].

Once the purpose of the interview was explained with a background to the project and explanation of pervasive computing, each participant was given a complete list of the preliminary requirements. They were instructed to keep in mind the previously explained problem, while reading, thinking and making observations aloud. They were encouraged to ask questions about specific requirements. Each requirement that was queried was marked for ambiguity. Observations on the reactions and thoughts of the interviewee for each requirement were noted as they were reading. The conversation was then steered, to satisfy the aforementioned objectives of the research. Should a relevant idea or point be highlighted in any interviews, these ideas were explained to other interviewee's to obtain an opinion of these new ideas.

The last task of the interview was ask the interviewees to rate each requirement on their importance with a regard to solving the original problem on a scale of 1 -5, with 1 being the least important.

5.2 Example Interview Write-Up

The interviews were all written up and a full list can be found in Appendix 3. An example of the write up for one interview participant is as follows:

Interview number: 09

Date: 02/04/2014

Interviewee name: Andrew Moyse

Andrew has lived in 3 different student houses, each living with 5 others. Andrew had heard of the term 'Pervasive Computing' before and already had a very vague understanding of it. He seemed to have a good grasp on the concept when explained to him.

Andrew seems to be a very frugal person, and expressed a keenness for the requirements that would save money, such as the appliances learning when they are never used so they can automatically power down, and automatic quantities of water produced from a tap that can deliver boiling water – saving energy on boiling a large kettle of water (although he did state there would be a need to free pour water).

Andrew has had disputes over other housemates not buying certain communal items when he feels that it is their turn to and as a result he has stopped buying and using communal items. He feels that a system that measures who has been using specific items would be useful in keeping the peace in a household but pointed out that it would be impossible to quantify how much of particular items have been used by people. When asked to elaborate on this, he pointed out the scales would only be sensitive to a gram and using communal items such as salt, or pepper will not register a change on the scales in cupboards. Andrew correctly pointed out that an edit of the requirement was necessary. This was the only hole that Andrew managed to find in the specification and feels that the system would be a success in both delivering pervasion and solving issues in a student household.

5.3 Conclusion

Overall every person asked, came to the conclusion that the requirement specification would counter a great deal of problems in student kitchens. The problems that were impossible to solve through technology were made easier, but not solved completely. Not one person asked could think of any problems in a kitchen that wasn't either solved or improved by the requirements. Notably every student asked stated that their kitchen although tidy, wasn't cleaned often enough for their liking, although everyone was willing to put up with the dirt as it wasn't unhygienic or intrusive to everyday kitchen tasks. For some, cleanliness wasn't a big problem they have experienced in student kitchens so didn't feel too strongly about specific requirements that looked to improve the issue.

No requirements were seen as useless. Although some students stated that some requirements were not useful to themselves, they recognised them as useful features for others. The only requirement that was deleted was the requirement which provided 'self-cleaning' pans. This requirement was impossible to introduce and was replaced with the two minute dishwasher (later labelled requirement *FR-AC01*).

While we can assume, from the lack of an argument raised for a requirement that was being read, the interviewee approved of it, specific requirements that had approval expressly mentioned on multiple occasions have been specially mentioned.

After all the questions had been answered, the interviewees were then asked to mark each requirement on a scale of 1-5 on their opinions on the level of importance the requirements were to solving problems in a student kitchen, and creating a kitchen as pervasive as possible. The average value for each requirement was assigned to the requirement in the specification.

Overall the requirements list countered the current problems in a student kitchen to an excellent standard. Although some reservations were made about the system eradicating current problems that are only to be replaced by future problems that are associated with a new generation of kitchen use, the system requirement specification successfully addressed any and all problems that the interviewees knew, or could think about.

5.4 Summary of changed requirements

The main points that were raised in the interviews have been altered in the requirements specification. The following is a list of each requirement and the identifiers altered, and by extension, the main points raised and the actions taken upon them:

- Storage spaces have key slot to enable manual unlocking by a master key. (**NF-UI02**)
    - *Confirmed a good idea due to a potential lack of trust in the locking system.*
- Up to 15 users' thumbprints can be registered on the central database for each storage space. (**NF-SI02**)
    - *Changed from 10 to 15*
- The system will have capabilities to 'understand' recipes found on the internet.(**FR-CC04)**
    - *Confirmed a good tool in follow up research as students do not always know timings of food.*
- The oven will have the capability to detect differing levels of dirt inside the oven.(**FR-AC02**)
    - *Every student stated that the kitchen wasn't cleaned as often as they'd like.*
- The system has the capability to find possible recipes for meals, based on items in storage. (**FR-CC09**)
    - *Confirmed as a very useful tool.*
- Quantities and heat of water distributed are recognised by commands.(**FR-TC02**)

    - *Confirmed as a useful tool for energy efficiency and speed – not waiting for a kettle to boil.*
- The system will keep records of the last 20 people who accessed the communal shelf and what items were removed. (**FR-CS02**)
    - *Requirement was altered as it is not possible to assess weight of smaller items such as salt.*
- The system will allow contactless scrolling through pages.(**FR-SC04**)
    - *Added after it was seen as necessary through interviews.*
- The system will have the capability to 'look-up' information on health attributes for specific foods to display them either on charts or by text. (**FR-HI01**)
    - *Confirmed as a very useful tool.*
- The system will learn patterns of when appliances are used. (**FR-EM05**)
    - *Confirmed as a very useful tool.*
- The system will include a dishwasher that cleans its load in up to 2 minutes. (**FR-AC01)**
    - *Added after it was seen as necessary through interviews.*
- Interactive games are available within the interfaces. (**FR-EC01**)
    - *Added after it was seen as necessary through interviews.*
- Surface must be responsive to intentional touch, not accidental. (**NF-PR02)**
    - *Added after it was seen as necessary through interviews.*
- Taps will have the option for free pouring water. (**FR-TC04**)
    - *Added after it was seen as necessary through interviews.*
- The shopping list can be exported to all major online shopping sites. (**FR-SM04**)
    - *Added after it was seen as necessary through interviews.*
- The system will remember a user's 'current state' on any interface that is being used.(**FR-IM02**)
    - *Added after it was seen as necessary through interviews.*
- The system will be able to play music from any Bluetooth device. (**FR-EC02**)
    - *Added after it was seen as necessary through interviews.*
- The system must provide the option to turn off all automatic systems, to manually cook. (**FR-CC02**)

    - *Added after it was seen as necessary through interviews.*
- The system will provide the option to leave all storage spaces unlocked. (**FR-SS06**)
    - *Added after it was seen as necessary through interviews.*
- Pans will self-clean. (**DELETED)**
    - *Deleted after discussing its feasibility.*

6. Emerging technology

The subsequent section is an investigation on the technologies that will make this kind of system possible in the home. To do this, a mixture of academic journals and technology companies will be researched, to investigate concepts and new types of technology that are currently being built and prototyped. New technology that is already on the market and how modern commercial appliances play a role in developing a pervasive kitchen for the future will also be examined. This investigation will not be looking into making a decision on which technology should be used in a completed pervasive system, instead it will explore options to allow for a future designer make decisions based on the outcomes of this investigation.

Once the original requirements list had been analysed, it was time to perform research onto the technologies that would allow creation of this system.

6.1 Definitions

- **Cloud Based Computing**

  Cloud based computing is about moving services, computation and/or data—for cost and business advantage—off-site to an internal or external, location-transparent, centralized facility or contractor.[22] This makes data easily and ubiquitously accessed.
- **Internet of Things**

  "*An emerging global Internet-based information architecture facilitating the exchange of goods and services*".[23] Essentially this is inter-connecting 'Things'- in this

[22] Creeger, M. 2009. *Cloud Computing: An Overview.* [ONLINE] Accessible at: http://queue.acm.org/detail.cfm?id=1554608 [Accessed: 30 April 14]

case kitchen appliances into a giant internet. This means that theoretically, a fridge at home could be connected, and could communicate, to a toaster on the opposite side of the world.

6.2 Technological advancements

The following is an investigation into technology that is not currently fully available on the consumer market that will aid in the development of a pervasive kitchen. The following technologies are for the most part, only in prototyping stages and still a distance from being released. The prototypes however, prove that the technology is possible and will be available for purchase in the near future.

6.2.1 Fingerprint scanners

Biometrics refers to unique quantifiable data related to physical characteristics of a person. In computer science Biometrics is used a unique form of identification. The main examples of biometrics are: Fingerprints, Face Recognition, DNA, Palm Print, Iris recognition and Retina scans.[24]

The requirements specify a system where fingerprints are used to prove a user's identity. Fingerprints are used as they are the fastest readable item that can be read without needing the user to deter from their normal processes. For example, a retina scan would require the user having to actively look into a scanner for a period of time before they are validated, whereas to open a cupboard, fingers make contact with the handles to enable automatic scanning from an embedded scanner.

Although the fingerprint scanner has been around for a number of years, scanners traditionally take a long time to scan and register a fingerprint. Only recently has the technology become available for fingerprint scanners to be as instantaneous as they can be. There are two methods for scanning a fingerprint. The traditional way, is essentially capturing an image, and comparing it to stored images of fingerprints in a database.

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[23] Weber, R. 2010. *Internet of things.* [ONLINE] Avaliable at: http://link.springer.com/content/pdf/10.1007/978-3-642-11710-7.pdf. [Accessed 30 April 2014].

[24] Biometrics Research Group. 2007. *Biometrics: Overview.* [ONLINE] Accessible at: http://biometrics.cse.msu.edu/info/index.html [Accessed: 30 April 14]

Traditionally this has a time delay, although the technology is becoming much faster and prototypes are being developed for instantaneous reading.

As you can see here 'Gun Safe Technology, Inc.' has created a prototype for a fingerprint scanner that allows only authorised people to fire weapons when their fingerprints are scanned.[25] The needs of the requirement are met by this method as this example essentially performs the same task as the lock on a storage space.

The main disadvantages of this method are; fingerprints have to be stored in a database which could pose a security threat should it be stolen by an external party. The scanners are fairly bulky and may cause problems when embedding into cupboard handles. Instantaneous scanners are not mass produced and could be a substantial cost.

The second method of fingerprint scanning has recently implemented by 'Apple Inc'. In their new model of mobile telephones they have implemented a scanner that scans fingerprints in a different way. This type of scanner uses a subcutaneous layer of skin that conducts electricity. When you touch the iPhone's fingerprint sensor, it measures the minuscule differences in conductivity caused by the raised parts of your fingerprint, and it uses those measurements to form an image.[26]

This method is not only instantaneous but it is also fairly cheap, as it can be mass produced – as Apple is doing currently. It is very small and can be imputed into a cupboard handle fairly easily. A big advantage of this method is that it does not store any fingerprints, therefore they cannot be stolen – even if the hardware gets taken.

