Play With Your Food

Tackling Fussy Eating in Children by Digitally Augmenting Meals

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Abstract

Persuading children to eat healthily has always been a challenging issue. Parents and guardians commonly have trouble with encouraging young children to eat their vegetables, who often prefer less wholesome alternatives, this can cause various diet and health related problems. To date, research involving digitally augmenting food has been primarily targeted at adults and in restaurant settings. This project shifts the focus towards children and evaluates the effect of using technology on behavioural change in eating habits. It seeks to alter the context of 'playing' with food, through the use of persuasive technologies by presenting 'FoodWorks!', a system designed to digitally augment food and provide rewards for completion of the meal, acting as a behavioural nudge to motivate fussy eating children to eat their vegetables.

A literature review was conducted to better understand the context surrounding digitally enhancing food, nudging techniques and persuasive technology for behavior change, and the current methods employed to encourage children to eat well. Various sketches and ideas were created to explore possible augmentations, and from these, three Wizard of Oz studies were conducted with different families to research the potential effectiveness of the approach. Based on these results the FoodWorks! system was designed which tracks the position of vegetables on a plate by colour, projects multicoloured lights onto them and awards virtual rewards for completing the meal. FoodWorks! was implemented using OpenCV and Visual C++, utilizing a HD camera and a pico projector. A comprehensive testing and implementation approach was undertaken that confirmed that FoodWorks! met the requirements.

User studies were then conducted with 7 families with children aged between 3-9. The focus of the studies were the social interactions between the parent and child regarding FoodWorks! and the effects it had on eating behaviour. Detailed analysis followed, noting behaviours and responses to help yield a better understanding of the experience it provided. The results from the studies demonstrate that the techniques adopted and the use of FoodWorks! has an overall positive effect on the eating habits of children.

Contents

1 Introduction

1.1 Problem Statement

Many parents face the daily challenge of getting their children to eat a balanced diet. Peer pressure and adverts often make sweet treats and junk foods more appealing than healthy, home cooked meals. In some cases, children have the problem of eating varied meals, perhaps never touching certain vegetables or even eating the same thing repeatedly. Techniques such as the well known aeroplane game, where parents pretend cutlery with food on is like a plane and fly it towards the child in the hope they will open their mouths and eat the food, although sometimes effective, may not be enough. Consequently, parents are having to resort to new ways of dealing with fussy eating, such as hiding vegetables in cakes [46], changing the setting of meal times [47], or giving food fun names like 'cowboy chicken' [48].

Current methods to stimulate healthy eating do not take advantage of the fact that children today are early adopters of technology. This project attempts to push the boundaries of the existing techniques and introduce persuasive technologies for eating related behaviour change through the development of FoodWorks!, an interactive system that nudges children to eat their vegetables by digitally enhancing the food on the plate and providing virtual rewards for completion of the meal.

1.2 Aims and Goals

1.2.1 Aims

- Investigate how different forms of augmented reality feedback can disguise and encourage children to eat food they previously did not like
- Understand background and related work on digitally enhancing food, nudging techniques and persuasive technology, fussy eating and current methods to encourage healthy eating in children
- Practice sketching techniques to create range of initial ideas
- Learn Visual C++ and OpenCV and apply them to building the system
- Design and implement a system that encourages eating related behaviour change
- Enhance skills in conducting ethnographic studies through carrying out pilot and user studies

1.2.2 Goals

- Conduct a pilot study involving children to assess initial ideas for the system.
- Produce a literature review
- Conduct a risk assessment
- Design, build, test a system composed of a camera and projector which does the following:

  - Perform colour segmentation of food on a white plate and track movement of food around the plate
  - Project multicoloured lights onto particular foods on the plate, lights should disappear once food disappears from the scene observed by the camera
  - Project real time positive feed back surrounding the plate once the multicoloured food has been eaten

- Deliver a presentation on the project at Microsoft Research Cambridge
- Write and submit a work in progress paper for CHI 2013 (See Appendix K)
- Complete UCL ethics approval process to conduct user studies
- Conduct user studies
- Obtain and analyse information from the pilot and user studies
- Deliver a user manual

1.3 Overview of Approach

In directing this project, first a wealth of sketches of various ideas were created on ways to digitally enhance food towards motivating children to eat their meals. From these, a few sketches were selected and employed in pilot studies with 3 families to observe their responses to such technologies. Based on these findings a set of requirements were defined on which to construct FoodWorks!. An incremental and iterative approach was followed to design, build and test FoodWorks!. The system was deployed for user studies, and the effect the technology had on eating behaviour and family mealtime dynamics was observed and analysed.

1.4 Overview of Report

Chapter 1 introduces the problem and the main goals. In chapter 2 a literature review is presented on fussy eating children and methods to deal with associated problems, digitally enhancing food and behavioural change. It also highlights the research issues outstanding that have been addressed by this project. Chapter 3 provides an overview of the methodology used to design the system. Chapter 4 describes the pilot study conducted based on the Wizard of Oz approach[33] using a subset of the sketches created in the previous chapter, the findings from these are reported, and an idea is proposed for the construction of the system. In chapter 5 the requirements are defined and a risk assessment is provided. In chapter 6 the design, implementation, system components and functionality of FoodWorks! are explained and key challenges and design decisions are discussed. In chapter 7, the test strategy is outlined and test results are specified. In chapter 8, the planning and methodology for conducting the user study is described, and an analysis with the findings is presented. Finally in chapter 9 evaluation of the project and findings are provided, and recommendations proposed for future work.

2 Background

2.1 Literature Review

2.1.1 Fussy Eating

Fussy eating in children is a worry faced by many parents [42]. A study conducted by the World Cancer Research Fund (WCRF) reported that four out of five children are eating less than the recommended five portions of fruits and vegetables a day [74]. In particular, it has been found that vegetable consumption is 10% lower than fruit consumption [71]. Several schemes have been created to address this issue, Jamie Oliver is trying to raise attention for this problem by organizing a challenge together with open IDEO to "raise kids' awareness of the benefits of fresh food so they can make better choices" [31], similarly the Media-Smart Youth program [43] works to help young people critically assess media messages so that they can establish healthy eating habits. However, these programs are primarily targeted at adolescents, whereas food choices are influenced as children enter school and enjoy more social experiences with friends [10], this requires the need for children to be stimulated to eat healthily from a young age.

Fussy eating can cause meal times to become a battlefield for parents. One method utilized to make their lives easier is hiding vegetables in food that the children do eat, however, specialists find this method controversial, arguing that hiding vegetables fails to encourage them to make the choices themselves [54]. In addition, research has found that kids still may eat foods they know contains vegetables [53], the findings from the study reported that children tasted no difference between food labeled with a vegetable name and the same food without the label, e.g. broccoli gingerbread spice cake vs gingerbread spice cake, consequently, if we are able to educate kids about healthy eating rather than hiding it, they will consciously choose eating vegetables. Other techniques employed by parents include involving children in meal selection and preparation, and offering small colourful portions at mealtimes [49].

Smith et al argue that children refuse to eat food due to aversions towards textures, smells or temperatures or even if they are unfamiliar [62], however, research has shown that judicious use of rewards may facilitate children's acceptance of healthy foods [19]. Early studies have highlighted that rewards such as hugs, tickles, stickers encouraged children to select healthy over non-healthy food [2, 66], and an observational family study found that a food reward (if you eat this, you can have dessert), increased the child's intake of the main meal [52]. Additionally, the effectiveness of a reward system in studies involving taste exposures, where significant increases in intake of a new food was observed after two weeks of daily tasting rewarded with stickers [72]. Consequently, there is a wealth of evidence to suggest that incentivising children, results in change in eating behaviour. Many parents also view this technique as effective and widely put it to use. A survey in the USA found that 55% of parents use rewards as encouragement for their children to eat [16], and studies conducted in the UK [44], Canada [68] and Australia [15] also found similar results.

The family mealtime environment plays a significant factor in motivating acceptance of food, Wardle et al [73] showed that a parental led intervention for children aged between 2-6 holds promise for improving fussy eating situations. Similarly, researchers suggest that in eating together with others, the family teaches children eating practices regarding how to comply or

not to requests to finish their food [39]. Dealing with fussy eaters can be a difficult issue, with the belief that childhood habits could become adult habits [32], and that behaviours at a young age are more malleable [61]. It is consequently necessary to introduce effective techniques that provide the appropriate intervention in young children's dietary habits.

2.1.2 Presentation and Digitally Enhancing Food

The appearance of food forms an integral part of how we perceive it's taste. Zellner et al [75] investigated the effect of the arrangement of food on flavour, they found that neatly presented food was expected to taste better and come from higher quality restaurants than the same food presented in a messy manner. Moreover, certain colours are associated with certain tastes and dietary feelings, blue for example is an appetite suppressant, whereas pink reflects sweetness [18], Spence et al [64] also found that the colour of the plate changed flavour perceptions and likeability. Various artists have experimented with engaging our visual perception of food, through creating art from food; Freymann's 'Food for thought' [25] artistically sculpts various fruits and vegetables into different characterizations, moreover, Warner creates 'Foodscapes' [24]which are essentially landscapes made entirely of food.

Researchers have identified the potential for growth of digitally enhanced food [60], and various methods have been developed to stimulate our senses through fusing technology with food. Heston Blumental's "Sounds of the Sea" dish involves the diner listening to sea sounds whilst eating the meal, this results in the enhancement of it's taste. The creation of this dish is based on research which has shown that sounds affect perceptions of food [63]. Visual and olfactory information can also be manipulated through the use of technology. The Meta cookie [45], combines a head-mounted display (HMD) with an olfactory display to present different kinds of cookies (strawberry, chocolate, tea etc), the visual effects makes the user perceive that they are eating different varieties but in fact it is a plain cookie.

However, these examples are targeted towards adults and restaurant settings. Moreover, it has been argued [7] that current research in HCI has focused on introducing digital artefacts into the kitchen (e.g Cook's Collage and Panavi [69, 70]), but do not recognise that it is a place where people create social bonds. At the dinner table, parents engage with their children by teaching them what is and isn't edible, appropriate preparation methods, and proper eating etiquette [22, 5], research has also shown that parents play an important role in children's perceptions, beliefs and attitudes[57], consequently, it is recommended to introduce technologies in these contexts to augment the interactions [27].

Introducing technology in the kitchen for children, has thus far involved research about teaching kids about making healthier choices in the cooking stage [65]. The Playful Tray project [40] designs a device to reduce poor eating behaviour in children. This work creates an external digital display, rather than directly augmenting the food and aims to lessen the interactions between parent and child during meal times, moreover, the work by Spermon et al [65] showed that children wanted to involve their parents. There is an opportunity in the HCI community to design technologies which digitally enhance food for children, not only as a means to reduce fussy eating, but also as a medium to facilitate and augment family meal time interactions.

2.1.3 Behavioural Change

In order to facilitate behaviour change in people, King et al [37] describe five persuasive strategies which utilise digital technologies, these include the surveillance strategy which monitors and responds to a user's behaviour, environments of discovery, where rewards are given for good behaviour, and personalization, which enhances the persuasion of the technology by tailoring it to the individual's needs. Fogg [23] introduces 42 principles in designing persuasive technology, these include the principle of conditioning, where technology employs positive reinforcement to shape behaviour, the principle of virtual rewards, which states that rewarding target behaviours in the virtual world influences people to perform the behaviour more frequently and effectively, and the principle of attractiveness, where technology that is attractive is likely to be more persuasive. Consequently, such factors must be taken into account when designing technology for eating related behaviour change in children.

Persuasive technology has been widely used to target various behaviours. Rogers et al [56] have explored whether ubiquitous technologies can nudge people to take the stairs over the elevator in their place of work, with findings suggesting the ambient displays drew people towards behaviour change and promoted physical activity. Researchers have also looked at manifesting persuasive technology into everyday objects. Tooth Tunes [67] is a smart toothbrush designed to encourage better teeth brushing in young children, this plays a 2 minute piece of music whilst brushing to reinforce to children they must continue the activity for 2 minutes. CarCoach [1] is an educational car system which employs in built sensors in the car to detect good or bad driving habits, it then provides polite and appropriate feedback to the driver, taking into account the conditions and their mental state.

Through adopting approaches in persuasive technology in this project, we can facilitate observable behavioural improvements, through inviting children towards disliked foods, detection of activity and providing appropriate responses to behaviour.

2.2 Research Issues

As shown by the literature review, schemes to tackle fussy eating have been primarily aimed at adolescents, without significant emphasis on encouraging young children to make healthier choices. Moreover, research in digitally enhanced food is an emerging field and has thus far been focused on adults and in restaurant settings. The research that does involve employing technology to deter fussy eating, has been targeted either at the cooking stage or fails to facilitate sufficient mealtime interactions to allow parents to engage with their children. Consequently, this project addresses the application of digitally enhanced food and persuasive technologies in a family mealtime environment to nudge young children towards better eating behaviour.

3 Methodology

In designing systems Buxton [14] recommends creation of several low cost sketches in the ideation phase, in order to prevent features becoming too concrete too soon, thus cutting off other ideas. Following this advice and to explore possible system designs, methods including creating Adobe Flash animations, stop motion and story boards were employed. The range of methods were adopted as they enabled the research question to be addressed in various lights, e.g stop motion would facilitate 3D perceptions and direct interactions with food such as moving the meal around, Adobe Flash allows direct augmentation of the food using lights, and storyboards allows exploration of the use of the system over time. The following sketches utilise these methods in various scenarios.

3.1 Guided Eating

With a plateful of food, it could overwhelm children not knowing where to start or what to eat next. In this animation (see figure 1), which was created using Adobe Flash, a number would appear on the item of food you have to eat. Once this was done the next number appears on another item of food.

Figure 1: Guided Eating

3.2 Coloured Plates

Developing on from the idea of guided eating, we have coloured plates. A light projects down onto the plate and changes according to the colour of the food you have to eat next, this was again implemented using Adobe Flash. From figure 2 below we can see that yellow indicated that a banana should be eaten, pink for the apple, and green for the pear.

Figure 2: Coloured Plates

3.3 Characters

Monkey and Penguin are two stop motion animations (see figure 3) which show a character interacting with food on a plate, by navigating around and climbing on the food. Rabbit is an Adobe Flash animation, which projects a rabbit on top of some carrots, a food they are commonly associated with. The notion of using characters was derived from the bento boxes [8] designed by Japanese parents, in which they made food to look like cute and popular characters which children know of and can relate to.

Figure 3: Monkey and Penguin and Carrot Bunny

3.4 Food Games

Gamification is a notion that can be used in non gaming contexts [20]. Researchers have shown that games are effective ways for health-related behaviour change in children, as they provide an immersive environment based on goal setting [4]. Figure 4 illustrates an interactive plate, which awards points for eating two pieces of fruit. It is based on a cumulative points system, when after collecting a certain number points you get a small treat such as a chocolate bar, and with larger targets you can obtain bigger rewards such as a day out to Legoland.

Figure 4: Fruit Storyboard

Day 1 - Eat two fruits a day and win 10 points
Day 2 : Eat two fruits and win 10 points and a treat !. Current total 10 points. Next target 20.
Day 4: Eat two fruits and win 10 points and a treat !. Current total 30 points. Next target 40.
Day 20: Get to 200 points and win a day out to Legoland!. Current total 190 points. Next target 200.

A flash animation was created to extend the idea of the gamification of food and guided eating wherein the participant was given certain portions of the meal to finish within a time limit, with the incentive of winning a virtual badge that would be projected on the plate (see figure 5). Instructions were projected onto the plate, indicating what to eat and the time left, and characters were employed to create a sense of fun.

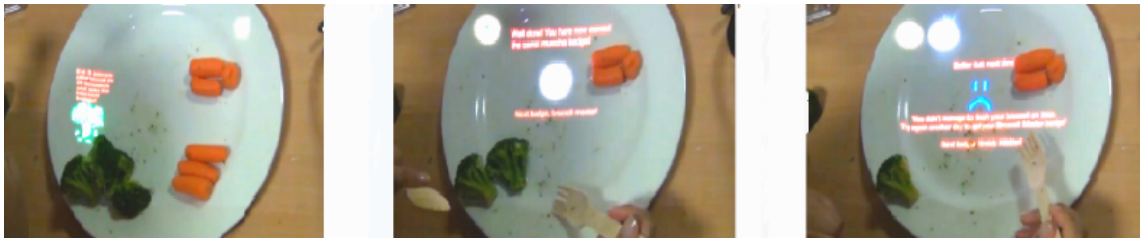


Figure 5: Eating Game and Badges
In the image on the far left the instructions say 'Eat 3 pieces of broccoli in 10 seconds to win a badge', next to an animation of a dancing broccoli. On the top right hand corner of the plate a timer is counting down how much time there is left to finish the portion of food indicated by the instruction. The middle image shows a virtual badge being earned as the target portion of food is eaten within the given time. Badges won are displayed around the top of the plate.The image on the far right shows what happens if the food is not eaten according to the instructions. The text says 'Better luck next time. You didn't manage to finish your broccoli on time. Try again another day to get your Broccoli Master badge! Next badge Nimble Nibbler!'.

3.5 Multicoloured Peas

Children are known to be attracted to a variety of bright colours [48], or foods that they can identify with sweetness [11, 9]. The multicoloured peas animation was created using Adobe Flash, and involved projecting different colours which changed, onto some peas. This made the peas almost look like sweets, however, their presence in meals was not hidden, as parents tend to do in foods disliked by their children, thus, the children are still aware of the real nature of the food they are eating so they can directly make a healthy choice. The left hand image in figure 6 illustrates how this animation worked. This animation was extended so that, when the peas were picked up, they would form a different coloured light on the spoon which would follow the spoon as it left the plate. The animation also displayed a sad face if it noticed that the child was hiding their peas rather than eating them. Since this was a Wizard of Oz animation, care had to be taken to ensure that the spoon was actually following the light, rather than the other way round as would be expected from a fully built system. The remaining two images in figure 6 show the light tracking and the sad face appearing.

Figure 6: Moving Colours and Hiding Peas

4 Pilot Studies

Pilot studies were conducted with 3 families with young children. Scaife and Rogers [58] recommend that involving children in the design process allows us to realize what they found stimulating as the technology is for their use. It was decided to use the eating game (see figure 5) and multicoloured peas (see figure 6) in the pilot studies as they seemed to be particularly effective in creating a structured game play and changing the appearance of food without hiding them.

4.1 Approach

To observe and evaluate the animations, Wizard of Oz studies[33] were conducted. For each study a standard meal of pasta with a side of peas was used, a typical supper the family would have. The studies were split into two parts, so each child could participate with one of the animations, the first involved projecting the colours onto peas, and the second projected the game (adapted for a meal of pasta and peas), without the timer, onto the plate.

4.1.1 Equipment

A pico projector connected to a computer and held up by a tripod was used to project the animations down onto the plate. The meals had to be staggered between the two children as only one set of equipment was available.

4.1.2 Participants

Studies were done in the homes of 3 families to ensure a natural, comfortable setting. This also allowed for observation of the reaction of the parents/guardians as well as the children.

Family 1 Family 1 had two boys aged 4 and 6. As the game required understanding of instructions and some reading ability, it was employed with the older child, and the multicoloured peas animation was used for the younger boy. The children were supervised by their mother. The 4 year old did not particularly like peas, however, the 6 year old was generally not a fussy eater.

Family 2 Family 2 had two girls aged 2 and 4. The game animation was used with the 4 year old, who required a large amount of assistance with the reading from the parent, and the multicoloured peas was used with the 2 year old. During the meal, both parents were present. The 4 year old disliked peas, and the 2 year old was impartial to vegetables.

Family 3 Family 3 had a boy aged 7 $\frac{1}{2}$ and a girl aged 5. The game was projected onto the plate for the boy, and the multicoloured peas for the girl. Both parents, and an older brother aged 14 were present. The girl aged 5 was not a fussy eater, however the 7 $\frac{1}{2}$ year old boy disliked pasta.

4.2 Findings

Multicoloured Peas It was commonly found that sampling was done from the coloured area of the plate, and the children would also often place food in these regions. The 4 year old boy from Family 1 said he preferred pasta to peas, but it was observed that he would finish all the peas first and then push the pasta into the glowing area of the plate, he would also become distracted by placing his hand under the projector and allowing the lights to appear on his hand exclaiming 'now I'm glowing!'. In Family 2, the 2 year old, placed the peas on the lighted dots and ate from these areas. The 5 year old from Family 3, also responded in a similar manner, and pushed the food into the coloured parts.

The children from Families 1 and 3, with exception of the 2 year old from Family 2, who was too young to fully articulate, also seemed keen on the notion of the colours following the food on the plate. The 4 year old from Family 1 liked the idea and said he also wanted it to 'disappear once [he] ate it'. Similarly, in Family 3, the 5 year old said that she prefers brighter colours and 'want[ed] the colours to stay on the food when [she] move[d] it around'.

There was also a lot of conversation created by the parents in all the families, to focus the child's attention on the glowing dots. In Family 1 the parent referred to the peas as 'disco peas', and hinted they were 'magic' asking the child 'do you think you will glow if you eat glowing food?'. In addition, with Families 1 and 2, the parents suggested that the peas 'taste yummier when it's glowing'. This illustrates that the technology was used as a cue to support parents' own persuasive techniques. Finally, another key finding in the case of the multicoloured peas, was with the elder sister in Family 2, who disliked peas. Although she was not taking part in this animation, she was intrigued by the colours and was motivated to try some, thus confirming the nudging effect of this technology.

Food Game The game was found to have an unexpected educational quality as the child, and in some cases with the help of the parent, tried to read the instructions. This shifted the attention from the meal, which may be beneficial in breaking up the task of eating. It was also noted that parents would create stories out of the characters appearing next to the instructions, with phrases such as 'Oh look who it is! It's Bernie the bowl!' and 'you won't be making the characters happy if you don't eat your food'.

With each family, once the child was told they would earn a virtual badge if they followed the instructions, they promptly abided. The effectiveness of this incentive can be illustrated in each case. In Family 1 the 6 year old was asked if they would like a timer counting down the time they had left to finish the food in order to win a badge, they said 'no, because I won't win badges'. In Family 2 the participant did not like peas. There was a stage in the meal where the parent said 'you don't have to finish all those peas if you don't want to', to which she responded 'but then I won't get the badge' and continued eating her peas. Finally, in Family 3 the participant disliked pasta, however, at the end of the meal he said, 'I hate eating pasta, but I did it because I wanted the badges'.

4.3 Analysis

From the results of these studies, it was seen that the children were being stimulated to try, and finish foods they may usually dislike, this was particularly evident in the case of the 4 year old from Family 2 and the 7 $\frac{1}{2}$ year old from Family 3. By creating this immersive environment, there is a shift in attention from the food to the animation or the game. This enables the children to engage in fun rather than focus on their meal, which motivates them to eat better.

4.4 Proposed Approach

The animations employed in the studies worked very well in providing a fun, immersive environment to encourage eating related behavioural change. Consequently, it's capabilities and functionalities were enhanced in FoodWorks!. The studies highlighted a couple of key factors which led to the design decisions for FoodWorks!:

- With the multicoloured peas there was a lot of interest from the children, in the lights 'following' the vegetables around the plate, as a result motion tracking and object detection should be implemented in the system.
- During the game, although the children followed the instructions, they did so with the incentive of winning badges. The badges took up a lot of space when projected on the plate, thus, in the system they will be projected around the outside of the plate.

Based on the sketches and findings, the system tracks the movement and projects coloured lights on vegetables on the plate, as these are generally problem foods amongst children. The light corresponding to each vegetable switches off once it has been eaten, and virtual badges are earned at certain points of completion, for example, after eating half or all the vegetables. A detailed requirements and analysis is provided in Chapter 5.

5 Requirements and Analysis

Requirements were gathered from the initial sketches and analysis of data from the pilot studies, this defined the scope of the project and enabled functional integrity to be maintained. The MoSCoW approach was used to prioritise the requirements. The MoSCoW categories are:

M – MUST: These requirements are of highest priority and must be completed. S– SHOULD: This is a high priority requirement that should be included in the project if possible. C– COULD: This is a requirement which is considered desirable but not necessary. W– WON'T: This is a requirement that will not be implemented but may be considered for a future release.