The main disadvantages of this technology are that it is fairly new and not completely reliable. It has been reported (although not proven yet, as they have not been in circulation long enough) that the scanner will be affected by overuse or impact after approximately two

[25] ksdk.com. 2014. *Instant fingerprint scanner designed to make a safer gun | ksdk.com* . [ONLINE] Available at:http://archive.ksdk.com/money/article/387597/5/Building-a-safer-gun-. [Accessed 30 April 2014].
[26] Macworld. 2014.*The iPhone 5s fingerprint reader: what you need to know | Macworld*. [ONLINE] Available at: http://www.macworld.com/article/2048514/the-iphone-5s-fingerprint-reader-what-you-need-to-know.html. [Accessed 30 April 2014].

years – not leaving a very long lifespan.[27] These, however, are most likely introductory issues that will inevitably be ironed out.

6.2.2 Hobs

The most modern hobs , called 'Induction Hobs', use a technology that uses magnetic fields to induce an electric current in the pot on the hob. This means that the hobs can be inbuilt into the surface of the kitchen, allowing for a seamless transition between appliance and surface. This technology can even be adapted to allow all surface space to be used as a 'hob'.

Induction hobs use coils of copper wire to create a magnetic field by flowing an alternating current through the coils. This magnetic field then induces an electric current in the pot, causing heat only in the pot.[28]

More than 90% of touch-screen interfaces use 'Transparent Indium Tin Oxide' (ITO) as a conductor that detects fingertip motion. From 2013, a company called 'Kodak' started developing a new alternative to the touch screen. This method uses virtually invisible nanoscale lines of copper (or silver) to form a metal mesh conductor to be used in touch screen interfaces.[29] With further research and development this technology could, in theory, be developed to allow a full touch screen kitchen surface that can utilise the copper in the interface to create induction cooking, although this technology has not been prototyped yet.

With this method of cooking, induction pans can be used to detect spillage, or 'boiling-over', and should anything spill onto the side, due to a registered change in the conductivity of the surface. Spills will not be burnt onto the surface as the bottom of the pan is the only thing that is heated. It is far more energy efficient than gas or electricity and safer with regards to fire risks or burns. The pan can also be used in an untidy kitchen as induction pans can be used over layers of newspaper safely. The system will also have the capability to detect

[27] Digler, D 2013. *Apple, Inc. gets its fingerprints on advanced touch sensor, appears difficult for Android to copy* [ONLINE] Available at: http://appleinsider.com/articles/13/08/07/apple-inc-gets-its-fingerprints-on-advanced-touch-sensor-appears-difficult-for-android-to-copy. [Accessed 30 April 2014].

[28] The Induction Site. 2014. *How Induction Cooking Works*. [ONLINE] Available at: http://theinductionsite.com/how-induction-works.shtml. [Accessed 30 April 2014].

[29] Loudon, B, 2013. *Kodak touchscreen markets*. [ONLINE] Available at:http://www.usatoday.com/story/money/business/2013/07/12/kodak-touchscreen-markets/2512641/.[Accessed 30 April 2014].

when a pan has been boiled dry as a result of the change in conductivity in the pan. In theory this technology can be used to allow as many users of a hob as there are pans and surface space, helping to solve the problem of users having to wait for appliances to become available. With this technology however, it will be difficult for the computer system to differentiate the different pans being used in order to control timings for one particular meal.

As special 'Ferromagnetic' pans need to be used on an induction cooker a feasible solution for this could be to input a small thumb scanner on the handle of the pans that can transmit the identity of the user of a specific pan, to the automated cooking system to allow the system to know effectively what pans need to be controlled for a specific meal. Another, cheaper solution would be to have the interface automatically allocate a free space on the surface for the placement of pans; the user would then simply place the pan on the highlighted area. Algorithms would have to be designed for this feature to make it as space efficient as possible but this would be a cheaper and just as effective alternative to fingerprint scanners in pan handles.

6.2.3 Fingerprint sensitive interfaces

A new technology is emerging that allows interfaces to recognise users by their fingerprints. Currently interfaces only emit light; they cannot sense it – meaning that it is impossible to read fingerprints unless a supplemental sensor is added. A prototype has been developed by the 'Hasso-Plattner Institute' in Germany.[22] It uses millions of tiny optical fibres bundled together. Each fibre emits rays of light from a projected image below the screen, while an infrared light source bounces light off the fingerprints and back to an infrared camera. Although it would be a challenge coupling this technology with the technology used in the inductive surface interfaces, the Hasso-Plattner institute are researching a technology that will allow fingerprint reading to occur on interfaces that do not require a projected image. In the meantime it would be a feasible solution to employ both different technologies in the kitchen, with the surface interfaces using the aforementioned inductive interfaces and the other interfaces in the kitchen using the light sensitive interfaces.

Another advantage of using this is the precision that this will offer to the touch screen, especially with re-scalable sizes. It was proved that extracting fingerprints on a sensitive interface, the touch accuracy will almost double.[30]

It will only be a matter of time before the technology evolves in personal tablets to allow the interface to read fingerprints using the technology previously mentioned.

6.2.4 Accidental touch rejection requirements

Especially with surfaces that are also interactive, it is important that accidental touches are not registered while other tasks are being completed.

There are a few practices which prevent accidental touches registering on an interface although they are not completely established. There are a few methods for rejecting errant touches on devices, both hardware and software related.[31] Using a multitude of techniques side by side will effectively counteract the potential problems of accidental touch. Both hardware and software requirements can prevent accidental touch.

Hardware:

The first technology is differentiating between different parts of the body (fingernail, finger-tip, fist, elbow etc.) by the acoustic signatures generated.[32] It can be programmed into the system to only accept input by a particular method/implement.

Software:

Touch rejection can be implemented through the use of API's, which implement touch rejection through the use of 'Confidence Bits'. A confidence bit, in this perspective, is a flag that indicates whether the interface driver thinks a touch is accidental or intentional. For example, touches on the interface that are not in the vicinity of the area of focus, or touches that cover too large an area to be a fingertip, e.g. a forearm, are deemed 'unconfident'. It

[30] Baudisch, P & Holtz, C, 2010. The Generalized Perceived Input Point Model and How to Double Touch Accuracy by Extracting Fingerprints. [ONLINE]. pp. 8-10. Available at:http://www.christianholz.net/2010-chi10-holz-baudisch-the_generalized_perceived_input_point_model_and_how_to_double_touch_accuracy_by_extracting_fingerprints.pdf[Accessed 30 April 2014].

[31] K, Shu, 2013. *Understanding and Rejecting Errant Touches on Multi-touch Tablets.* PHD Thesis, Sinagapore Management University. [ONLINE] Avaliable at: http://ink.library.smu.edu.sg/etd_coll/95

[32] [Lopes, P., R. Jota, and J.A. Jorge, *Augmenting touch interaction through acoustic sensing*, in P*roceedings of the ACM International Conference on Interactive Tabletops and Surfaces*. 2011, ACM: Kobe, Japan. p. 53-56.]

was stated however, that the performance of rejecting errant touches using this system has not been investigated.[23]

A touch-rejection feature called the 'palm ignoring' area has been released for an app called 'smartNote'.[33] This is essentially an electronic 'cover sheet' that can be dragged over the interface to allow a space where touch input is not recognised. This has not been implemented as an automatic function however, and must be put in place by the user before it is used. It can be programmed into the system as a virtual kitchen implement, e.g. 'chopping board', to allow a re-sizeable space in which to allow the user to perform tasks in, without interacting with the system.

Apple has also implemented a new technique to reject accidental touches. With their new iPad mini, in order for it to be handheld they have had to reduce the size of the border (or Bezel), meaning that thumbs will now have to rest on the screen without being registered as an interaction. This problem was solved by Apple who developed a touch-rejection algorithm that can perfectly differentiate between resting fingers and inputs.[34]

6.2.5 Dirt Detection

The technology for dirt detection is already being used in vacuum cleaners. It is done using infrared sensing. It involves two parts, a transmitter and a receiver. If a beam of light is broken then there is a dirt presence.[35]This can be used on the oven door to determine how transparent the glass is. The less transparent it is, the more dirt there is in the oven. The system can be programmed to only start self-cleaning when there is an acceptable level of dirt – set by the user. The system will have a good idea of how dirty the oven is and can then schedule a clean at the next opportune moment.

As temperatures in the oven reach 900^{o}F while cleaning, it is important to ensure that the Infra-Red sensors are protected properly in heat resistant casing as it is impossible to

[33] Liliputing. 2014. *SmartNote for iPad lets you write, draw with palm-ignoring technology.* [ONLINE] Available at:http://liliputing.com/2010/05/smartnote-for-ipad-lets-you-write-draw-with-palm-ignoring-technology.html. [Accessed 06 May 2014].
[34] 2013. *Apple - iPad Air - Design*. [ONLINE] Available at: http://www.apple.com/ipad-air/design/. [Accessed 30 April 2014].
[35] Breckon, T, Edinburgh University. 2014. *Visualisation of "Real" Objects & Environments.* [ONLINE] Avaliable at: http://breckon.eu/toby/teaching/vis/lecture_notes/lecture16-2x2.pdf

commercially purchase a basic sensor that can withstand such temperatures. It would be more plausible and realistic to case the sensor in a heat resistant casing.

6.2.6 Interfaces

Since the inception of tablets, touch screen interfaces have become more and more popular and common and there is now virtually no limit to the dimensions of a touch screen. There are two main methods for implementing a touch screen surface/interface.

The first method involves using a number of 'tablets' that have no borders to form a grid of tablets that as a whole form one whole user interface. These, in theory, can take any size, and can be mounted into almost any surface. This means the kitchen can have interfaces as small as 1 inch or as large as a whole wall. Moore's Law states that the number of transistors on an integrated circuit would double every two years.[36] This means computers have had the capability to become smaller and smaller. Sony has recently released a tablet that is 6.4mm thick and only 426g in weight.[37] With specifications like this tablets could very easily be mounted into any surface. This method would be the most suitable for eye level interfaces around the kitchen.

Fujitsu have also developed a tablet with an extractor fan that can be totally submersed in water meaning the technology is already in place for a 100% waterproof tablet. [38] There are a lot of advantages to using this method of interface. The reactions to touch will be instantaneous, the picture quality will be high definition and there will be no differentiation between surface and interface, reinforcing the pervasive nature of the kitchen by allowing the technology to be blended into the background. Tablets, notably Apple tablets, include a voice recognition software package that understands voice commands. This means that voice control of the entire kitchen can be easily programmed, with many production tablets already containing the required hardware and software to recognise and understand voice.

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[36] Moore, Gordon E. (1965). "Cramming more components onto integrated circuits" (PDF). Electronics Magazine. p. 4.

[37] Sony. 2014.*Specifications | SGP511/SGP512/SGP521 | Xperia Tablets | Sony*. [ONLINE] Available at: http://www.sony.co.uk/electronics/xperia-tablet-z/sgp511-sgp512-sgp521/specifications. [Accessed 30 April 2014].

[38] EnGadget.com. 2014. *Fujitsu made a Windows 8 tablet with a fan that works underwater*. [ONLINE] Available at: http://www.engadget.com/2013/10/09/fujitsu-windows-8-tablet-waterproof-fan/. [Accessed 30 April 2014].