5.1 Functional Requirements

ID	Requirement	Priority
Tracking and Light Projection		
TL.01	The system shall project coloured lights on a portion of the food on the plate	M
TL.02	The system shall track the position of food on the plate and project the light as necessary, as it moves	M
TL.03	The system shall detect when a lit up portion of food has been eaten, and the corresponding light will then disappear	S
TL.04	The system shall project different coloured lights, that change colour as the meal is being eaten	S
Badges and Rewards		
BR.01	The system shall award a virtual badge once half the portion of lit up food is eaten	M
BR.02	The system shall award a virtual badge once all the lit up food has been eaten	M
BR.03	The system shall award virtual badges suitable to children less than 10 years old	M
BR.04	The system shall display the badge outside of the plate	S
Software Interface Design		
SI.01	The system shall have a graphical user interface that allows the users to select foods and display the projection	S
SI.02	The system shall allow the user to select up to 5 different foods to project lights on	C
SI.03	The system shall allow the user to select the colour to project	C
Diner Interface Design		
DI.01	The system shall have an interface appropriate for children	M
Help and Documentation		
HD.01	The system shall contain a help functionality which briefly explains the features of the system and how to use it	M

5.2 Non-Functional Requirements

ID	Requirement	Priority
Implementation		
IP.01	The system shall be implemented using OpenCV libraries and C++	M
IP.02	The system's external hardware shall be composed of a HD camera mounted on a pico projector, both of which shall be connected to a computer	M
Performance and Usability		
PU.01	The system shall completely load under 10 seconds	M
PU.02	The system shall track and project light with a delay of less than 1 second	M
PU.03	The system shall only be used by two users at a time, the child eating the meal and the software operator	M
Availability		
AV.01	The system shall only be available when a parent or guardian is present	M

5.3 Use Cases and Use Case Diagram

Use Cases define the interactions between an actor and the system (see figure 7) and highlight the series of steps needed to achieve a goal and the response of the system to the user's actions. Refer to Appendix L for full list of use cases.

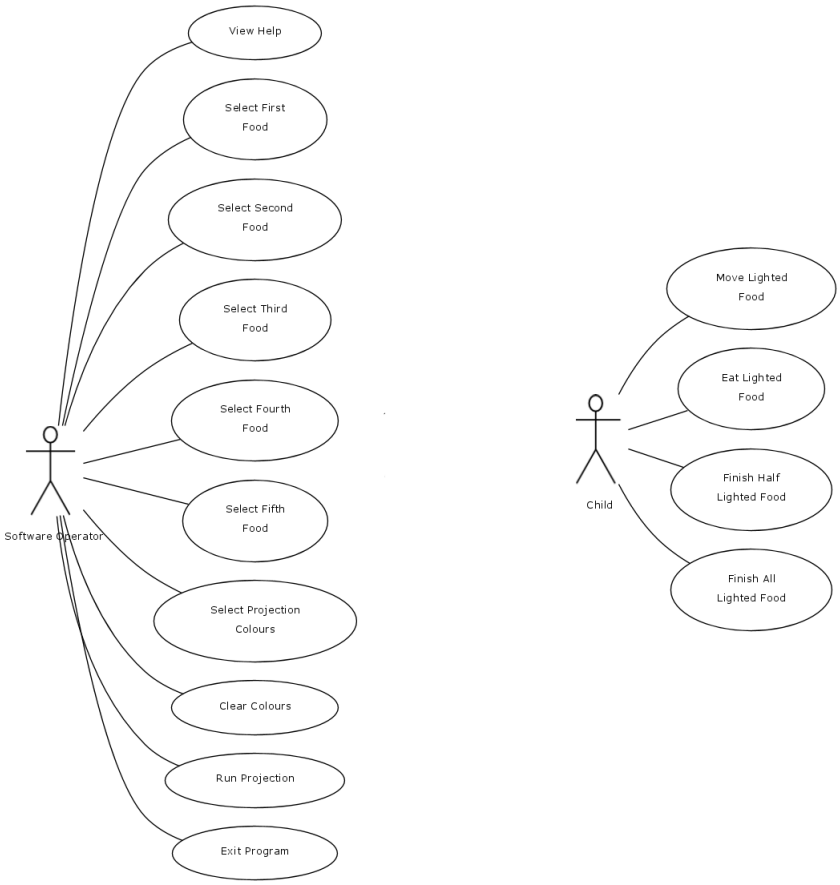


Figure 7: Use Case Diagram

5.4 Risk Assessment

The risk assessment and the mitigation actions are described in table 1 below.

No.	Risk	Risk Description	Probability /Impact	How the Risk was Mitigated
1	Ability to deliver complex project to timescales	Project involved complex solution development, lengthy approval processes, a work in progress CHI paper, presentation at Microsoft and planning and conducting studies.	Medium/ High	A project plan and Gantt chart (see Appendix A and C) was created, with regular progress review with the supervisor.
2	Solution may not meet requirements	A number of hardware and software components needed to be integrated for the requirements to be met.	Medium/ High	An iterative approach was implemented that ensured the system features were gradually built and tested.
3	Unable to obtain CRB check	A CRB check was required to work with children which took weeks to arrive.	Low/High	All documents were submitted early in the project thus ensuring CRB check was received in time for user study.
4	Unable to obtain data protection registration	A data protection registration number was required from the UCL Legal Services department to apply for ethics approval.	Low/High	Forms for data protection registration were submitted in good time so that number arrived before request for ethics approval was to be submitted.
5	Unable to obtain ethics approval	Ethics approval from the UCL ethics committee was required to conduct the user studies as they involved working with children.	Medium/ High	The ethics deadlines were in the project plan, forms clearly described purpose of the study, outlined safety measures, data to be gathered, and how it will be used.
6	Unable to find enough volunteers for studies	User studies needed to be conducted with 7 families with children between the ages of 3-9 at a time convenient to them.	Medium/ High	Outlined what the study will entail to ensure that participants are comfortable with the arrangements. Sent emails within the UCL community and contacted friends and neighbours to take part.
7	Researcher unable to safely visit participant homes	User studies needed to be conducted in family homes, involving partcipants the researcher had not previously met. Care must be taken that the safety of the researcher is not compromised when visiting homes.	Low/ Low	Recruited participants known within UCL or friends and neighbours. Ensured a relative is informed where and when a study was done. The researcher carried a mobile phone and left it switched on for the duration of the study.

Table 1: Risk Assessment

6 Design and Implementation

This section describes the design and implementation of FoodWorks!. An overview of the system, development tools and the hardware used is provided. Wireframe drawings of the design of the user interface are shown. Each iteration in designing and building FoodWorks! is described, important algorithms and the outline of the source code is explained and key challenges and design decisions are discussed.

6.1 System Overview

FoodWorks! contains four main components: the colour selection screen which allows the user to select the foods to be tracked and the colours to be projected, the projection screen - this appears on the laptop and is the screen that is projected on the plate, the camera which picks up the food on the plate and the projector which projects the lights and badges. Figure 8 below shows how each component interacts with the others.

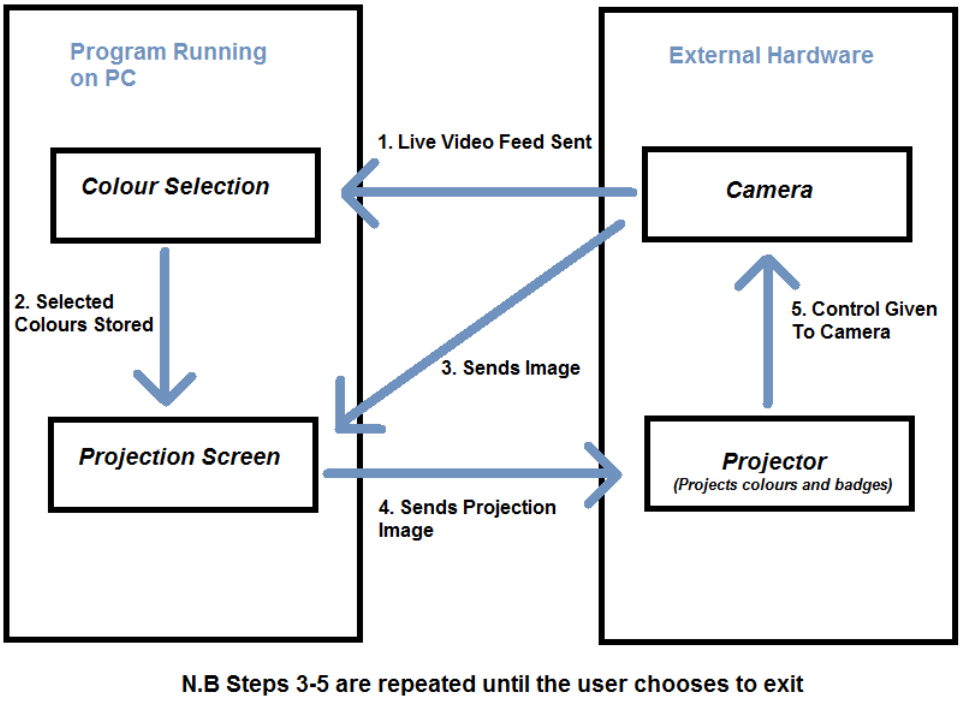


Figure 8: System Schematic

6.2 Development Tools and Hardware

The following software and hardware tools were used for the development and construction of FoodWorks!.

6.2.1 OpenCV

OpenCV (Open Source Computer Vision Library) is a library of programming functions primarily for real-time computer vision. OpenCV is written in C++, and has been used for colour segmentation, tracking and image generation. OpenCV was chosen in preference to using native Windows APIs or other graphics/computer vision libraries (e.g Matlab) as it provides a

faster route to development and has no licensing cost. In contrast, commercial libraries such as Matlab are very expensive and for the purposes of this system did not offer any significant advantage over OpenCV to justify the expense.

6.2.2 Visual C++ and Microsoft Visual C++ 2010 Express

Visual C++ is an extension of the C++ programming language. It contains extra classes and functions which have been provided by Microsoft. Visual C++ implements the standards set by C++ and integrates well with the OpenCV library, in addition, the modifications provided, allow it to work better on a Windows operating system. Windows was chosen primarily on the basis of its ubiquity and the availability of a number of PCs on which to undertake development and testing. Microsoft Visual C++ 2010 express is an integrated development environment. It is specifically geared towards Visual C++ development, and allows for the debugging, design and compilation of applications.

6.2.3 Logitech HD Webcam C310 and Acer DSV0920 DLP Projector

The Logitech HD Webcam C310 allows for real time capture of the food on the plate thus enabling the application to manipulate the video feed for tracking and projection. The Acer DSV0920 DLP Projector is a portable LED projector which offers 200 lumens brightness. It is easy to carry and can be set up in various environments, ideal for conducting user studies.

6.3 Badge Design

Two virtual badges were created that would display around the plate upon completing half and then all the vegetables respectively. For the 'half way' badge, the design idea was taken from the gold stars children get at school, and was called the 'Growing Star' badge to show that the child still had a little more to go. For the 'full completion' badge, the design idea was taken from the pilot studies, in which it was observed that the children would often engage with the characters, consequently, a cartoon spinach was used, the spinach was chosen as it reflected the notion of eating vegetables, moreover, the name 'Champion Muncher' was given to this badge, the idea of 'munching' had cute connotations which are generally liked by children, and the 'champion' signified that they had attained the highest level and had finished all their vegetables. The badges were designed using Adobe Photoshop and the cartoon spinach was obtained from a publicly available clip art library (see figure 9).

Figure 9: The Growing Star and Champion Muncher Badges
The Growing Star Badge was displayed once half the vegetables was eaten, and the Champion Muncher Badge was displayed when all the vegetables had been finished.

6.4 User Interface Design

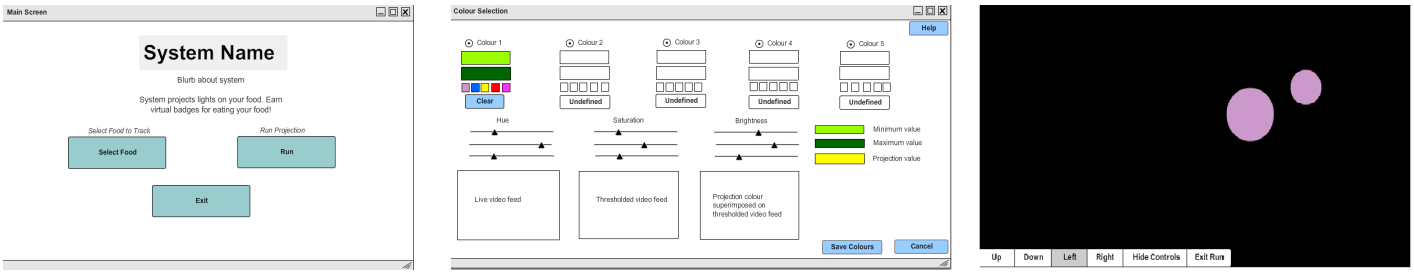
6.4.1 Design Principles

In the 'Design of Everyday Things' [51], Norman introduced several user interface design principles which aid in creating usable interfaces. The interface was designed with consideration of these principles in order to create an effective user interface for the software operator.

- Visibility: Making functions visible to the users allows them to understand better what they can do, e.g displaying the options to select colours to track and project, and running the projection.
- Feedback: This involves sending information to the user on whether an action conducted has had any effect, e.g changing the colours will allow the colours in the colour boxes to change and the HSV and RGB values to update. Moreover, using the displacement buttons on the projection screen displays the movement of the image.
- Constraints: This concept involves restricting the kind of user interactions, e.g the user cannot select a second colour to track without specifying the first.
- Mapping: This involves making the relationship between the controls and their effect clear. e.g if the user clicks the 'Help' button, a help page should open. Also, the track bar control to select the colour, increases in value of hue, saturation or brightness, as the track bar is moved to the right to match general conventions.
- Consistency: This refers to designing interfaces using similar elements for similar tasks, e.g fonts are consistent throughout, track bars are consistently used for colour selection.
- Affordance: Affordance refers to an attribute of an object that allow people to know how to use it, e.g the buttons on the application can look like they can be pressed.

6.4.2 Wireframe Drawings

Wireframe sketches (see figure 10) were developed to show the arrangement of elements of the interface to achieve the purpose of the system and the range of functions available.



From left to right: Main Screen, Colour Selection Screen, Projection Screen.

Figure 10: Wireframe Sketches of the Interface

6.5 Algorithms and Important Functionality

6.5.1 Thresholding (Colour Segmentation and Tracking)

Thresholding provides the user the functionality required to configure the system to track the food items that are of interest, on the basis of their colour. Thresholding is implemented in the system in two primary steps:

1. Calibration: This is the configuration of the system to specify the different colours of food that need to be tracked. The system can be configured to track up to 5 different colours. During calibration the target colours (colours that will be projected on the food) are also specified.

2. Tracking: This is the operation of the system to track the food on the plate as they are consumed.

The identification and processing of colour in the images is based on the HSV (Hue, Saturation,Value) colour space. The specification of the colour in the calibration step is implemented using trackbars which allow the lower and upper boundaries to be set for each colour – this is required as any given object is perceived in various shades by the camera based on the ambient lighting. The colour that is being detected shows up as white pixels in the picture box in the calibration screen, the OpenCV function inRange is employed to carry out the thresholding. These white pixels are then replaced with the target colour that is selected in order to provide the calibrator visual feedback to gauge what the image projected will be for the specific colour being tracked.

In tracking mode, individual colours on the plate are thresholded to determine their locations and shapes, and randomly replaced with the target colours selected. For each colour being tracked the following occurs:

- A target colour from the specified set for the colour being tracked is randomly chosen and replaces the white pixels of the thresholded image, this is repeated for each colour being tracked

- The final image that is projected onto the food is created by combining the images with the target colours for each colour being tracked

6.5.2 HSV to RGB Conversion

At present, OpenCV thresholding works only with the HSV colour space. This necessitates the use of HSV ranges as input to the thresholding functions, i.e. the colour to be detected has to be specified as lower and upper HSV values. Visual C++ natively works with RGB values for the specification of colour i.e. all the objects visible on the user interface have foreground and background colours specified in RGB values. On the calibration screen there is a need to provide visual feedback to the user that allows them to view the colours being set through the use of coloured panels. Consequently, the system should convert colour values between HSV and RGB colour spaces.

Using ideas derived from open source contributions made by the OpenCV community [29], this conversion was accomplished in the following manner:

1. In the HSV colour space, H determines the hue (colour), S the saturation (depth) of the colour and V the brightness or luminance of the colour.
2. For a given input value of hue (0-179), a square HSV image is created where the individual pixels are set to increasing values of saturation (from 0 to 255) on the X axis and increasing value of value (brightness) on the y axis.
3. This HSV image is converted to a RGB image using OpenCV functions.
4. The input S and V values are used to identify the pixel in the converted image that represents the precise shade of colour.
5. The values of the 3 bytes that make up the pixel and hence its RGB colours are then read as unsigned integers. These values are returned as appropriate values for the Red, Green and Blue components of the colour, which are then used to set the colours of the user interface objects.

Such a mechanism was used as there is no straight forward formula to convert from HSV to RGB values.

6.5.3 Add Badges

Virtual badges are displayed based on completion of the food. This is determined by monitoring the number of pixels representing the food items being tracked, this works as follows:

- The camera scans the food during the gaps in the projection of colours onto the plate. During the initial few scans, a baseline is established as to the total number of pixels of each tracked colour that is detected on the plate.
- During subsequent scans, the total number of detected pixels for each colour is compared against the total in the baseline. A completion percentage is calculated based on these values.
- When the completion percentage reaches 40% i.e. 40% of the pixels being detected have disappeared from the plate, the Halfway Completion Badge is displayed.
- When the completion percentage reaches 80%, the Full Completion badge is displayed.

The following pseudocode shows how this works.

```
addBadges(inputFrame)

{

CompletionPercentage = 1 - (currentNoPixelsInputFrame/initialNoPixelsInputFrame)

        if (0.4<= completionPercentage < 0.8)

        { Display Halfway Completion Badge}

        if (completionPercentage >=0.8)

        { Display Halway Completion Badge & Full Completion Badge}

else

return inputFrame

}
```

6.5.4 Morphing and Magnification

The coloured lights from the projector were smaller than the objects it was projecting on. Increasing the distance between the projector and the plate did not solve this issue, so the image retrieved by the camera was cropped to its central 50% and the projection image was resized to twice the size. The image was also dilated by a factor of 10 and morphed by a factor of 2 to reduce issues of pixallation of the projected image. This was done as follows:

```
cropFrame()
{
        int croppedWidth = width of image from webcam * 0.5 // crop to half its size

        if (croppedWidth not multiple of 4)
        {round to nearest value divisible by 4}

        int cropXPoint = (width of image from webcam - cropCols)/2);
        // x coordinate of where rectangle showing region of interest will start
        int croppedHeight = (croppedWidth/ height image to maintain aspect ratio);

        if (croppedHeight not multiple of 4)
        {round to nearest value divisible by 4}
        int cropYPoint = (height of image from webcam - cropRows)/2);

        Rect roi = Rect(cropXPoint,cropYPoint,croppedWidth,croppedHeight);
        // create rectangle

        trackingThresholdedFrame =
        getTrackingThresholdedFrame(trackingFrameCaptured(roi));
        // creates image using rectangle defined
}
```

```
morphAndDilate(Matrix inputFrame)
{
// input frame has been cropped to central 50%

        const int DILATE_SIZE = 10
        const int MORPH_SIZE = 2

        Create dilateMatrix(DILATE_SIZE)
        Create morphingMatrix(MORPH_SIZE)

        HSVToRGB(inputFrame) // convert RGB image to HSV
        threshColorFrame = new Matrix  // initialise black image

        for (each colour to track)
                {
                morph(morphingMatrix)// remove noise
                dilate(dilateMatrix) // smooths image
                combine morph and dilate matrix on threshColorFrame
                }

        resize(threshColorFrame) // resize to twice its size
        bigImage = new Matrix
        Add threshColorFrame to bigImage
        return bigImage
}
```

6.5.5 Multithreading

One of the challenges faced during system development was the fact that the constant scanning and processing of images severely affected the responsiveness of the system to user interactions. To solve this issue, it was decided to use a multithreaded approach. Visual C++ provides excellent support for multithreading through an out of the box component called the background worker. The background worker object enables the creation of a background thread that is controllable from the main UI thread. In the system, the tasks of scanning the plate and generating the images to be projected is performed by the background thread while the foreground thread (UI thread) is responsible for displaying the images as well as reacting to user input.

6.6 System Structure

6.6.1 Hardware

The system hardware consists of a Logitech HD Webcam C310 taped on to an Acer DSV0920 DLP Projector (see figure 11). The webcam picks up the food on the plate, recording at a rate of 30 frames per second, and the projector subsequently projects the colours and badges. The camera lens is aligned as closely as possible to the projection lens to reduce as much as possible the displacement distance between what the camera is picking up and where the projector is projecting. This device is held up by a clamp attached to a tripod. The height had to be adjusted according to the size of the plate and the area of the projection required. The projector and camera are connected to a laptop which runs the software.

Figure 11: Setup & Camera taped to Projector

6.6.2 Software

In essence, the system works by tracking food on the plate based on their colour. Badges are awarded depending on progress towards consumption by determining the reduction of the total amount of the tracked food items on the plate. The system employs image processing principles of thresholding, cropping and merging to achieve it's functionality. The following are the key classes and header files used in the system.

Form1.h This is the home screen where users can select the option to choose the food to track, play the game or exit the application. This file is connected to FTCalibrateCamera.h and TrackFood.h.

FTCalibrateCamera.h This allows the user to select the food to track, and set the colours of the lights to project (the target colours), users can choose up to 5 foods of different colours to be tracked, and specify up to 5 different target colours for each food.

TrackFood.h This header file displays the interface of the screen when users play the game. This screen will be projected on the plate and will display the colours and the badges. It has been set up to occupy a computer screen of size 1366 x 768, and with a black background as black will blend in with ambient light, so only the different colours being projected will provide illumination. In addition TrackFood.h creates two threads, the foreground thread which responds to user interactions with the interface, and the backgroundworker thread which gathers data from the camera. The image from the camera is cropped to it's central 50% in this file. TrackFood.h also adjusts the projection image to align the projection with the food on the plate. This is required due to the small difference in distance between the projector lens and the camera lens which picks up the image.

CalibrationHelp.h This is the window that appears when the 'Help' button in the calibration screen is clicked.

CalibrationFileStructure.h This file contains structure definitions to set the colour of the food to be picked up, to set the target colour, to count the number of pixels projected, and constant definitions such as the webcam and laptop resolution.

FoodTrack.h FoodTrack.h contains global variable definitions which are included across the header and source files. These include global method definitions for converting between HSV and RGB values, displaying images in picture boxes and adding the badges.

FoodTrackUtilities.cpp FoodTrackUtilities.cpp holds the implementation of various methods. These include methods which convert between RGB and HSV values, performing thresholding and manipulating the size of the projection image, pixel counting to award badges, converting the white in thresholded images to chosen target colours and displaying the video feed, thresholded images and food with target colours in picture boxes.

6.7 Iterations

In building and designing the system, an iterative and incremental approach was adopted. Eight iterations were carried out, and each is described as follows.

6.7.1 Iteration 1

In this first iteration, a simple command line application was created. This would capture an image from the webcam and attempt to threshold it (perform colour segmentation). This function creates values for the thresholded image, which were manually written to another file and read again by a different application, this application would track the colours that had been thresholded. By doing this in the first iteration, we could see whether the application would fit the behaviour of thresholding then tracking.

6.7.2 Iteration 2

In the second iteration the overall framework for the Visual C++ Windows application was created from which the OpenCV libraries could be called. The incompatibility in memory management between Visual C++ and OpenCV was resolved by changing the Common Language Runtime support flag passed to the compiler to /clr from /clr:pure to allow for automatic management of pointers.

6.7.3 Iteration 3

Three main goals were accomplished in the third iteration. Firstly, sliders were introduced in FTCalibrateCamera.h, to allow the user to select an object by its colour for thresholding by specifying a minimum and maximum Hue, Saturation and Brightness settings. Secondly the windows which appeared that displayed the webcam feed and the object being detected were replaced by picture boxes within FTCalibrateCamera.h which are native Visual C++ form controls. Finally, the form TrackFood.h was created, this was a large picture box which was sized to occupy the laptop screen, this is the screen that would eventually be projected onto the food, additional functionality was introduced that if this picture box were to be clicked on, the application would exit.

6.7.4 Iteration 4

It was considered that guessing the colour that needs to be tracked may be difficult for the user, consequently, this iteration introduced functionality that would display the colour being selected for the maximum and minimum values. However, the challenge here was that the colours were being displayed using Visual C++ which used the RGB system, whereas the colours were being selected through OpenCV which used HSV. As a result the HSV values had to reliably be converted to the RGB values, to do this, an algorithm was created which built a matrix that represents the colours specified by the minimum - maximum range given, from this the HSV values were chosen to be translated to the RGB, this was done by the function cvCvtColor(imageHSV, imageRGB, CV_HSV2BGR), where imageHSV is the input HSV image and imageRGB is the output image (see figure 12).