Samsung also have developed the software to enable control of tablets without contact using the front facing cameras of their devices.[39] This technology allows interfaces to be controlled by hand gestures made into the camera of the devices, a useful tool with dirty hands in the kitchen. It also allows the user to scroll automatically down pages with their eyes and the tilt of a head.

Should all of these technologies be combined it would allow implementation of interfaces of any size with the full necessary capabilities to easily satisfy the requirements of the student kitchen system.

The other method for interfacing would be to project images. This turns any surface into a usable interface using a projector and depth camera controlled by software that can be input onto any computer.[40] In July 2013 a prototype was finished that uses this technology and since then companies like 'Whirlpool' have developed it further to enhance its capabilities, usability and technology.[41]

There are many advantages with this method. The interface can be used hands free, an important feature while cooking. There is also no physical screen so no interfaces would need to be treated for heat and water resistance, which would reduce costs. It would be easier to integrate it with an induction cooking system as no hardware will have to be synergized; the depth camera could even assist with accidental touch rejection. It would be cheaper on the whole as items like projectors and depth cameras are already being mass produced with products like the 'Xbox One' using a depth camera with built in microphone for voice activation on each console.[42]

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[39] TechRadar.com, 2014. *Samsung Galaxy S4 review: Smart Stay, Smart Scroll, Air View, Air Gestures | Phone Reviews | TechRadar*. [ONLINE] Available at: http://www.techradar.com/reviews/phones/mobile-phones/samsung-galaxy-s4-1137602/review/10. [Accessed 30 April 2014].

[40] Tech & Innovation Daily. 2014. *How to Turn Your Kitchen Table into a Touchscreen | Tech & Innovation Daily | Life Inside the INNOVATION Pipeline* . [ONLINE] Available at:http://www.techandinnovationdaily.com/2013/07/15/worldkit-touchscreen/. [Accessed 30 April 2014].

[41] Consumer Electronics Show. 2014.*Interactive Cooktop Wows Crowds At CES | Whirlpool CES 2014 Hub*. [ONLINE] Available at: http://ces.whirlpool.com/interactive-cooktop/interactive-cooktop-wows-crowds-at-ces/. [Accessed 30 April 2014].

[42] Xbox Support. 2013. *Use Kinect voice commands with Xbox One.* [ONLINE] Available at: http://support.xbox.com/en-GB/xbox-one/kinect/voice-commands. [Accessed 30 April 2014].

A drawback of this method is the reaction time in the interactions. It is clearly possible to see a time lag between hand movements and changes on the interface. This is expected with real-time computing constraints and with the advancement of technology and more efficient software. A reduction in the reaction time of the system will be expected over a period of time. The image quality isn't as good as inbuilt interfaces, however, and the image will get projected onto anything in the way of the projector and the surface. With this solution the automatic fingerprint reading function would not be an option, however with high quality depth cameras, other methods of biometric recognition is a real possibility. With the use of depth cameras it is also possible to determine a user's location in a room. This can be used for extra functionality in automatically 'following' the user's movements and automatically turning on and off interfaces that are relevant to the individual's position in the room without the use of another sensor.

The most feasible solution for the interfaces would be to use tablet computers of any size for the eye-level displays, and a projected interface for the surface interface with the use of induction cooking, although the final decision would be made by the project designer.

6.2.7 Storage Detection

Applications that allow users to see what is in their fridge are recently emerging onto the market. This is not an automated process, it requires users to manually input and remove the items from a list displaying the items in the fridge. Samsung has created such a fridge called the 'RF4289HARS'.[43]

This fridge has the capability to be controlled on a touch screen interface and uses an app called 'Evernote'. This is Cloud based so when shopping lists are scribbled down, they get pushed to a mobile device. There is no automation however as the user has to input the list to then receive the list on a connected device.

To ensure the system automatically registers the inputting and removing of food from storage, a number of sensors can be used in the storage spaces. All products, except from loose items such as fruit and vegetables, have barcodes attached to them that can be used

[43] Samsung, 2014. *28 cu. ft. 4-Door Refrigerator and 8" LCD Digital Display with Apps | Samsung Refrigerator RF4289HARS*. [ONLINE] Available at:http://www.samsung.com/us/appliances/refrigerators/RF4289HARS/XAA. [Accessed 30 April 2014]

to look up information. Commercially available barcode readers are available on smart devices that allow a user to lookup information on items, meaning that no special permissions are needed to access a supermarkets inventory database. Should the perimeter of a storage space be covered with inwards facing barcode readers, as the user enters an item to storage, the barcode of the item should be read regardless of the angle in which it is entered. This will then compile a list similar to that of supermarket checkouts as objects are passed through the storage perimeter.

Although there is no known existing system where food storage compartments have inbuilt scales it would not be difficult for a designer to build in this functionality. Sensitive scales are not a new or emerging technology and it would take little technical expertise to program in a simple function that allows the system to measure the weight difference if an item is removed, used and replaced.

RFID (Radio Frequency Identifier) are being used more and more in retail.[44] Although they are already common place in clothes and electronic products, they are finding themselves more and more into the food and drink market.

While high-end or expensive items, such as spirits or meat, already contain RFID as anti-theft technology in most large supermarkets, supermarkets have been looking to increase their RFID usage since as early as 1998.[45]

RFID is mostly used by major supermarkets to track supply chains and provide information on whole pallets of stock, security and anti-theft purposes and tracking of customer patterns by RFID tags inbuilt into trolleys. If the uses of RFID scanners continue to follow the current trend of deployment then it is realistic to assume that they will one day replace barcodes altogether. This can be done in an inexpensive and efficient way.[46]

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[44] IEEE Xplore Abstract, 2014.*IEEE Xplore Abstract - RFID security and privacy: a research survey* . [ONLINE] Available at: http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=1589116. [Accessed 30 April 2014].

[45] Jones, P, Clarke-Hill, C, Comfort, D, Hillier, D, Shears, P. 2005. *Radio frequency identification and food retailing in the UK.* [ONLINE] Avaliable at: http://www.emeraldinsight.com/journals.htm?issn=0007-070X&volume=107&issue=6&articleid=1508946&show=pdf&PHPSESSID=qtkteslk214i284vampohc8864. pp 1-2 [Accessed 30 April 2014]

[46] IEEE Xplore Abstract, 2014. *IEEE Xplore Abstract - A Novel Chipless RFID System Based on Planar Multiresonators for Barcode Replacement* . [ONLINE] Available at:http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=4519383. [Accessed 30 April 2014].

A RFID scanner input into the storage devices would be instrumental and more reliable in the detection of food entering a space due to the difficulty in disrupting the reading of the information by the system. For example, if a hand is covering the barcode of the item then it would be impossible to be registered by the system, whereas it is very difficult to interrupt a radio frequency accidentally.

6.3 Available Technology

The following is an investigation into technology that is available on the consumer market that will aid in the development of a pervasive kitchen. The majority of the following technologies are for the most part, uncommon in houses but available for purchase nonetheless.

6.3.1 Bin sensors

Bin sensors are a well-established technology, both to detect when they are full up and to sense when a user is approaching the bin to automatically open. This technology will use infrared lasers similar to that of the dirt detection technology previously mentioned in section *6.2.5*. When the line of light is broken for a period of time the bin can tell if it is full up. The only challenge with implementing this technology would be passing on the information to the system processor once the bin has been registered as 'full'. This would not be a difficult task for any engineer with the relevant technical expertise.

6.3.2 Two minute dishwasher

Fast dishwashers are rarely found in the standard household; instead they are mostly reserved for a commercial environment where fast washing is a necessity e.g. a Hotel, restaurant, pub etc. There is no reason, however why the student household cannot have one installed. Generally they are bulky and unattractive due to the lack of need for aesthetics in a 'back of house' environment, although the external design would be extremely easy to modify.

Dishwashers are a key selling point for student houses. Student houses are even advertised as having a dishwasher in the title, proving their importance to students in their

household.[47]

These fast dishwashers, which are commercially available, work by rigorously washing the items with very hot water (up to 180°F) for a short burst of time to sanitise the plates, or by washing slightly cooler (approximately 140°F) with an attached detergent tube to provide the sanitation. Rinsing is then completed with high pressured water. They do not have an inbuilt drying capability as this takes time; instead they use a drying technique whereby heated racks in the dishwasher meet cool air once the washer is opened to evaporate the remaining water as a result in the rapid change in temperature. An approximate time for a wash in such a dishwasher is as follows:[48]

- Wash time: 57 Seconds
- Rinse Time: 48 Seconds
- Purge Time: 15 Seconds
- Total Time: 120 Seconds

6.3.3 Programmable Hobs

Programmable hobs and ovens have been readily available for a fairly cheap price on the market for some time now. They have also moved away from traditional dials and buttons into more integrated interfaces. It would not be difficult for a skilled electrical engineer to either alter existing oven or hob computer systems to allow them to be remotely controlled, or design a new a new system that would allow the appliances to be controlled from a separate interface.

6.3.4 Boiling/ Cool taps

The technology is already in place for boiling water taps. These taps can be readily purchased, providing safe and instant hot, cold and boiling water.

'Grohe', a company that specialises in bathrooms and kitchens have developed a system that allows the taps to be controlled remotely by a digital control pad. This digital device has

[47] 2014. *Bills inc – spacious 5 bedroom house with dishwasher! - Pads for Students*. [ONLINE] Available at:http://www.padsforstudents.co.uk/properties/bills-inc-spacious-5-bedroom-house-with-dishwasher. [Accessed 30 April 2014]

[48] 2014. *CMA Dishmachines L-1X Stainless Undercounter Dishwasher Low Temperature 30 Rack/Hr*. [ONLINE] Available at: http://www.acitydiscount.com/CMA-Dishmachines-Stainless-Undercounter-Dishwasher-Low-Temperature-30-Rack-Hr-L-1X.0.23514.1.1.htm. [Accessed 30 April 2014].

the capability to do everything outlined in the requirement specification; Control temperature, flow of taps, even automatic water dispensing. [49]

As it is possible to control the taps through an external interface it would be realistic to assume that the taps can potentially be controlled through the interfaces, and by extension, touch and voice. Taps made by 'Grohe' also satisfy the testing criteria in requirements: *FR-TC01* & *FR-TC03,* which states that the taps must not conduct heat from the boiling water causing a safety hazard.

A key issue that the designers of the system would have to consider is how to prevent the accidental release of boiling water as this could again, prove a hazard.

6.3.5 Self-detection of burning

No oven commercially available that supports the capability to turn off if burning is detected was discovered through research. Because ovens retain their heat for a long time after they are powered off due to their effective insulation, ovens like this do not exist in the kitchen. This means if an item of food were to begin burning in the oven, despite the oven powering off, it would still continue to burn in the heat.

A solution for this would be to encase a heat proof carbon dioxide/monoxide alarm in the oven that is set to send a signal to the system processor when there is an unacceptable amount of gas in the oven, i.e. the food is burning. The system would then switch off the power and start up a fast cooling system.