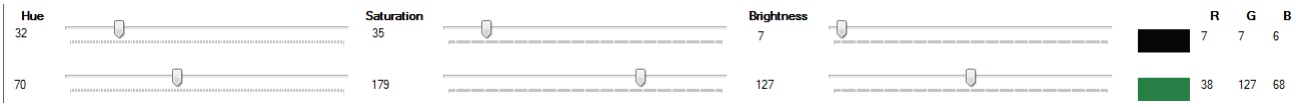


Figure 12: HSV Trackbar and the chosen colours being displayed by conversion to RGB

In iteration 4, functionality to select 5 colours to be tracked (see figure 13) and the logic for displaying the badges was introduced, the latter was done by initially measuring the number of white pixels and then measuring the change in each subsequent frame.

Figure 13: 5 Tracking Colours

6.7.5 Iteration 5

This iteration introduced the concept of target colours (i.e the colours that would be projected onto the food). This required the need for an additional picture box to be placed in FTCalibrateCamera, so that there were three picture boxes in total (the webcam feed, the thresholded feed and the target colour superimposed on top of the threshold image). In order to get all 3 boxes to fit on the screen, the image that was captured by the webcam had to be resized to 33% of what was being captured.

6.7.6 Iteration 6

Multithreading was introduced to improve performance. Two threads were created, the user interface thread which recorded the user interactions, and backgroundworker, a Visual C++ provided component. The introduction of multithreading required certain variables to become global in order for both threads to be able to access and modify them. Visual C++ also does not provide direct access to the backgroundworker thread, so it cannot be directly suspended, consequently, coordination between the backgroundworker thread and the UI thread when they are accessing shared variables is done through status flags and WaitKey() which can be found in TrackFood.h. It was found that the colour being projected would interfere with the colour the camera would pick up, to solve this issue, the projector would display a completely black image which mimicked the natural light, alternately with the projection image, the camera frame would be captured when the black image is being displayed. This also caused the flickering of the badges, as they were superimposed on the projection image, this was solved by superimposing the badges on the black image and the projection image when the user had earned them.

6.7.7 Iteration 7

Due to the gap between the projection and the camera lenses, the projection image was slightly shifted from what the camera was seeing. It was also found that the projected light was smaller than the object, thus the distance of the camera and projector from the objects had to be countered. To address the former issue, displacement buttons were introduced in the tracking screen which allowed the projected image to be shifted up/down or left/right by 10 pixels,

as this was the available space on the screen, this enabled alignment with the objects on the plate. The latter was done by cropping the image retrieved by the camera to its central 50% and resizing the image to twice it's size. However, this caused problems as was discovered that the conversion of the OpenCV image to the bitmap needed by Visual C++, threw a pointer exception if the height and breadth of the reduced image measured in pixels was not divisible by 4, subsequent resizing had to be done to ensure that this condition was met (see figure 14).

Figure 14: Displacement buttons to shift projection

6.7.8 Iteration 8

In the final iteration, functionality to choose multiple colours was created. Each of the 5 target colours shown on the bottom can be changed by clicking on the small box, and setting the colour using the sliders on the interface, and can be reset to black by clicking the 'Clear' button (see figure 15)

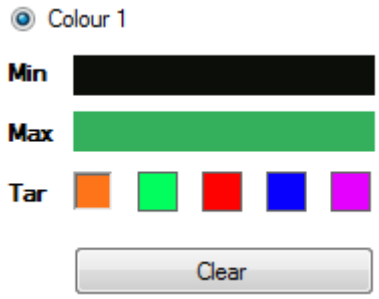


Figure 15: 5 Specified Target Colours

6.8 Challenges and Design Decisions

The iterative development process highlighted a number of design challenges with the proposed approach, consequently, a number of changes were incorporated in the final system.

6.8.1 Colour Selection

Selecting the colours to track is done manually through the use of trackbars, the following methods were also considered but were not used.

Selection through point and click The use of this method results in a very small area of the image being sampled for colour, limiting the accuracy of object identification – e.g food items of the same colour in bright light manifest a different shade from the areas that are away from the light. Moreover, thresholding works most effectively with a colour range provided as input and it was felt that using point and click to specify a range will not be precise.

Selection through tracing object boundary using a mouse This option was not pursued as it was quite difficult to accurately identify the object boundaries of small collection of items

such as peas or beans. The boundary often contains pixels of a vastly different colour and hence the input to the thresholding function results in an inaccurate range.

6.8.2 Alternate Projection of Black Image

As the system works by detecting the object's natural colour, projecting a coloured light may result in the object not to be detected correctly. Detecting the change in colour of the object is difficult, as the projected colour is randomly chosen from the target colours selected. As a result, a plain black image was projected between the displays of colour, as black most naturally mimics ambient light; the camera then reads the image at this point, resulting in a 'strobe like' effect. This caused the badges to flicker as this was projected on the image with the colours, this was solved by superimposing the badges on the black image, as it did not interfere with the colour detection as they appeared outside the plate.

6.8.3 Single Colour Projection

With the initial sketches, the idea was that each vegetable, i.e each pea on the plate, would be a different colour. However, it is extremely difficult to differentiate between objects of similar colour, as a range needs to be specified in OpenCV, consequently, only a single projection colour at a time can appear on vegetables of a similar colour.

6.8.4 Selection of Projection Colours

Rather than hardcoding the colours that would be projected, the user had flexibility to choose up to 5 different colours randomly for each food item. For example if the user selects blue, pink, yellow, purple, orange to be projected on some peas, the system may first project yellow, then pink, then pink again and then orange etc. on all the peas.

6.8.5 Displacement between Camera and Projector

There is a slight gap between the camera and projector lenses resulting in the projector not projecting on the same place as the area the camera is 'seeing'. To solve this, the lenses were taped together to align as closely as possible, and up, down, and left, right buttons were introduced to allow the user to move the projected image so that it overlays with the food.

6.8.6 Badge Projection

Children faced the projector at meal times. Whilst the actual coloured shapes are detected in the correct positions as the camera is placed with the same view as the projector, the badges were presented upside down on the plate. Consequently, the badges appear upside down and at the bottom of the computer screen, resulting in them appearing correctly to the child.

6.8.7 Preset Colours

Manually selecting the colour to detect can be time consuming and/or difficult. Preset buttons for common vegetable colours were introduced in the calibration interface, these include dark green, lighter green, yellow, orange and brown.

7 Testing

7.1 Testing Strategy

A test strategy was developed comprising of unit, integration, performance and usability testing phases. Test cases were developed from the requirements and focused on interaction with the system, either with the GUI of the software or the projection on the plate; this is because it's main use is through these mediums, thus, testing by inspection would be appropriate in this context to effectively investigate whether the system works as expected. All test cases resulted in the expected outcome, a detailed description of each test case can be found in Appendix M.

7.1.1 Unit Testing

As code was written, unit tests were carried out on appropriate classes and header files to ensure that individual functionality worked as expected before proceeding further with development. Test harnesses were created as stand alone command line programs that called the units being tested with appropriate input data. Example of a unit test includes testing of the HSV-to-RGB conversion function.

7.1.2 Integration Testing

Modules of tracking, calibration and projection were integrated and tested independently and together. The system works well with all its components.

7.1.3 Performance Testing

Performance testing was carried out to confirm the two non functional requirements outlined earlier were met. The first that the load time should be less than 10 seconds was tested by running the system multiple times and recording the time it took to load. This ranged from 2.3 to 8.4 seconds, thus, meeting the requirement. The second requirement, that tracking and projection delay should be no more than 1 second, was tested by introducing two timers on the projection and calibration screen that took timestamps after processing and projection. The first timer indicates the elapsed time in seconds between the camera capturing the image and processing it, and the second timer conveys the time taken for the projection to be displayed. These numbers would usually be either 0 or 1, hence, meeting the requirement.

7.1.4 Usability Testing

Nielsen's revised 10 usability heuristics [50] was applied to to FoodWorks! to systematically inspect the user interface design to see whether it complies with certain principles (heuristics). In conducting the heuristic evaluation, particular goals were selected, these included detecting a colour on a plate, assigning target colours, and running the projection. Table 2 illustrates the findings.

No.	Usability Heuristic	Strengths (+) and Weaknesses (-)
1	Visibility of system status	+ Colour boxes are visible to view the colour being selected + A live video stream is available to see the food being selected as the user performs selection + Projection colours overlayed on the live stream of the food can be viewed - Upon pressing the 'Save Colours' button, the system returns to the main screen, a dialogue could inform that the colours have been saved
2	Match between system and the real world	+ The language used by the system is understandable to the user + The name 'Select Food' is appropriate as it tells the user they can select the food to track + 'Run' is appropriately named to suggesting running the projection + 'Save Colours' allows the user to save the colours selected + The labels 'Hue', 'Saturation' and 'Brightness' for colour section are typical of any colour manipulation tool
3	User control and freedom	+ Users can select the food and adjust and change it very easily through the use of the trackbars + Users can select the colours they want to project + Users can navigate easily between the projection and the selection screen + Users can employ the video feed to select food and overlay colours + Navigation buttons are available to align the projection over their food + Users can easily cancel selection, hide navigation buttons and exit the application
4	Consistency and standards	+ Fonts consistent + Buttons consistent + Food to track are selected in the same way + Colours to project are selected in the same way
5	Error prevention	+ Functionality has been put in place so that users cannot select the 2nd colour to track without selecting the first, 3rd colour to track without selecting the previous 2, etc. + If users do not specify a colour it is automatically set to black
6	Recognition rather than recall	+ All options the user may require are clearly visible + Selecting colours is done in the same way, so users do not have to remember new methods + Video feed is shown so users can view the food being selected and the colour being overlayed
7	Flexibility and efficiency of use	+ Colour presets have been introduced to help users select common colours + Colours to track and project from a previous session are automatically saved so users simply have to press 'Run' the next time they use the system if they wish to reuse the colours
8	Aesthetic and minimalist design	+ Only necessary information is visible to the user
9	Help users recognize, diagnose and recover from errors	+ Errors are not present in the system + If the projection does not overlay with the food, buttons are available to move the projection
10	Help and documentation	+ Help feature is clearly visible in the system + Help function covers all features of the system

Table 2: Heuristic Evaluation

8 User Study

8.1 Planning and Methodology

A user study was conducted to investigate the social interactions around FoodWorks!, and the effect it had on eating related behaviour change. The study was designed using the PRET A RAPPORTER framework [12], which incorporates consideration of the purpose of the study, resources, constraints, ethics, data gathering techniques and analysis and reporting of findings.

8.1.1 Purpose of Evaluation

The primary purpose of the study is to understand the effect of introducing FoodWorks! in a family meal time environment. It provided the opportunity to delve deeper into some of the practices hinted in the pilot study, obtain user data to test hypotheses about the value of using two types of ethnology intervention (attention and distraction from the meal), and observe any changes brought about in eating behaviour.

8.1.2 Resources and Constraints

Documentation Before the studies were conducted, a CRB check (see Appendix F) , data protection registration (see Appendix G) and ethics clearance were obtained (see Appendices D and E) as it involved working with children.

Participants 7 families with children in the age group 3-9 years participated. They were recruited via an email sent around the UCL Computer Science department (see Appendix H) and through friends. Participants were given a £10 Tesco gift voucher as a thank you for taking part.

Equipment The researcher took all equipment to the homes of participants.

8.1.3 Ethics

The UCL Ethics Committee approval process highlighted ethical issues relating to informed consent, protection from harm, right to withdraw, storage of data, confidentiality and anonymity that were factored in the design and implementation of the user studies. For instance, all studies were conducted in a public room i.e dining room or lounge with the child's parent or guardian present. Participants were given an information sheet (see Appendix H) to read beforehand and had the study explained to them. Participants signed two consent forms on behalf of themselves and their child (see Appendix I). Participation was voluntary, with the right to withdraw at any time. They were informed that the session will be video recorded, and if they had any concerns it can be stopped and any footage will be destroyed. All data collected was stored on a password protected computer and any information they provided was anonymous and was only used for the purposes of this project.

8.1.4 Techniques for Data Collection

The study was audio/video recorded for further analysis and observational field notes taken. At the end or during the study, the researcher using a semi-structured approach, asked the participants questions (see Appendix J) about their experiences with the technology. This enabled pursuit of interesting paths of conversation [59] and delved deeper into their experiences.

8.1.5 Analysis and Reporting

Data analysis involved video interaction analysis [28] and identifying common issues and themes through thematic analysis, this offered flexibility in creating theories that may affect the interaction [13]. This allowed further investigation into the behaviours and responses to the technology, which yielded a better understanding of the experience provided by FoodWorks!. Findings were documented, based on themes with vignettes to illustrate particular notions. Participant's identities were protected in the vignettes provided.

8.2 Participants and Meals

The participants included fussy and non-fussy eating children from a range of ethnicity and cultural backgrounds (see table 3). The study was conducted as part of their typical meal patterns i.e at home during normal meal times with mothers present and other family members participating as per usual with all meal selections made by the parents. This ensured the findings were influenced by the use of Foodworks! as part of the normal family interactions.

Family	**Children**	**Setting**	**Ethnic Group**	**Meal description**	**Level of Fussiness**
A	Boy 5 yr Girl 7 yr	Siblings ate together	Indian	Pasta, carrots and cucumbers	Both children dislike carrots
B	Girl 7 yr	10 year old sister also ate	Indian	Pitta bread, dhal, carrots, beans and cucumbers	Girl does not like Indian food and beans
C	Boy 6.5 yr	Parents also ate	French	Carrots, Salads and Sausages	Boy hates carrots
D	Girl 3 yr	1 year old brother also ate. Girl was also watching TV	Irish	Potatoes, broccoli, carrots and ham	Girl does not eat any vegetables
E	Boy 5 yr	6 year old brother also ate	European and Asian	Sweetcorn, beef carrots, broccoli and garlic bread	Boy is not a fussy eater
F	Boy 8 Yr	Boy ate alone	Indian	Spinach, dhal, roti, salad and rice	Boy is not a fussy eater
G	Boy 5 yr	Twin sister also ate	English	Pasta, sausage, broccoli and cabbage	Boy hates cabbage

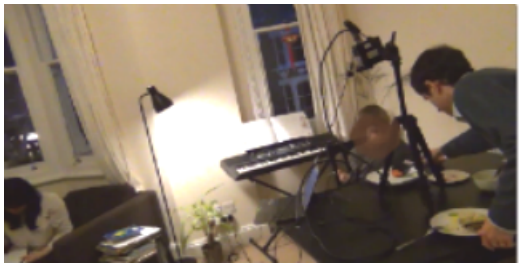
Table 3: Participants and Meals

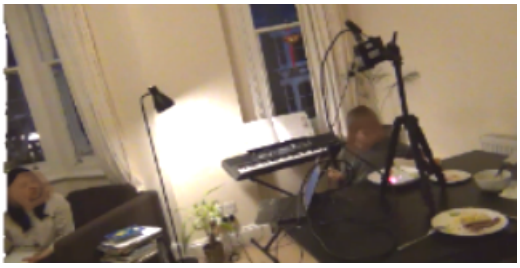
8.3 Findings

The family environment combined with the features of FoodWorks!, affected the interactions of the meal and encouraged healthy eating behaviour. Children were motivated to try or even finish foods they usually disliked due to the attraction of the colours and badges, and distraction from the disliked foods. The themes that had an effect on the interactions that occured, are eating motivation, interaction with parents, equipment and between siblings are detailed in the sections below.

8.3.1 Eating Motivation

In family B the participant played with the colours by moving the food around the plate, this acted as a form of distraction, consequently, she would just eat rather than think about what she was eating. Similarly in family C, when asked why he ate the carrots the boy responded, 'I don't know, I didn't think anymore, I just ate it'. In families B and E, the participants placed lighted portions of food over unlit portions to see what would happen. The display of colours had a positive effect on their eating behaviour by taking their mind off the food being eaten. However, inquisitiveness also had other effects, as with family C (see figure 16).





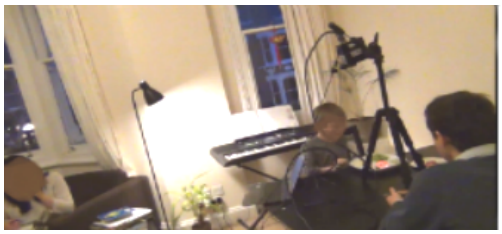
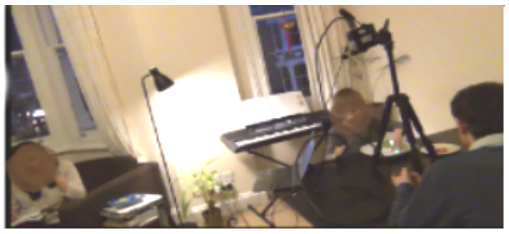
[child has finished eating all his carrots, dad puts more carrots on his plate]
[child picks them up and puts them on the table]
Dad: Maybe you can get another badge, but I think putting it on the side is cheating.
Child: No it isn't!
Dad: No I think it is.

Figure 16: Hiding Carrots

The appearance of the badges also had a positive impact. In families F and G, after being told they would get a second badge for eating all the vegetables, the children were aiming for a clean plate, as the system would not award the badge if any pieces of vegetables were left. In families A, C and E, the children were exclaiming 'Look a badge!' or proudly stating 'I got a badge!', this spurred them on to continue eating. In family G, as the participant ate cabbage, the badge would flicker as they blocked the view of the camera, so, the system thought the required amount had been eaten and awarded a badge, however, as the participant retreated, the vegetables were visible and so the badge disappeared. As a result, the child went back and forth and kept eating to see if the badge re-appeared. Once the required amount was eaten they were excited that the badge did not flicker any more, eagerly shouting 'it's staying there!'. They then continued eating to see if they would get the second badge. The children associated the appearance of the badge to eating their vegetables thus, were constantly being rewarded for their behaviour.

8.3.2 Interaction With Parents

Directing Attention Parents would typically nudge their child to focus attention on the food. As shown in figure 17 the child would eat the meal without touching the carrots, however, FoodWorks! created an element of curiosity in the child, through the parent directing their attention. In family F, the parent asked the child 'What colours do you see?', bringing their focus back to the meal, this prompted them to resume their pace of eating.

[Child eats all his sausages first]
Dad: What happens if you eat the carrots?
[Child picks up carrots and puts it in his mouth, then leans over to see what happens]

Figure 17: Family C trying carrots

Interacting with Colours The appearance of the colours was often entwined into the meal-time conversation. In family A, we observed the parent relating the colours to other experiences, this was also evident in family D.

Family A
[Everyone is looking at the colours on the plate]
Mum: What's your favourite colour?
5 Year Old: Yellow
Mum: Yellow is your favourite colour? You changed it.
7 Year Old: He always changes it...
Mum: He had yellow when he was in nursery, he asked for a yellow plate and a yellow cup
7 Year Old: Then he asked for a blue plate and a blue cup
Mum: Do you remember?
5 Year Old: The special blue cup
7 Year Old: What's the special blue cup?
Mum: This colour [pointing at the plate]

The effect of parent interacting with the colours, was not limited to relating to other life events, it was often observed that parents would create games out of the colours. In family D, the mother often used the child's favourite colour and say 'let's see how much you can eat before the purple comes back' or 'the purple won't come back until you eat all your vegetables. Similarly, in family E, the parents used the lights as a reward and tell their child 'you won't get lights if you are moody about your broccoli'. In family G the mother gets the child excited about the meal by saying 'What can we see? Ooh, shining lights! What we've got to see is what happens, when we start eating'. From the pilot studies we observed that parents would call the food 'disco [peas]', this was also noted with the user studies. In family F, the parent called

the colours 'disco lights' and tells the child 'you can dance and eat'. Likewise, in family E the mum asked her child 'shall we put disco lighting on your food every night' to which he responds 'yeah!'; he can also be observed dancing at the suggestion of 'disco food'. In the majority of the families studied, the parents said that they found themselves talking more about FoodWorks! and using it to encourage their child, than if it had not been there. This shows that the system had a significant impact in the dynamics of the family conversation.

Interacting with Badges The reference to badges by parents encouraged the children to eat their meal. In families A and D, both parents tell their children they have to 'eat all your [vegetables], and then you will get a badge', to motivate them. In family G the parent focuses on the badges to encourage her child (see figure 18)

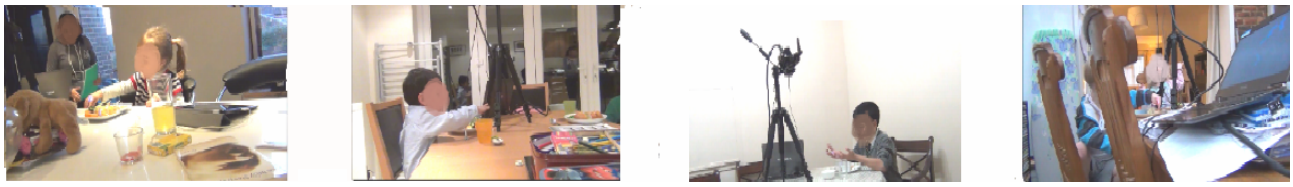
First picture
Mum: Go on try some cabbage, because then we can see what it does, we can see if it gives you a badge.
Child: What does that mean?
Mum: Well we need to see it, it will show up on your plate. That means you'll be a super duper eater, who tries new things... and then we can tell your friend tomorrow that you had cabbage and it made a badge on your plate. Come on, prod a bit of cabbage and put it in your mouth.
Child: Yucky!
Mum: Oh come on, I want to see what happens when you've got a clean plate.
Child: [Pauses for a while.] I'll have a tiny bit.
Second picture
Mum: Oh look you've got a badge! Did you see that?
[Badge appears and disappears]
Child: What where?!
Mum: Pick up another tiny piece
Child: Alright!
Mum: Put it in your mouth!
Sibling: Put it in your mouth!
Mum: Look!
[Child looks at the badge on the plate and gets excited]
Child: Yay!!

Figure 18: Trying Cabbage Family G

This shows that the reward of badges proved to be a key motivational factor to try and finish new vegetables. We also noted the parent suggesting that they can inform friends about winning badges for eating food. By offering to share their achievements with others, the child is able to see a purpose in what they are doing.

8.3.3 Interaction with Equipment

From the pilot studies, we saw that the children would place parts of their bodies under the projector to make themselves glow. This was again observed across families in the user study. In families D, E, F, G all children interacting with the meal, would put their hand or arm under the projector. In family E the participant excitedly exclaimed 'my hand's lighting up!', and in family G the participant would put his hand or head under the projector and his mother would say 'the projector will think your head is broccoli!'. Figure 19 shows the various interactions of the children putting their bodies under the lights.



From left to right families D, E, F and G

Figure 19: Lights on body

The children were also curious about the effect of eating on the computer screen. In families C and G, the boys would eat and see what happens on the computer, the parent then had to bring their attention back to the plate. Not only were children intrigued by the computer, some would also look up at the projector to see what it was doing, this was particularly evident in the case of families D, F and G as shown in figure 20.

From left to right family D, F, G

Figure 20: Looking up at the projector

These findings show that the children were very inquisitive about FoodWorks!. In family C, the child asked the researcher questions about how it was working. Parents also volunteered to explain it's functionality to their child. In family D the mother was heard saying to her daughter, 'because this [pointing up at the projector], can tell what you've eaten, and will then give you a special sticker', similarly in family G, the mum tells her child 'you see where the blobs are, I think the blobs might be picking up where the vegetables are... so where the colour's showing up that's the bit you have to pick up and eat'. This suggests that most children were intrigued by how the system worked, and through explaining it's operation, parents would encourage their kids to eat their food.

8.3.4 Interactions Between Siblings

Families A, B, E and G all involved a sibling interacting with FoodWorks!.

Formation and Participation The position of the sibling influenced the interactions as shown in the figure below where they lean over to see what was happening on the plate, this would focus the attention of the child eating their meal. The spatial formation created around FoodWorks! encouraged group interaction. Those siblings who were at the right orientation to the plate interacted more easily. In the case of family E (see figure 21), the face to face configuration had FoodWorks! in between, thus, obstructing the view of the sibling, leading to the interactions being only described by the participant using the system.

Figure 21: Sibling formation and Participation in families A and E

In family A, the sister impatiently asked her brother 'can you not eat any more pasta so I can have a go next?', this shows that children do not hesitate to try new technologies and are eager to take part. Moreover, the younger brother was initially shy about taking part, but once his sister volunteered he said that he wanted to go first. In family E when the participant says: My plate's lighting up! My plate...Dad! Dad! Daddy! Daddy! Daddy! My plate's lighting up! the sibling asks: Why haven't I got any disco food? Can't it just be on me?. It was also found that sibling participation resulted in distraction from their own meal, in the case of family G, the parent confided that 'see that's interesting because usually she would have finished all her meal, so was actually being distracted by doing that [pointing at her brother's plate]'.

Playing Games and Opinions In family A, the sibling engaged the participant by playing games with the food, she suggests to him 'lets name all the colours!', and he immediately begins listing all the ones he sees. Similarly in family G, the sibling tells the participant to 'eat that bit' and excitedly asked her mother 'what does it say?', regarding the words under the badges. The siblings would often also offer their own views even if they were not the ones directly manipulating FoodWorks!. In family B the sibling said that 'if there were different colours on my carrots, it would put me in a good mood to eat my carrots', moreover in family G the sibling also stated her favourite colour despite not being the one eating the meal with the projection. This shows that FoodWorks! intrigued siblings and engaged them as well as the participant eating the meal.