Rapid-cooling ovens are in operation, but not for kitchen use. The technology is there however, as rapid cooling ovens are used in laboratories and industry. They function by using a technique called 'Forced air cooling'. This is essentially employing high performance fans to swap the cool air with the hot air, which is dispersed using heat sinks. As previously mentioned however, this technology is only used in industrial laboratory environments and employing it within a student kitchen is impractical. The most appropriate solution to preventing food from burning is to turn the oven off and notify the user. Modern ovens do contain cooling fans which will slow the speed of burning to a slight extent.

[49] GROHE , 2014. *Pageflip Catalogue*. [ONLINE] Available at:http://downloads.grohe.com/files/uk/pageflip/GROHE_Kitchen_Brochure/index.html. pp 18 [Accessed 30 April 2014].

6.3.6 'Nest' thermostat and smoke alarm

Smart thermostats are only recently being released into production. A smart thermostat implements a number of sensors to thoroughly monitor the environment and has the capability to learn preferences of the users, meaning it is energy efficient and autonomous in control of a climate.

Nest, a company that works exclusively on developing a thermostat like this has recently been bought by Google for $3.2 billon. Their thermostat is the first of its kind in automated thermostat technology. While other thermostats do allow remote controlling, its functionality is not limited to just remote control. Activity sensors learn when you leave the house to automatically turn off the heating. A humidity sensor is built-in to ensure your household isn't too humid or too dry. Temperature sensors learn how long the house takes to reach a target temperature so that it can ensure punctual heating of the house. The thermostat is also weather aware by accessing the internet weather reports, this helps it understand how the weather affects the heating in a household. The Nest Thermostat takes a week to learn the habits of the user before it can become fully automated and any alterations by the user after that are remembered by the device as the system keeps learning. There is also the option to remotely work the thermostat from a device connected to the internet.[50] This technology perfectly captures the pervasive ideals that this system is looking to encompass. As the technology has been developed fully to production it would not be difficult for developers to introduce like-technology into the system, or even use the Nest kit themselves to satisfy the requirements of the system.

Nest as a company have also developed a system that serves as an intelligent carbon monoxide and smoke alarm.[51] It closely monitors danger levels and pushes notifications of different alerts to a mobile device, while also relaying the warnings on the in-built speaker. It will not set off with burnt toast, an issue highlighted in the initial research; only provide a notice to allow the user to check up on things.

[50] Nest, 2014. *Inside & out | Nest*. [ONLINE] Available at:https://nest.com/uk/thermostat/inside-and-out/#explore-your-nest. [Accessed 30 April 2014].
[51] Nest. 2014. *Inside & out | Nest*. [ONLINE] Available at: https://nest.com/uk/smoke-co-alarm/inside-and-out/ [Accessed 30 April 2014].

Due to its ability to communicate with external devices as a result of triggers in the environment, the technology in the Nest Smoke alarm could easily be adapted to perform other functions within the system as a whole. For example, should a piece of food be emitting a lot of smoke, the detection of the smoke would trigger the smoke alarm to send a warning to mobile device and turn on an extractor fan. Again, like the Thermostat the technology could be imitated, or just purchased from Nest.

6.3.7 Remote controlling through smart devices

A lot of applications and programmes allow control through the use of a smart device and a lot of applications are already offering similar capabilities. Use of these applications would not be suitable for a system such as this however due to the heuristic impracticality of having many different applications on a Smart device performing many different tasks within a kitchen. It is important that all processes are run through a central operating system and interface.[52]

It is possible to install a series of adapters to allow appliances to be remotely controlled, although these adapters are expensive and only allow control over the flow of electricity to them usually in an on/off format. Control of current is also compatible to be used with features such as lighting. Adapters that allow remote control with more specific tasks are also emerging on the market, although it is likely that appliances will need to be developed to be compatible with this remote control technology before it can begin to be used in the pervasive kitchen such as the one outlined.[53]

There are a lot of problems that have to be addressed in remote controlling. Appliances prevent phone manufacturers from providing hand-designed interfaces on every phone and even if the appliance designers were to create a predesigned remote control user interface

[52] J. Nichols, B.A. Myers, and B. Rothrock, 2006. UNIFORM: Automatically Generating Consistent Remote Control User Interfaces, *Proc. SIGCHI Conf. Human Factors in Computing Systems* (CHI 06), ACM Press, , pp. 611–620.

[53] TechRadar.com 2014.*How to control your home with your iPhone or iPad | News | TechRadar*. [ONLINE] Available at: http://www.techradar.com/news/mobile-computing/tablets/how-to-control-your-home-with-your-iphone-or-ipad-1151155. [Accessed 30 April 2014].

on each appliance, then there are too many different kinds of phone to provide a different interface for each.[54]

Interfaces on web browsers also prove problematic due to their inability to perform certain tasks, for example, Apple portable devices do not support Adobe Flash Player - software used for interacting with a web browser. It was also suggested that Android have also removed Flash Player from their application downloader, meaning a lot of Android devices no longer have the capability to interact with the browser either.[55]

Phone Web browsers also suffer from poor rendering of pages, which could lead to low-quality user interfaces.

The many different methods of remotely interacting with an appliance are something the designers will have to think about, whether it is through a house Wi-Fi, Bluetooth or through Mobile internet. The nature of student kitchens also means that there could be up to 10 users at a time controlling the appliances either remotely or manually. This could prove a problem with real-time updates on appliance status and conflicting commands from different users.

The multiple interfaces in the kitchen would be either physically connected to the appliances through the system computer, or through the use of 'Communication Adapters' connected directly to the appliances through either cabling, Bluetooth, or Wi-Fi. With the 'Internet of things', any interfaces that are connected within the specific intranet, can then communicate with everything else in the network.

The designer would face a choice in how to implement the remote accessing of the network. The two options are: remotely controlling the interfaces that in turn control the appliances, or use a method that will allow permissible portable devices access to the network of appliances so that the device can, in turn, communicate with all applications alongside the interfaces within the kitchen.

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[54] IEEE, 2014. *Controlling Home and Office Appliances with Smart Phones* . [ONLINE] Available at:http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=1673368. pp. 61[Accessed 30 April 2014]

[55] Digital Trends, 2014.*Adobe Flash for Android: Gone with barely a whimper*. [ONLINE] Available at: http://www.digitaltrends.com/mobile/adobe-flash-for-android-gone-with-barely-a-whimper/#!FN0LU. [Accessed 30 April 2014].

Both options would require similar software and techniques; however one method will undoubtedly be more relevant to the needs of this system than another. In a system where a portable device controls an interface, which in turn controls the appliances, there could be problems with the time lags between sending and receiving information and system updates. This method would also render an interface useless to other users in the kitchen, meaning constant logging in and out would be necessary to ensure a portable device has 'vacated' an interface after tasks have been completed.

6.2.7.1 Telnet

Telnet is a network protocol that allows a user to enter a command as if they were the server.[56] Although mostly used as a way to remotely control web servers, Telnet can remote control after a log in with a username and password. It can however be flexible with its front-end, meaning the user interface can be designed specifically for this purpose due to Telnet. An advantage of telnet is due to it being a protocol there is minimal intrusion on the interface with software not having to be installed, with protocols already being in place. It may be unsafe to employ telnet due to the insecurity of mobile networks. Telnet provides access to the command line of the computer, meaning there could be serious consequences should the connection be compromised. SSH has been introduced as a more secure, advanced version of Telnet.

6.2.7.2 RDP controlling

Another method of remote controlling a computer remotely is through the use of Remote Desktop Protocol (RDP), if the system computer has RDP server software installed onto it, it would be simple to remotely connect and control the system computer using this software.[57]

6.2.7.3 VPN/Tunnelling Protocol'

An option would be to create an application with a suitable front-end interface that can 'Tunnel' into the network of appliances and communicate with appliances. Although it is defined as "*the encapsulation of a packet from one type of protocol within the datagram of*

[56] University of Indiana Information Technology Services. 2013. *What is Telnet?* . [ONLINE] Avaliable at: http://kb.iu.edu/data/aayd.html. [Accessed 30 April 2014].

[57]. Microsoft.2007 "How to change the listening port for Remote Desktop"2007. Microsoft KB article 306759, revision 2.2.

a different protocol"[58] In *extremely* simplified terms, tunnelling is the process of disguising information, to allow it to conform to a different set of rules to allow it to be sent - essentially bypassing normal channels of communication between networks. Once authorisation has been achieved, through certificates, log-in credentials etc., the portable device will have exactly the same capabilities and control over the appliances in the kitchen as the interfaces in the room. This method will also support access from multiple users. The designer would have to ensure instantaneous operation of the kitchen and very minimal lag times in receiving and sending information. Tunnelling protocols are used in setting up remote VPN's (Virtual Private Networks). A VPN extends a private network across a public network, such as the Internet.[59] It allows devices to send and receive data within that network. This is a tool that can be utilised to enable remote controlling regardless of distance from the kitchen.

6.2.7.4 M2M controlling

A new method of remote controlling devices is being investigated by the IEEE[60]. It is called 'Machine-To-Machine Communication' (M2M). This provides a gateway between a mobile and embedded internet through the 'Cloud'. This method has only recently emerged as a concept for remote controlling an 'Internet of Things'.

The main advantages of this method are:

- M2M will solve the issue previously highlighted in the delay between updates from the system occurring and reaching a portable device. With 3G established, and 4G in its infancy stages, this technology supports the capabilities M2M has to offer in by supporting its high value services with high data transfer rates.

- Capabilities for 'Ultra scalable connectivity'. Essentially this means it can cope with an 'Internet of Things' of any range or size. Essentially, if other devices were to be added to the pervasive kitchen, it would not be an extensive task to get them set up and implemented on a mobile control device.

[58] Microsoft. 2014 *VPN Tunnelling protocols*[ONLINE] Avaliable at: http://technet.microsoft.com/en-us/library/cc771298(v=ws.10).aspx. [Accessed 30 April 2014].
[59] Mason, Andrew G. 2002. *Cisco Secure Virtual Private Network*. Cisco Press, pp. 7
[60] IEEE, 2011. *M2M: From Mobile to Embedded Internet. Journal*. [ONLINE] Avaliable at: http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=5741144. [Accessed 30 April 2014].

In essence, it is an emerging technology that allows remote control of devices in the home through the use of ‘Cloud Computing’ and mobile phone networking.

The drawbacks of this method are:

- M2M does require a broad standardising in system interfaces, network architectures and implementation platforms.
- M2M has not been implemented yet, at the moment it is still a concept.

These methods may not work depending on how the designer would want to set up the control of the kitchen. For example, if the interfaces are purely capable of input and output to/from a central server which in turn controlled the appliances, then this method would be unsuitable. If the designer were to implement a network of Interfaces that could compute locally and then relay information to the central kitchen server, then this method would be possible if unsuitable.

7. Requirement Specification

After completing the investigation into the technologies needed to implement such a system, it is apparent that all technologies needed to satisfy the preliminary requirements are either readily available or being prototyped and are on the horizon. After the results from the follow-up research and technological investigation, it was time to create the full requirements specification.

7.1 Introduction

Once the preliminary requirements had been created, evaluated and analysed, and a further investigation the technologies had been completed it was time to codify all of the requirements into a complete requirement specification.

7.2 Definitions

The following is a list of definitions of the terms needed to understand the requirement specification.