8.4 Discussion

8.4.1 Eating motivation

The display of colours was observed to probe the child's curiosity, typical of when they are in a safe and familiar setting such as their home [17], thus, their interactions with FoodWorks! were more natural. Eating motivation was influenced by visibility limitations of the set-up. For instance in family C, the child had figured out that the colours would only appear if the food was on the plate, and he would get a badge when it disappeared, as a result, he picked the carrots and put it away from the camera's viewing area. FoodWorks! motivated the child to try the food in the first instance, however, the second time, the child had realised what to expect. In future development, the area picked up by the camera should be larger to avoid this type of 'cheating', additionally, the novelty value of the system should be maintained as the inquisitive and playful interactions encouraged good eating behaviour.

The effects provided by feedback loops, in which people are given awards or information about their actions, and the opportunity to continue with good behaviour was observed. The notion of a feedback loop to affect behaviour has been explored in work by Bandura [3]; drawing on experiments with children, he concluded that giving individuals a clear goal and a means to evaluate progress toward that goal greatly increased the likelihood of achievement, for example in family G, the child believed that their action of eating a piece of cabbage would result in the goal of a badge appearing, and the progress towards this would be measured if the badge stayed on the plate.

8.4.2 Interacting with Parents

Parents typically acted as the nudge to focus their child's attention on the food. This quality in a parent-child relationship has been observed [30], where parents would gently push their child towards certain artefacts. Across several studies, conversations revolved around FoodWorks! and mothers generally took on a central role in directing the verbal interaction; similar results can be found in Feiring and Lewis' [21] paper which states that mothers emit and receive most talk at dinner time. Parents would also create intrigue in the child to 'see what would happen' if they eat their food, this latter technique is reminiscent of several children's games and foods [36] in which children would perform an activity to unveil a surprise.

Interaction regarding the meal was not limited to the family, with parents suggesting they can inform friends about winning badges for eating food, acknowledging recognition allows the child to see a purpose in what they are doing. Glasser [26] has developed four types of verbal recognition, which motivate children towards good behaviour, these are active recognition, experimental recognition, proactive recognition and creative recognition. In our studies, creative recognition has been used, this combines requests 'eat your cabbage' with recognition 'You'll be a super duper eater, who tries new things...and we can tell your friend'.

8.4.3 Interactions between Siblings

Knight et al [38] found that the presence of siblings introduces a group dynamic and helps children open up faster. Moreover, the spatial formation created around FoodWorks! encouraged group interaction. Analysing F formations, formed when two or more people share transactional space, will help understand how the physical aspects of a setting influence interactions [34, 35]. Parents usually decided the seating place for their child, and the sibling would move themselves to share the space to facilitate joint visual attention. The most commonly observed F formation was the L arrangement (see figure 22), which assisted most interaction, as both siblings were able to see the plate at the right orientation. In a face to face configuration, FoodWorks! blocked the sibling's view, so the interactions were only described by the participant. This is similar to findings by Marshall, Rogers and Pantidi [41], where those group members left out from the transactional space were excluded from the interactions. However, the non participating children showed a keenness to try the new technology, findings similar to other studies [55] and a shy child would be motivated by the sibling to have a go. This is consistent with findings by Knight [38], as siblings offer support for an initially shy child.

Figure 22: F Formations

8.4.4 Cultural and Social Factors

The cultural background of the family had significant influence on the interactions and dynamics at mealtimes. Beaton and Kumar [6] observe that usability testing techniques were mainly designed and refined in Europe and North America, consequently, they perform substantially differently in Indian culture due to factors such as social status and differences between the participant and researcher. This was observed in the cases of the three Indian families A,B and F. In families A and B, the children were extremely shy about opening up and discussing FoodWorks! while the researcher was present. This behaviour is typical of Indian participants who may feel that the researcher is of a higher status than them (e.g. by being older), as according to Beaton and Kumar they may fear that a 'wrong' reaction would incite scolding from the researcher [6]. Thus, in family A, the researcher exited the room and came back once the study had finished; in the case of family B, this was not possible, as the mother preferred the researcher to stay in the room, so simple questions were asked during the meal to diffuse any tensions. In family F, the child felt that he should be on flawless behaviour due to the presence of the parent (higher status) and video camera, nevertheless, they were not under the impression that they should fulfill any particular reactions. Similar issues, were not encountered in European and mixed race families, only in family G were the children shy in the presence of the researcher, in this case, the researcher left the room to allow the natural interactions to take place. Further research is needed to assess different cultural practices and food likes/dislikes.

9 Conclusion

9.1 Evaluation

The Play With Your Food project set out to investigate the effects of using technology on behavioural change in the eating habits of young children. Techniques including digitally enhancing food and gamification coupled with use of persuasive technology were applied in a family context with children between the ages of 3-9. From the literature review, it is clear that current schemes to tackle fussy eating have been primarily targeted at adolescents, moreover, research in the area of digitally enhancing food has been focused on adults and in restaurant settings, and technologies which have involved improving eating habits in children have not been aimed at encouraging family meal time interactions. This project shifts the current focus towards young children in a family oriented environment, and presents the FoodWorks! system, this digitally augments food on the plate by projecting different colours onto the food, and provides virtual rewards for the completion of the meal, towards encouragement of eating related behaviour change.

The project approach was structured into 3 distinct phases:

- Ideation and Pilot Study
- Implementation and Testing
- User Study

Ideation and Pilot Study During ideation several initial sketches of design concepts were created using story boards, stop motion and Adobe flash animations. In the pilot study the children participated in the design process which led to the choice of the final concept to be used. The ideation and the pilot study phase provided excellent insight into what children found stimulating, and allowed a robust definition of requirements. Additionally, a presentation of the project was made to researchers at Microsoft to explore potential use of technologies.

Implementation and Testing During implementation the FoodWorks! system was built. The main design challenges faced in this stage related to the management of the colours i.e its selection and projection, and the displacement between the camera and the projector due to them being separate physical entities, hence, causing a shift in the projection image. The iterative development approach adopted for FoodWorks!, allowed solutions to be found to the design challenges and also ensured that the functionality outlined in the requirements was progressively built and tested. The overall testing approach was effective, as proven through the successful use of FoodWorks! in the user studies where key features such as calibration on a white plate, tracking of movement of food around the plate, projecting multicoloured lights onto particular foods and projecting badges were successful in operation. The performance and usability of the system also met the requirements.

User Study The user studies were comprehensive in their scope and diversity. The studies included several children in the defined age group of 3-9, of both genders and from families of varied cultural backgrounds and ethnicity. This enabled results to be observed from a

diverse range of participants, the researcher had to appropriately cater for cultural factors when conducting the studies, as Indian families were more shy in expressing their views.

The features of FoodWorks! facilitated various interactions from the children, parents and siblings. The family system, the role of the mother and siblings aided the child's eating motivations, and they also employed Foodworks! to divert the child's attention from dislike of particular food items. Parents would use the system to direct their child's attention towards the food, they would create conversation around the colours and relate it to other contexts. They would also use the badges as a nudge to encourage their children to eat their meal. This shows that the system directly affected the meal time conversation. Moreover, sibling involvement played a key role in the dynamics of the meal; they would be eager to get involved and would encourage gameplay with the food, additionally, their formation around the FoodWorks! also affected the verbal input they were able to provide.

Children and parents would interact with the physical equipment, with children putting their hands under the projector to make themselves glow, and parents explaining FoodWorks! to the children. The child's curiosity to understand how the system worked also created eating motivation, as they would distract themselves by playing with the colours, however, in one case the child tried to cheat the system by hiding their vegetables on the table so it could not be picked up. The children would also attempt to create their own notions on how to make the badges appear, and when they displayed on the plate it incited excitement with the child and gave them an impetus to eat their food.

9.2 Future Work

The combination of the projector and the camera as separate physical devices imposed constraints on light projection and capture of the food, so children could hide the food from the area being picked up and still be awarded a badge. Moreover, the size of the system would also take up a lot of the dining space. The availability of a smaller, integrated device could be investigated, that can operate across a wider dining space and enable easier and faster setup. Development could also be explored in the area of maintaining the novelty value of the system to ensure continued use with children, customising it for specific family needs e.g timing of appearance of certain colours and also enhancing the system for multi-cultural use.

9.3 Summary

The project achieved its main aim which was to investigate how different forms of augmented reality feedback can disguise and encourage children to eat food they previously did not like. It has shown that the family interactions facilitated by FoodWorks! and it's key features of digitally enhancing food and nudging techniques such as reward systems, had a positive influence on the eating behaviour of the children. There are further plans to submit a research paper based on this project to CHI 2014. Overall, the approach adopted and the FoodWorks! system worked very well in encouraging fussy eating and non-fussy eating children to eat their vegetables, with several participants thanking the researcher after the study for getting their child to try and/or finish foods they disliked.

Appendix

A Project Plan

Play With Your Food

November 12, 2012

Tackling Fussy Eating in Children by Digitally Augmenting Meals

PROJECT PLAN

Sangita Ganesh

MEng Computer Science

Supervisors: Prof. Yvonne Rogers, Dr. Paul Marshall

1 Aims and Objectives

Main Goal To determine how digital augmentation and motion tracking can be designed and implemented to nudge fussy children to eat vegetables

List of Sub Goals/ Aims

1. Develop a nudging technique using colour segmentation, appropriate animations and interactivity
   (a) Perform colour segmentation of vegetables on a white plate
   (b) Develop motion tracking of vegetables
   (c) Projection of multicoloured lights on the vegetables
   (d) Projection of virtual badges
2. Perform a user study to evaluate the prototype

1.1 Aim 1a

Perform colour segmentation of vegetables on a white plate

Objectives

1. Review techniques to perform colour segmentation in OpenCV
2. Develop software to achieve colour segmentation, first on a static image, then from a video stream.
3. Colour segmentation should distinguish between vegetables of different colours, such as orange carrots and green peas, rather than between vegetables of similar colours e.g. green peas and green beans
4. Test and evaluate the method using software testing techniques

1.2 Aim 1b

Track movement of vegetables around the plate

Objectives

1. Review techniques to perform object tracking in OpenCV
2. Develop software to carry out tracking of vegetables on a white plate
3. Test and evaluate the method using software testing techniques. Demonstrate method works on small vegetables such as individual peas, and larger vegetables such as potatoes

1.3 Aim 1c

Project multi-coloured lights onto each vegetable on the plate, lights should disappear once vegetable disappears from the scene observed by the camera

Objectives

1. Integrate tracking and colour segmentation methods
2. Register camera with projector
3. Develop software such that once detection of vegetables of a certain colour has been achieved, multi coloured lights are then projected onto the vegetables.
4. Ensure that the light projecting down on the vegetable disappears once the vegetable is removed from the vision of the camera
5. Test and evaluate the method using software testing techniques.

1.4 Aim 1d

Project badges surrounding the plate once the multicoloured food has been eaten

Objectives

1. Detect when projector switches off a light
2. Design badges as awards for finishing food
3. Develop software to project badges around the plate as certain amounts of the lit up food disappears
4. Test and evaluate the method using software testing techniques

1.5 Aim 2

Conduct user study to evaluate usability of prototype

Objectives

1. Obtain UCL ethics approval
2. Design study
3. Recruit participants (young children)
4. Organise location and travel arrangments to conduct study

2 Deliverables

1. A literature review surrounding fussy eating and a ways to encourage young children to eat their food
2. Results obtained when conducting initial wizard of oz studies, with analysis and discussion of their significance
3. Sketches and storyboards of other ideas that have been considered
4. A risk analysis
5. A design specification for the prototype
6. A working system which performs tracking and light projection
7. A test strategy
8. Discussion and analysis of results from performing the user study
9. User manual
10. Work in progress paper for CHI 2013 (to be submitted January)
11. Presentation at Microsoft Research Cambridge
12. Interim report
13. Final report fully documenting the prototype

3 Work Plan

15/10 - 28/10 Literature search and review. Gather and define requirements.

29/10 - 18/11 Refine requirements, develop test programs. Design system. Break down prototype into individual functionalities, and start planning on how to tackle the first functionality. Start writing final report.

19/11 - 02/12 Implement and refine design of colour segmentation. Test feature, modify design if necssary. Start writing work in progress CHI paper.

03/12 - 16/12 Refine design, implement and test tracking of vegetables. Start writing interim report.