- **Stimulus:**

  The definition of stimulus in the Oxford English Dictionary can be paraphrased to be defined by: '*A thing or event that evokes a specific functional reaction*'. [61]

- **Functional Requirement***:*

  "Functional requirements should define the fundamental actions that must take place in the software in accepting and processing the inputs and in processing and generating the outputs."[19]

- **Non-Functional Requirement:**

  "In software system engineering, a software requirement that describes not what the software will do, but how the software will do it."[62] Essentially it is the constraints on the operations of a system.

[61] Oxford English Dictionary, 2014. *stimulus: definition of stimulus in Oxford dictionary (British & World English)*. [ONLINE] Available at:http://www.oxforddictionaries.com/definition/english/stimulus. [Accessed 01 May 2014].

[62] L Chung, B Nixon, University of Dallas, Texas, 2000. *Non-functional Requirements.* [ONLINE] pp. 2 Avaliable at: http://www.utd.edu/~chung/RE/NFR-18-4-on-1.pdf. [Accessed 30 April 2014].

- **User Interface:**

  "*The logical characteristics of each interface between the product and its users"*[63]

- **Hardware Interfaces:**

  "Logical characteristics of each interface between the software product and the hardware component to be specified".[21] To put this in simpler terms; this essentially translates to 'the requirements employed to demonstrate the characteristics of the interface between the hardware and software'.

- **Software Interface:**

  "The interface of the software product with other software tools".[21] With regards to this project this outlines how the software in the system will utilise other software tools to allow the system to work.

- **Communications Interfaces:**

  "The various interfaces to communication, such as local network".[21]Essentially this is listing the requirements that allow the system to interface with communications systems external to the system, e.g. the house Wi-Fi.

- **Performance Requirements:**

  Performance requirements are the requirements outlined to ensure the system works to a satisfactory performance/ standard of efficiency.

7.3 Characteristics of Requirements

During the elicitation process, it is important that all requirements are consistent with the IEEE recommended practices on requirement specifications. Assuming this project was to be continued, improper requirements can have detrimental effects on the system. Should the requirements or the requirements specification fail to clearly represent a functioning system, it is likely they would all be discarded, rendering all research and requirements completed in this project inoperable. The following statement outlines the acceptance criteria for requirements and the requirement specification. This means that the requirements have to:

[63] Singh, Y (2012). *Object-Oriented Software Engineering*. New Delhi: PHI Learning. pp. 91-93.

- Fulfil the 8 quality characteristics outlined by the IEEE[51].
    - Correct, Unambiguous, Complete, Consistent, Ranked for Importance, Verifiable, Modifiable, and Traceable.
- Be uniquely Identifiable by both Category and Number.
- Have to have a considered layout to maximize readability.
- Be included in a table of contents.
- Have suitable testing criteria for each requirement.
- Include a timestamp.

The following is the aforementioned list of quality characteristics that any requirements designer has to consider when designing requirements and creating a requirement specification as outlined by the IEEE[64]. It is important that these must be kept in mind when designing the requirement specification, should any requirement fail to meet all of these requirements it is unsuitable for the specification.

- Correct

A requirement specification is correct if every requirement is met by the system. If, even one requirement is not met by the system, then the specification is incorrect. Although there is no official tool or procedure that ensures correctness, the key stakeholders (in this scenario, the students) are the ones to determine if the requirements meet their actual needs and fulfil the acceptance criteria for every requirement.[65]

In the context of this project, no system will be implemented so the correctness will be assessed in follow up research to the key stakeholders.

- Unambiguous

Requirements are unambiguous if they only allow for one possible interpretation. It is important to maintain unambiguity as each stakeholder can have their own perspective on

[64] IEEE, 1998. *IEEE Recommended Practice for Software Requirements Specifications. Journal*. [ONLINE] pp. 4-5. Avaliable at: http://www.math.uaa.alaska.edu/~afkjm/cs401/IEEE830.pdf. [Accessed 30 April 2014].

[65] IEEE, 1998. *IEEE Recommended Practice for Software Requirements Specifications. Journal*. [ONLINE] pp. 10. Avaliable at: http://www.math.uaa.alaska.edu/~afkjm/cs401/IEEE830.pdf. [Accessed 30 April 2014].

the system which can, in turn warp, an understanding of a requirement. Requirements should be self-elucidating and not require an explanation by the requirements designer.

- Complete

A requirements specification is considered complete if all requirements relating to every aspect of a system are complete. A complete requirement specification must also contain full references to each requirement in a directory with all terms and units of measurement defined.

- Consistent

Requirements are seen as consistent if all requirements maintain the same format. If two requirements contradict each other, the requirements are not consistent.

- Ranked for Importance and/or Stability

Typically requirements have varying degrees of importance/stability. Some are key requirements which are vital to the competency of a system where some can be desired features or optional aesthetic requirements which will are not as paramount in the operation of a system. To meet these criteria, requirements should be ranked with an identifier corresponding to the level of importance.

- Verifiable

A requirement is verifiable if it can be checked that the system meets the requirement(s). Ambiguous requirements cannot be completely verified due to multiple interpretations. Although it is impossible to verify the requirements as no completed system will be produced, detailed testing criteria will be included with the requirements.

- Modifiable

Requirements and Requirement specifications are deemed modifiable if they can be easily and completely changed while still retaining the same format. This can be ensured by stating each requirement individually and not inter-mixing different requirements. This is necessary with an iterative or ‘spiral’ approach to the ‘Waterfall Method’ of system design, as the requirement specification can easily be altered.

- Traceable

Requirements are traceable if the origin of each requirement is clear. With regards to the project it is important that the requirements clearly and accurately reflect the results of the research undertaken on students. This is 'Backward Traceability'. 'Forward Traceability' is not necessary in this project as there will be no further documentation or implementation.

With these characteristics in mind the requirements can now be developed. In order to maintain the same format and structure the next stage is to develop a template for the requirements. This ensures requirements are easily recognisable from one another and ensures that each requirement contains the correct information to enable it to conform to the IEEE regulations.

7.4 Requirements template

Keeping in mind the quality characteristics highlighted in section *7.3*, requirements will be developed with the following template. To help further understand the content of each requirement, each category within the requirement will also be described.

ID no		Category			
Description					
Justification					
Reference					
Timestamp		Importance		Version	
Change information					
Acceptance criteria					

7.4.1 Requirements Creation

- **Unique identifier**

  The requirements will be separated into functional/non-functional requirements, categories and then numbered and ordered within each category. Their unique identifier will be in the format of: AA-BB##. As it is not expected there will be any more than 99 requirements per category, 2 numerical digits are ample. The first set of letters will refer to the type of requirement. The unique ID is sorted by the first two letters 'FR' and 'NF', meaning 'Functional Requirement' and 'Non-Functional' respectively. The second set of letters will refer to the stimulus in which they are placed, for example, 'SC = System Control'. After the categories were in place for the requirements, they were then assigned numbers based on their importance. E.g. '03' would be the third most important requirement in its respective stimuli. A full legend will be provided at the start of the requirement specification (Appendix 4).

- **Importance**

  Importance will be ranked between 1-5, with 1 being the least important and 5 being the most important requirement. In the template this is also colour coded, from blue (least important) to red (vital).

- **Timestamp**

  Each requirement will have a date as to when it was last edited.

- **Requirement**

  This will be the outline and description of the actual requirement itself.

- **Justification**

  This is the reasoning behind the requirement.

- **Reference**

  In compliance to the 'Traceability' requirement, each requirement will have a reference to its origin, be it research results or external technology documentation. Essentially it is the evidence of the 'Justification'. In this document, the references will reference either the research results in the appendices where a need for the requirement is shown, or the future technology research which will highlight the technology to make it possible.

- **Version**

  In compliance with the 'modifiability' attribute of a requirement specification it is important that any modifications are correctly recorded, a version number will highlight how many times the requirement has been modified.

- **Change Information**

  This will be a brief description of the modification made to the requirement from the previous version.

- **Testing Criteria**

  This is the criterion that has to be met to ensure the requirement is verifiable. For example, if a requirement states "perform task 'x' in less than 3 seconds" then the acceptance criteria would be met if, under testing, task 'x' was performed in under 3 seconds.

The requirements will be written using a word processor due to the ability to manipulate tables effectively, the high text content and the ability to easily create content tables. A client-side storage system will offer more security against loss or theft of the requirements. Validation isn't supported in Microsoft Word as it is in Google Forms, meaning that boxes can be left blank or incomplete with no error messages and timestamps will have to be manually inputted. However as this is a relatively small, one man project validation rules are deemed not necessary due to there not being confusion about any inputs of requirements, or miscommunications.

On a project of this scale it is expected that the quantity of requirements will be in the hundreds – a relatively small requirement specification. Microsoft Word will be ideal for this as it supports easy extraction into reports and individual pages. Files can be sorted easily into folders corresponding to separate categories abstracting the system requirements into separate folders. This is appropriate to the project's scale.

7.5 Requirements

This was done by filling in the 'Description', 'Justification', 'Testing Criteria' and 'timestamp' sections on the template previously outlined. Any change information that was highlighted in the follow up research was also entered into the requirement template, the timestamp was updated and the importance scores of each of the requirements, highlighted by the

interviewees in the follow-up research, were averaged, and inputted. The next step was to sort the requirements. The requirements were sorted by stimuli. These were ranked for importance by the users through the average 'importance' scores of the requirements within them. The requirements within the stimulus were then sorted into their order of importance for the system and then allocated a unique ID. The functional requirements were then sorted into different stimulus. These were then assigned numbers based on their importance.

The following is an example of the most important stimuli, as deemed through follow-up research:

1.2.3 Stimulus 3 - Interface Management

The following is a set of functional requirements of the system in relation to methods and capabilities of the system with regards to its input and output through the interfaces.

1.2.3.1 Functional requirement 3.1

ID no	FR-IM01	Category	Functional – Interface Management		
Description	Each and every interface can run a different process for each and every user who is using the system simultaneously.				
Justification	Only 8% of students state they have had to never wait for appliances to become free where 20% of students say it happens very often. If more than one student can use an interface, the system can calculate processes to utilise more time-efficient ways of cooking, reducing the time needed for people to wait before cooking.				
Reference	Appendix 1 – 1.5				
Timestamp	07/04/2014	Importance	5	Version	1
Change information	N/A				
Testing Criteria	There is a 0% change of speed in processing time between 1 and 10 simultaneous users of the system.				

1.2.3.2 Functional requirement 3.2

ID no	FR-IM02	Category	Functional – Interface Management		
Description	The system will remember a user's 'current state' on any interface that is being used.				
Justification	A need for this requirement was made obvious through future research. This gives the users the capability to use multiple different interfaces when navigating the kitchen, and allows other users to use any interface without interfering with the first users processes.				
Reference	Appendix 3 – Interview 7				
Timestamp	11/04/2014	Importance	4	Version	1
Change information	Added after follow up research.				
Testing Criteria	0 second time delay between changes on display of any inputs. One touch transition to new user's control.				

1.2.3.3 Functional requirement 3.3

ID no	FR-IM03	Category	Functional – Interface Management		
Description	The system will have the capability to re-scale the surface-interfaces so they can cover as much, or as little of the surface space as necessary.				
Justification	Gives the user control over how much they wish to utilise the interactive surface.				
Reference	N/A				
Timestamp	08/04/2014	Importance	4	Version	1
Change information	N/A				
Testing Criteria	Touch control accuracy and image quality is not affected by the size of the interface. Maximum size is up to 2mm from the surface edge.				

1.2.3.4 Functional requirement 3.4

ID no	FR-IM04	Category	Functional – Interface Management		
Description	Interfaces will have full internet connectivity and browsing capabilities.				
Justification	Only 11% of students have not used recipes when cooking. Internet would provide a capability to find recipes, instructional videos, and anything else available online.				
Reference	Appendix 1 – 1.3				
Timestamp	07/04/2014	Importance	4	Version	1
Change information	N/A				
Testing Criteria	Must have capabilities to install and run any commercial internet security package. Must not lack any functionality that can be found on any device-equivalent internet browser.				

A full list of the requirement specification can be found in Appendix 4.

7.6 Requirement Specification Template

A template to display these requirements in a specification was provided by the IEEE.[66]

Template of SRS by stimulus

X. Specific requirements

X.1 External interface requirements

X.1.1 User interfaces

X.1.2 Hardware interfaces

X.1.3 Software interfaces

X.1.4 Communications interfaces

X.2 Functional requirements

X.2.1 Stimulus 1

X.2.1.1 Functional requirement 1.1

….

X.2.1.n Functional requirement 1.n

X.2.m Stimulus m

X.2.m.1 Functional requirement m.1

….

X.2.m.n Functional requirement m.n

X.3 Performance requirements

X.4 Design constraints

X.5 Software system attributes

X.6 Other requirements

7.7 Limitations of Requirement Specification

Due to the scope and time constraints not allowing for extensive research on this project, it is only possible to produce extensive functional requirements. These are all listed within the objects from the template above. Although some non-functional requirements have been created, these are liable to change due to improvements and changes technology as time goes on. It is also difficult to create detailed non-functional requirements without the required expertise and in depth knowledge into systems such as these. For these reasons,

[66] IEEE, 1998. *IEEE Recommended Practice for Software Requirements Specifications. Journal*. [ONLINE] pp. 24 Avaliable at: http://www.math.uaa.alaska.edu/~afkjm/cs401/IEEE830.pdf. [Accessed 30 April 2014].

sections; '*Design Constraints*' (*X.4), 'Software System Attributes' (X.5) & 'Other Requirements' (X.6)* have been omitted from the specification.

Sections labelled *'User interfaces'* (*X.1.1), 'Hardware Interfaces' (X.1.2), 'Software interfaces' (X.1.3), Communications interfaces (X.1.4) and 'Performance Requirements' (X.3),* have only a few 'skeleton' requirements contained within them.

An advantage of ordering the requirements in regard to their importance is it can allow easy visualisation of the most important requirements.

8. Requirements Analysis

The success of the requirement specification has been proven in the interviews as it was apparent from the responses that all problems highlighted were solved to the best possible degree. It is important to also assess how successful the requirement specification was in keeping with the standards of the IEEE. This will be done with an analysis on the attributes and characteristics previously outlined in section *7.3*.

8.1 User analysis

Figure 2 depicts the average importance rating for each stimulus. As you can see from this, the important stimuli of the kitchen seem to be; 'Interface Management' – the abilities of the system interfaces. The 'System Control' – The methods of controlling the system, and 'Cooking Control' – the functions of the system that allow it to cook. Through analysis it emerged that the traditional functions of a kitchen, and the aspects that make it pervasive, are the most important facets in its design. Other functions, although deemed useful, are not integral to the running of the system as a whole.

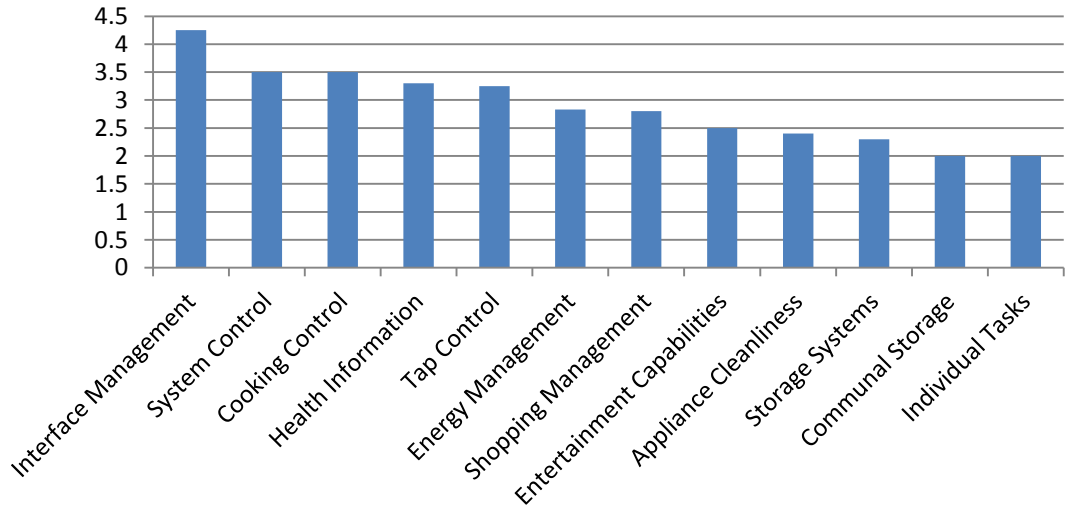

Figure 2 – Average importance of each Stimulus within the system.

8.2 Requirement Characteristics Analysis

Where possible, the IEEE regulations on the characteristics of a requirements specification have been upheld. The instances where the requirement specification does not completely meet the standard are 'Correct' and 'Complete'. On an abstract design of a system it is impossible to ensure that the requirements of the system are 'Correct'. This is because in

order to analyse the correctness of the requirements, there needs to be a completed system to compare the requirements against. The requirements have been deemed as complete as possible due to the results from the interviews, as no other functions could be thought of. As previously mentioned, it was not possible to create all non-functional requirements due to the timescale and nature of the project. The functional requirements are however, complete.

The other characteristics have been met however:

- **Unambiguous**

  The requirements have been thoroughly checked for ambiguity. Any confusion on specific requirements in the follow-up research was noted and the requirement was re-worded.
- **Consistent**

  As proven in the full requirement specification (Appendix 4), each requirement written into the same template.
- **Ranked for Importance and/or Stability**

  Each requirement has an importance rank assigned. They are also ordered for importance within the stimuli, which itself is ranked.
- **Verifiable**

  Each requirement has detailed testing criteria attached to it to ensure that they can be verified.
- **Modifiable**

  A framework of the requirements is in place to allow changes to be made to the requirements that will not cause any disruptions to the system as a whole.
- **Traceable**

  Each requirement has a unique identifier and is located within a table of contents.

8.3 Conclusion

In conclusion, the requirements specification, although not complete with non-functional requirements, satisfied the parameters of the problem. The functional requirements coincide with the IEEE characteristics while solving the initial problem of the project; creating a pervasive kitchen to solve problems within a student kitchen. There were problems highlighted in the original research that were not completely solved by the technology due to the need for human effort, although each problem does have an attached functional requirement that helps to solve the problem. These problems and their technological solution were:

- **Bins not being put out**
    - Sensors were placed on the bins to provide notification when they were full.
    - A cleaning rota was inbuilt into the system.
- **Storage Space**
    - Despite system features that remove the need to allocate separate cupboards to users, limitations exist with the physical dimensions of the kitchen.
- **People not washing up**
    - The two minute dishwasher will help, but it still requires human effort to load and empty the dishwasher.

9. Feasibility analysis

The technology that was researched and the functional requirements developed, proved it was theoretically possible for a system such as this proposed one to be developed. The following is an analysis on the feasibility of the system as a whole. It is important to mention that while the system may be technologically and fiscally unfeasible at the moment, pervasive technology is in its infant stages of development and the achievability of the system in the *near future* will be explored.

To complete the feasibility analysis, the influences and constraints on pervasive technology will be assessed, and a brief SLEPT (Social, Legal, Economic, Political and Technological) analysis will be employed.

Essentially the system aims to solve all current problems in a student kitchen while introducing the concept of pervasive and ubiquitous computing into student homes by using advanced technology to automate and ease processes. In order for the proposed system to be introduced into student homes it is necessary that everyday homes will start to adopt pervasive technology. Student housing would then be forced to keep up with housing standards and have no choice but to follow suit once pervasive homes become the norm. As with any emerging technological product it is traditionally expected to be adopted early by the wealthy and will eventually be filtered down to other households once the technology becomes cheaper and readily available. For this reason the following analysis will be mostly relevant to the introduction to pervasive techniques in the normal, everyday household, referring to the kitchen where possible, instead of analysing the feasibility of releasing the system immediately into a student specific housing market.

9.1 Costs

As the following report will explain, the market for emerging technology is going from strength to strength. A lot of new companies are introducing 'Smart' home appliances that range from entire entertainment centres, down to individual light bulbs. The household is becoming more technologically aware and some of the new technologies previously highlighted in section: *6. Emerging Technologies,* are only the tips of the iceberg in the development of connected devices in a large 'Internet of Things'. Any emerging technology or technological advancement is usually expensive to purchase and implement, meaning the

initial potential customer base will be limited to the wealthy. For example, a Smart light bulb set would cost a user approximately £54 per bulb, 121,000% higher than equivalent standard bulbs that can be bought as cheaply as £0.45 per bulb.[67]

Due to the youth of pervasive technology within homes, a lot of the technology has not reached the production stages, meaning that any smart technology in the home is usually only communicated through the use of physical interaction or smart phone acting as 'middle-men' of the communications between devices. There is no 'grid' of communicating appliances.

There is no incentive for landlords to purchase and install such equipment, at risk of theft or damage, at a high cost unless it gave them a competitive advantage, which it would not do, until it is more commonplace in regular homes.

The lack of a current demand does not mean that in the near future, demand for this system would not increase dramatically. If the current trend of devices coupled with the predictions of 'Moore's Law' increases, connected devices will only become cheaper and more ubiquitous in everyday life, Inevitably causing exponentially increasing demand.

9.2 'Smart' Device Market

As you can see in *Figure 3*, smart phone ownership has increased sharply in the US alone.

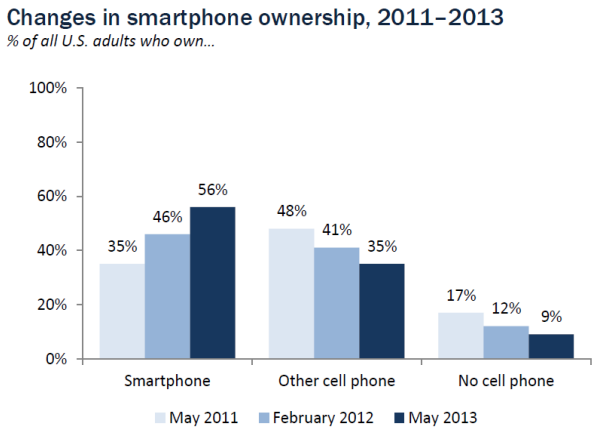

Figure 3 – Changes in smartphone ownership, 2011-2013[68]

[67] *LIFX Store, 2014* [ONLINE] Available at:http://store.lifx.co/. [Accessed 30 April 2014].

[68] Smith, A. 2013. *Smartphone Ownership – 2013 Update, Pew Research Centre. [ONLINE] Available at:http://boletines.prisadigital.com/PIP_Smartphone_adoption_2013.pdf. pp 2-12. [Accessed 30 April 2014]*

In two years – from May 2011 to May 2013 smart phone ownership has increased by 21%. Based on a US population of approximately 317,000,000, over 66,000,000 more smart phones have been purchased over two years in the US alone. It is predicted that currently over 1 in 5 people on the planet own a Smart phone.[54]

Household Income			
Less than $30,000	22	34	+12*
$30,000-$49,999	40	46	+6
$50,000-$74,999	38	49	+11*
$75,000+	59	68	+9*

Figure 4 – Changes in smartphone ownership based on household income 2011- 2012.[69]

From this *Figure 4* it is clear to see there is no trend between household income and purchasing of Smart phones. This could be either because of relatively low costs of purchasing them, due to Moore's Law and/or Automated mass production, or the fact they are 'must-have' items. Either way it further proves the assumption that there will be a need and very large market for such a pervasive kitchen system in the near future regardless of the initial costs.

Research undertaken from Morgan Stanley in 2012 goes to re-enforce this hypothesis.

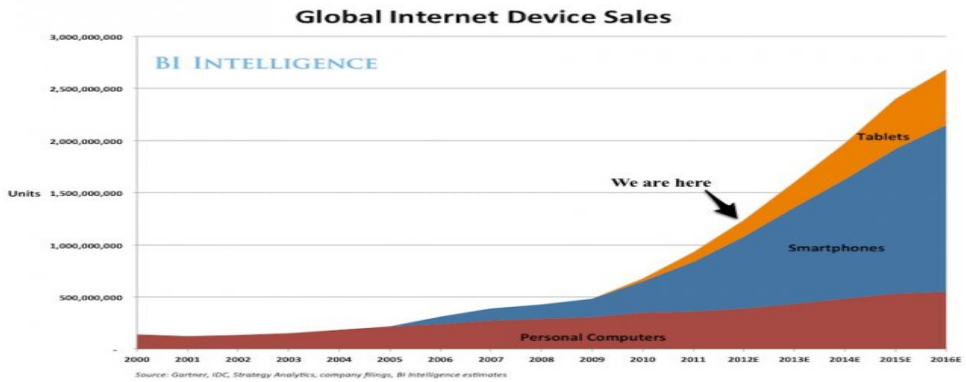

Figure 5 – Global Internet Device Sales [70]

It is apparent from *figure 5* that there is a sharp increase of internet device sales. The number is increasing almost exponentially and it estimated that in two years the amount of connected devices will exceed 2.5 billion. With the computing and smartphone industry

[69] Smith, A .2012. *46% of American adults are smartphone owner.* [ONLINE] Avaliable at http://www.pewinternet.org/files/old-media/Files/Reports/2012/Smartphone%20ownership%202012.pdf. pp 4. [Accessed 30 May 14].

[70] BI Intelligence & Morgan Stanley, 2012, *Global Internet Device Sales* [ONLINE]. Available at:http://www.energise.co.nz/blog/internet-news/smart-phone-growth/ [Accessed 30 May 14].

always developing and evolving and with the sharp increase in sales it is not unreasonable to assume a culture of 'early-adoption' where consumers purchase the latest version or technology, explaining the ever increasing trend.

As new technology is introduced into the market it is inevitable that there will be a market in the future for pervasive systems.

New, more advanced Smart systems seem to have a much faster penetration into the market as well. Tablet penetration hit 6% within 2 years. This is almost double as fast as the Smart phone when it was conceived, which took nearly 4 years. The *Figure 6* shows the gradient of device penetration per capita, as you can see it is only rising and shows no signs of slowing.[71]

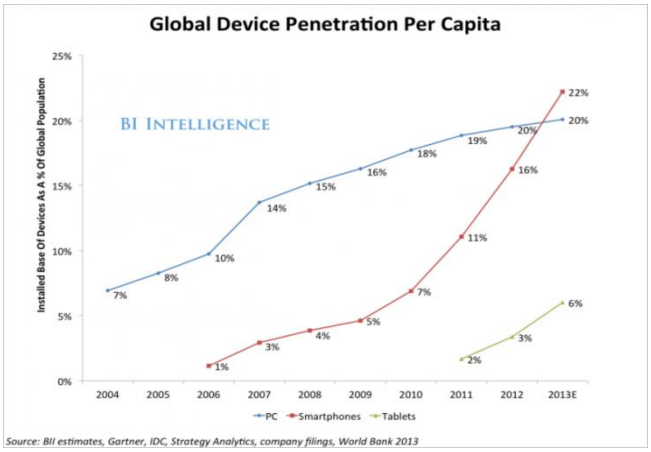

Figure 6 – Global device penetration per capita

9.2.1 IPv6 and the progression of connected devices

The depletion of unallocated IP addresses has been anticipated since the 1980's.[72] IPv4 allows a total of 4,294,967,296 (2^{32}) networked addresses. With an estimate of approximately 7,162,000,000 people alive on the planet IPv4 only allows, on average, 0.6 devices connected to the internet per person. Even ignoring the populace of LEDCs (Less Economically Developed Countries), who's infrastructure does not support the use of widespread internet access, the numbers for devices per person are alarmingly low. This is

[71] BI Intelligence, 2013. *Global Device Penetration Per Year* [ONLINE]. Available at:http://static4.businessinsider.com/image/525c66a369bedd583b84c278-960/global%20smartphone%20shipments-3.png [Accessed 30 May 14].

[72] The Internet Corporation for Assigned Names and Numbers, 2013. *Available Pool of Unallocated IPv4 Internet Addresses Now Completely Emptied*. [ONLINE] Available at:http://www.icann.org/en/news/press/releases/release-03feb11-en.pdf. [Accessed 30 April 2014].

the reason IPv6 was developed. IPv6 will support the rapid growth of connected devices by offering a vast number of possible addresses, and therefore internet capabilities, for emerging devices. With IPv6, possible address spaces has increased from 2^{32} (IPv4) to 2^{128}. This means there is a possible number of over $4.7x10^{28}$ addresses per person.[73]

9.3 SLEPT /TELOS analysis

A 'TELOS' analysis refers to the 5 areas of feasibility – Technical, Economic, Legal, Operational, and Scheduling. The first three factors (Technical, Economic, Legal) overlap with a SLEPT analysis, while the last two factors (Operational, Scheduling) have been covered in this report. The Operational header refers to "*how well a proposed system solves the problems, and takes advantage of the opportunities identified during scope definition and how it satisfies the requirements identified in the requirements analysis phase of system development".*[74] This is covered in section 8.3 of the requirements analysis. The Scheduling header refers to an estimation of how long the project will take to develop, something touched upon in the conclusion of this section of the report.

A SLEPT analysis has also been undertaken to add depth to the analysis. 'SLEPT' looks at the Social, Legal, Economic, Political and Technological, constraints and advantages of pervasive computing in homes. A SLEPT analysis is also used because it gives an accurate description of the macro-environment the product would be released into. Although it is a tool mostly used in strategic management it is relevant to this project due to the relevance of every aspect of the analysis. Each section of the SLEPT analysis will affect the development and production of the system and should be considered when carrying this project on to completion.

9.3.1 Social

As previously mentioned, the social pressures of adopting the latest technology are great. The household has been a point of pride, and figure of social standing for decades due to its reflection on a person's income – a traditional factor of social status[75]. The installation of a

[73] S. Deering, R. Hinden, 1998. RFC 2460, *Internet Protocol, Version 6 (IPv6) Specification*.
[74] Bentley, L & Whitten, J (2007). *System Analysis & Design for the Global Enterprise*. 7th ed. (p. 417).
[75] AB Hollingshead, 1975. *Four Factor Index of Social Status – Yale Journal of Sociology. [ONLINE] Available at:* http://elsinore.cis.yale.edu/sociology/yjs/yjs_fall_2011.pdf#page=21. *pp. 26-40[Accessed 31 April 2014].*

pervasive kitchen will be a key selling point for any home and status symbol for any homeowner. Social pressure to be an 'early-adopter' and keep up with the modern technology will only support and reinforce the growing pervasive market.

In the pervasive household, and the pervasive kitchen plan outlined, there is a lot of safety features involved, whether it is smarter fire detection or induction cooking, the risk of accident will decrease. Health and safety is paramount in any development of technology and can even prove to be strong selling points for manufactures.

According to the 'Royal Society for the Prevention of Accidents' (RoSPA) study in 2002 the kitchen area was one of the largest specified areas within the home to be the place of personal accidental injury, with almost 10% of accidents occurring in the kitchen.[76] Notably the other largest area for accidents was the 'dining area' – an area often combined with the kitchen in student houses. These two were the setting for 1 in 5 estimated household accidents. The kitchen is also the cause of the most house fires, meaning the safety features of the proposed system will only prove to strengthen the demand for pervasive systems.

9.3.2 Legal

Legal constraints will be a big issue with the proposed system and the technology involved in it. Copyright laws will be an issue to overcome, especially when employing technology from a range of different companies. If a company has invested a great deal in research and development of a new technology, patenting laws will prevent other companies from adopting their advancements in a new system. This will mean that in order for one company to create an entire pervasive kitchen as a product they will either have to affiliate themselves with a multitude of different companies – difficult with large developers in oligopolised markets, or develop, or purchase all the technology themselves. Should companies have to develop or purchase the companies who have developed the technology it would likely set back the rollout times of the system. There would also likely be a rigidity to the system as technology companies, notably Apple, often implement functions that are not cross compatible with other systems , for example 'Facetime'. This

[76] Home and Leisure Accident Surveillance System, 2002. *Home and Leisure Accident Statistics. [ONLINE] Available at:http://www.hassandlass.org.uk/reports/2002data.pdf. [Accessed 30 April 2014].*

technology ensures video calling is not possible over different operating systems. This hypothesis is reinforced by the previously mentioned purchase of Nest by Google.

Implementing a system full of technology from different developers would be a legal minefield. A notable example of this is the lawsuit that Apple won over Samsung over disputes of copying software.[77]

9.3.3 Economic and Political

As already outlined in section *9.2*, the economic potential for this system is massive. With the market only growing, purchasing, installation and supplying on a large scale will provide large benefits to any macro or micro economy. With this developing market and the potential it has, opportunities are abundant for established or new companies to seize. It would require organisations to be versatile and could have adverse effects on companies and small business that do not have the capabilities to adapt.

As the technology is still only just creeping its way into households and fully pervasive households are still on the horizon it is impossible to predict any economic obstacles, such as interest rates, exchange rates, inflation rates etc.

It is unlikely that the government will intervene significantly more than they already do with the industry. This being said, with the previously described increase in technology sales there will be an almost equal rise in imported electrical goods. The government may have to reconsider tax legislation on the imported goods, although without the knowledge to create financial analysis and the turbulence of markets, it is impossible to state the effect this will have on the development of pervasive kitchens in this report. As mentioned in the social heading, due to the safety features of the kitchen should look to reduce accidents, and ease a slight strain on the NHS.

With technology growing and spreading into other markets so fast it will be a priority for governments to ensure that the global market for technology is not controlled by the small number of corporate giants who have the resources to develop and control the market.

[77] The Guardian. 2014. *Apple sues Samsung for $2bn as tech rivals head back to court.* Article. [ONLINE] Available at: http://www.theguardian.com/technology/2014/mar/31/apple-sues-samsung-for-2bn. [Accessed 02 May 2014].

Foreign companies controlling global markets of such magnitude could have real noticeable effects on the macro economy of a country that relies heavily on imports.

9.3.4 Technological

The demand for technological advances is only increasing as outlined in section 9.2. The highlighted result also proves the technology and technological infrastructure is already in place to implement such a proposed system. Given a healthy budget and the removal of copyright laws, companies could begin producing the system as a whole almost instantly. Technological companies with the might and wealth to implement a system like this would also have the manufacturing capabilities to roll out the new technology on a large scale.

The rate of technological change could be an issue with the nature of pervasive computing. With the costs associated with research and development, the costs of introducing a new product into the market can be unfeasible with the short estimated lifespan of technological products – For example, Apple release a new iPhone approximately every year meaning phones are almost immediately out of date as they are purchased. Companies will be wary of rolling out a new product at great expense, only to have it replaced with a new, more efficient and advanced technology in a year or two in such a new market. For example, a new technology is being conceptualised currently, that allows basic control of machines using electrical signals generated from thinking. Currently it is possible to control basic operations on a robot with a 'Brain-Computer Interface' or 'Mind-Machine Interface'.

Although it has been conceptualised since the 1970's, only recently has it looked to become available, despite its imprecision, on a consumer market.[78] This technology still has a long way to go before it is fully effective at controlling multiple appliances in the kitchen, but it is on the horizon and could be a factor holding back the development of the system proposed. The system could be seen as not cost-efficient due to its redundancy in the near future with other technologies, such as mind-control technologies emerging.

[78]Progue, P. 2014. *6 Electronic Devices You Can Control with Your Thoughts - Scientific American*. [ONLINE] Available at:http://www.scientificamerican.com/article/pogue-6-electronic-devices-you-can-control-with-your-thoughts/. [Accessed 02 May 2014].

9.4 Feasibility Conclusion

Despite the complications, notably legal and economic, due to the potential market size, current investments in emerging technologies and the emergence of pervasive technologies in homes coupled with social pressure, it is almost a certainty that the pervasive home is looking to be normality in the near future. By extension, with the constant development of technology and the market showing no danger of slowing down, the pervasive environment in the student household is inevitable. With this being said, it is highly unlikely due to legal, economic and other, issues that a whole completed system will be introduced as a whole. It is more likely that in order for a home to become pervasive, technology will have to be installed almost one function at a time.

With the current costs and ever-changing market with technology, it is only speculation when this technology will be common place in the normal household. Whenever that date comes, it will certainly be even further down the line for the student household.

10. Future Work

The feasibility analysis *(8)* showed that the topic of this project is not only realistic, but also highly likely to be implemented in the future.

10.1 Requirements Modelling

Given more time, a main objective that would look to be accomplished would be designing the visualisation of the functional requirements. To do this UML tools would be utilised. Use case diagrams are commonplace in requirement sections of design reports as they allow a visualisation of the outlined requirements, and how they work with one another. This will enable somebody carrying on with this project to envisage the requirements, their uses and purposes. It would also show to any future designer the extent of the 'pervasiveness' of the kitchen, i.e. the extent of the interaction by a user, or actor, in the system and could highlight need for alterations in the requirements specification itself to either better solve the problem or increase the pervasiveness of the system.

To further allow visualisation of the processes in a student kitchen, an activity diagram would be designed. This diagram represents actual workflows in a graphical manner. This method of visualisation most accurately represents the vision for the pervasive student kitchen that could get misinterpreted by a reader of this paper, despite every effort to keep the requirements specification unambiguous. Essentially this diagram would be a way for future developers to understand how the requirements are relevant to solving the initial problems of the current student kitchen. It is almost a 'dry run' for an abstract system.

10.2 Next Stage of Development

Although preliminary design is external to the scope of the project, assuming a sequential design process using an spiral 'Waterfall Method', after the functional requirements have been specified the next stage would be to design both the software and hardware of the system, before iterating round to then address a complete non-function requirement design.

10.2.1 Design

As a start has already been made in looking at emerging technologies, more specifically, into the hardware that would be needed, the next stage would be to look at the software

interface design. In the brief it was specified that although this project would outline a conceptual design, the aesthetics and hardware choices of the kitchen would be down to a designer who would continue the project where this report left off.

10.2.1.1 Class diagram

With the requirements and processes modelled, the next stage undertaken would be design of the User interface. The pervasive kitchen conceptualised is centred on the interfaces as they control every aspect of the kitchen. The approach to designing this would be in two stages. The first would be to design and model the relational databases. This would be done by adopting another UML technique; Class diagrams. This will show the operations and relationships between each class/function of the system.

10.2.1.2 User Interface design

After the class diagrams are completed the next stage would be to design the user interface (UI). This would be done using a programme such as 'Microsoft Expression'. This allows a semi-functioning interface prototype. Essentially it has the capability to create a fully functional 'front-end' of a system without the 'back-end'. It allows visualisation of interface processes and capabilities. This can be then heuristically analysed and provide a design for software designers to create the software.

11. Conclusion

11.1 Variations from Initial Plan

The initial plan had to be flexible. As pervasive systems are a young concept it is difficult to know exactly what deliverables the project needed to provide. Progressing throughout the project it became apparent that some of the proposed deliverables were not relevant or realistic with the system. Although SSM modelling was originally scheduled as a deliverable it was not deemed relevant to the project and had there been enough time, UML modelling would have taken its place. In its place the report contains research into emerging and current technologies that can be used to support the systems design, a task that was not highlighted in the initial plan, but necessary to couple with the feasibility analysis.

11.2 Aims

The primary aim of this project was to create a detailed requirement analysis describing an abstract design of a system that would detail ubiquitous, pervasive technology to solve problems in a student kitchen. This aim has been completed to an adequate degree. All problems highlighted in both stages of research have been satisfied to the best degree that technology can realistically solve the problems. In essence, if it were possible for technology to solve a problem highlighted, it has been solved. Some problems highlighted were problems that could only be helped with technology, for example it was highlighted that bins in a student kitchen weren't emptied often enough. Technology can only help with solving this problem as it requires human input to physically remove bins. This success in solving problems was proved by further research.

With the nature of this project and realistic time constraints it was never possible to create a fully completed requirement specification. Although all functional requirements have been covered to solve the problems, realistically, with such a complex system made up of a large number of different functions the expectation a complete requirement specification was extremely unreasonable. Without the technical knowledge, or testing criteria on certain functions it would be an impossibility to list every requirement. Realistically, a team of experts would be needed to create a requirement specification for the voice control aspect of the system, and that function is only one of many in the whole system. To create the proposed system from scratch would require thousands of requirements to cover every

technical aspect. This is obviously grossly unfeasible for a project of this nature. With this in mind however, the requirement specification does address every problem outlined in the research and the analysis through stakeholder interviews reflected the success of the requirement specification in solving problems in the student kitchen.

The secondary aim of this project was to undergo a feasibility study on the proposed system. Due to the distance of the technology becoming common place, the uncertainty on interfering forces (future technology, economic sanctions etc.) meant the results from the study were mixed. Despite the barriers to the application of the proposed system, with the growth of the market and progression of technology, the feasibility study highlighted the almost certainty of pervasive kitchens, with very similar requirements and functions to the system proposed in this report, becoming common place in homes as the technology is already either readily available, or currently being prototyped.

With hindsight and the results from the feasibility analysis (8), should this project be completed again, a fundamental change in the scope would be undertaken. As it was deemed unfeasible and unlikely that a pervasive system would be designed as a whole, the scope and aims of the project would be steered towards looking creating a requirements analysis of a framework of a pervasive kitchen that would support the introduction of various different pervasive technologies. This would be more in-keeping with the way that pervasive technology is filtering into the household.

To sum up, the main purpose of the project has been satisfied. The outlined problems have been solved with the requirements drawn and the feasibility analysis indicated it would be almost certain for pervasive technology to find its way into homes. Despite this it is unlikely, though not impossible, that a whole system would be developed to combat student specific issues.

12. Reflection

In the design of this report I feel I have learnt a lot about the processes of designing an abstract system.

The large amount of research that was necessary for just a small section of the development cycle was a shock. It gave me an appreciation of the scale of a similar sized project. If I was a part of a larger team creating a system such as this, mistakes that I made throughout designing this report would have bigger implications in real-world industry.

This project was inevitably going to slightly vary from prior plans, as new directions in which I could take the project constantly appeared. Because of this, I quickly learnt the importance of proper documentation of everything. Some of the most time-consuming and frustrating aspects of this report were ones where only slight changes were made, but due to a lack of planning and thorough documentation, these small changes had an unanticipated knock on affect to the whole document. I found even the smallest changes caused continuity errors and even made whole chunks of text irrelevant. As I couldn't remember every decision that I had made throughout the project, when it was time to re-read the document there was confusion and doubt on the overall direction and deliverables of the project. I learnt it was very time-consuming ensuring that every section was still relevant to the initial problem of the project. I recognised the need for proper documentation and change management in projects to provide a means to make necessary changes and alterations throughout the report without damaging the integrity of it.

Should this be a larger project with other working alongside myself, even the smallest undocumented change can snowball into a much bigger problem that is can be potentially very difficult and time consuming to fix and can potentially result in deadlines being missed.

Time management was another thing that I felt is an important lesson. Although a rough time management plan had been outlined, as the project varied slightly from the planned deliverables it also varied from the time budget. Due to my own fault the workload wasn't spread equally over the time allocated, it meant that towards the latter stage of the allocated time, working on this project involved a lot of late nights, which in turn, affected the quality of writing and took a lot of time to correct. In that respect, I learnt that working

long hour days was almost counter-productive. After I started to use detailed time-plans coupled with mini-deadlines, I felt that I was much more productive and motivated as the progress I was making was more apparent.

With regards to specific skills I feel that I have a much better grasp on creating high-quality requirements for any project. A lot of reading went into the methods for creating professional and usable requirements, and although due to the unavoidable time constraints of this project, some requirements didn't contain as much content as they could, I feel I have learnt the skills that are necessary to create industry-suitable requirement specifications.

This report is a point of pride to me due to the amount of effort in it. All mistakes I made throughout its creation were taken on board and learnt from, and I think that this project has better prepared me for the technological industry.s