17/12 - 06/01 Integrate colour segmentation and tracking. Implement, refine design and test light projection system. Continue writing interim report, finish CHI paper. Organise ethics approval for user study.

07/01 - 27/01 Integrate light projection system with badge system. Design badges and implement method to project them around the plate. Finish interim report.

28/01 - 03/02 Evaluate design. Conduct any final testing before user study. Should be at least half way through writing final report at this stage.

04/02 - 03/03 Design and conduct user study. Assess and analyse results.

04/03 - 24/03 Finish writing final report.

Supervisor Signature(s):

Play With Your Food

January 21, 2013

Tackling Fussy Eating in Children by Digitally Augmenting Meals

INTERIM REPORT

Sangita Ganesh

MEng Computer Science

Supervisors: Prof. Yvonne Rogers, Dr. Paul Marshall

1 Progress Made To Date

- Literature review has been completed: List of literature and their key points have been highlighted for use in final report
- Sketches of other ideas have been created
- Results from Wizard of Oz studies have been obtained
- Requirements have been defined: List of detailed requirements and use cases have been constructed
- Prototype has been designed: Overall structure of prototype has been defined. Alternative techniques having been explored with reasons for design choices
- Virtual badges have been designed
- Colour segmentation has been implemented
- Food tracking has been implemented
- Virtual reward system has been implemented
- Basic testing of functionality has been conducted
- Application to ethics board to conduct user study has been submitted
- User study has been designed, with information sheets, consent forms and recruitment emails having been written
- Presentation at Microsoft Research Cambridge has been done
- Work in progress paper and poster for CHI 2013 has been submitted

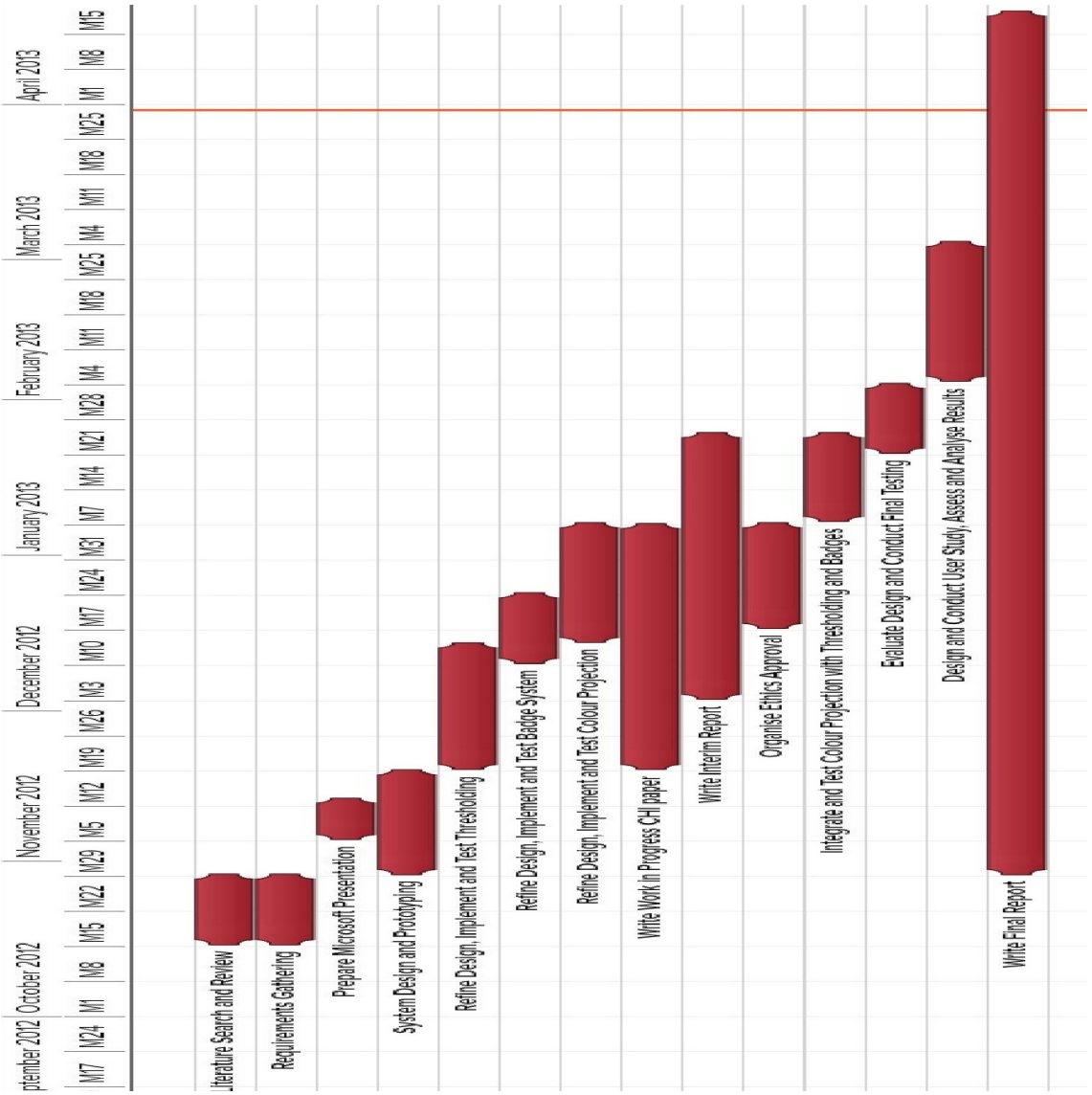
2 Remaining Work To Be Done

- Implement colour projection
- Synchronize camera and projector
- Complete testing of prototype
- Recruit participants for study and organise location and travel arrangements
- Conduct user study, and analyse results
- Create user manual
- Complete writing of final report

Supervisor Signature(s):

C Gantt Chart

The gantt chart below visually represents each stage of the project over time. Mxx indicates the start of the week on date xx, e.g. M24 indicates Monday 24th.



UCL RESEARCH ETHICS COMMITTEE

IMPORTANT: ALL FIELDS MUST BE COMPLETED. THE FORM SHOULD BE COMPLETED IN PLAIN ENGLISH UNDERSTANDABLE TO LAY COMMITTEE MEMBERS.

SEE NOTES IN STATUS BAR FOR ADVICE ON COMPLETING EACH FIELD. YOU SHOULD READ THE ETHICS APPLICATION GUIDELINES AND HAVE THEM AVAILABLE AS YOU COMPLETE THIS FORM.

APPLICATION FORM

SECTION A APPLICATION DETAILS

A1 Project Title: Play With Your Food

Date of Submission: 08/01/2013	Proposed Start Date: 01/02/2012
UCL Ethics Project ID Number: 4337/001	Proposed End Date: 26/04/2013

If this is an application for classroom research as distinct from independent study courses, please provide the following additional details:

Course Title: Individual Project Course Number: COMPM091

A2 Principal Researcher

Please note that a student – undergraduate, postgraduate or research postgraduate cannot be the Principal Researcher for Ethics purposes.

Full Name: Yvonne Rogers	Position Held: Director of UCL Interaction Centre
Address: University College London Malet Place Engineering Building (8th Floor), UCL, Gower Street, London, WC1E 6BT, UK	Email: y.rogers@ucl.ac.uk Telephone: +44 20 7679 7843 Fax:

Declaration To be Signed by the Principal Researcher

- I have met with and advised the student on the ethical aspects of this project design *(applicable only if the Principal Researcher is not also the Applicant).*
  - I understand that it is a UCL requirement for both students & staff researchers to undergo Criminal Records Checks when working in controlled or regulated activity with children, young people or vulnerable adults. The required Criminal Record Check Disclosure Number(s) is: Only student researcher is to have contact with children during the study. Discolosure Number: 001385290004
  - I have obtained approval from the UCL Data Protection Officer stating that the research project is compliant with the Data Protection Act 1998. My Data Protection Registration Number is: Z6364106/2013/01/15
- I am satisfied that the research complies with current professional, departmental and university guidelines including UCL's Risk Assessment Procedures and insurance arrangements.
- I undertake to complete and submit the 'Continuing Review Approval Form' on an annual basis to the UCL Research Ethics Committee.
- I will ensure that changes in approved research protocols are reported promptly and are not initiated without approval by the UCL Research Ethics Committee, except when necessary to eliminate apparent immediate hazards to the participant.
- I will ensure that all adverse or unforeseen problems arising from the research project are reported in a timely fashion to the UCL Research Ethics Committee.
- I will undertake to provide notification when the study is complete and if it fails to start or is abandoned.

Signature: Y Rogers Date: 2/1/13

A3 Applicant(s) Details *(if Applicant is not the Principal Researcher, e.g. student details).*

Full Name: Sangita Ganesh	
Position Held: 4th Year MEng Computer Science	
Address: 31 Tindale Close, South Croydon, CR2 0RT	Email: sangita.ganesh.09@ucl.ac.uk Telephone: 07969013057 Fax:
Full Name:	
Position Held:	
Address:	Email: Telephone: Fax:

A4 Sponsor/ Other Organisations Involved and Funding

a) Sponsor: ☒ UCL ☐ Other institution
If your project is sponsored by an institution other than UCL please provide details

b) Other Organisations: If your study involves another organisation, please provide details. *Evidence that the relevant authority has given permission should be attached or confirmation provided that this will be available upon request.*

c) Funding: What are the sources of funding for this study and will the study result in financial payment or payment in kind to the department or College? *If study is funded solely by UCL this should be stated, the section should not be left blank.* UCL funded

A5 Signature of Head of Department or Chair of the Departmental Ethics Committee

(This must not be the same signature as the Principal Researcher)

I have discussed this project with the principal researcher who is suitably qualified to carry out this research and I approve it. The project is registered with the UCL Data Protection Officer, a formal signed risk assessment form has been completed, and appropriate insurance arrangements are in place. *Links to details of UCL's policies on data protection, risk assessment and insurance arrangements can be found at: http://ethics.grad.ucl.ac.uk/procedures.php*

UCL is required by law to ensure that researchers undergo a Criminal Record Check if their research project puts them in a position of trust with children under 18 or vulnerable adults.
Full details of UCL's policy on criminal record checks can be found at: http://www.ucl.ac.uk/hr/docs/criminal_record.php

"HEAD OF DEPARTMENT TO DELETE BELOW AS APPLICABLE"

I am satisfied that checks: 1) have been satisfactorily completed
2) have been initiated
3) are not required

If checks are not required please clarify why below.

Print Name:

Signature Date:

UCL RESEARCH ETHICS COMMITTEE

Chair's Action Recommended: ☐ Yes ☒ No

A recommendation for Chair's action can be based only on the criteria of minimal risk as defined in the Terms of Reference of the UCL Research Ethics Committee.

SECTION B DETAILS OF THE PROJECT

B1 **Please provide a brief summary of the project in simple prose outlining the intended value of the project, giving necessary scientific background** *(max 500 words).*

This study wil be conducted as part of a dissertation project to meet the requirements for the MEng Computer Science. This research project explores the potential of using technology to enhance meals, and in particular as a behavioral nudge to encourage fussy eating children :o eat their food. Many parents and guardians have trouble with persuading young children to eat their vegetables, and children in hospitals often tend to lose their appetites. However, as a means to get better they must eat healthy, nutritious food. To solve this issue, we present a prototype that digitally augments vegetables on a plate, and provides virtual rewards for eating the meal. The prototype involves a small camera that tracks the food on the plate, with the projector then shining multicoloured lights onto the food as it moves, with virtual badges being earned and displayed around the plate, once half or all the vegetables have been finished.

B2 **Briefly characterise in simple prose the research protocol, type of procedure and/or research methodology (e.g. observational, survey research, experimental). Give details of any samples or measurements to be taken** *(max 500 words).*

The research will follow an observationa approach. The student researcher will visit participants' homes in the month of February to observe and analyze responses to the prototype. Methodologies to be used will include naturalistic observation and data analysis.

Responses tc the technology will be noted using video/audic recording and observational field notes. Of interest are the social interactions between the parent and/or child with regards to the prototype, and the effects it has on eating behaviour. Both the parent(s) and the child will be present throughout the duration of the study.

Analysis will be conducted by reviewing the videos once the studies are completed, noting behaviours and responses to the technology, and identifying potential problems. Combining data analysis and observational study will help yield a better understanding of the experience provided by the prototype.

Attach any questionnaires, psychological tests, etc. (a standardised questionnaire does not need to be attached, but please provide the name and details of the questionnaire together with a published reference to its prior usage).

B3 **Where will the study take place (please provide name of institution/department)?**
If the study is to be carried out overseas, what steps have been taken to secure research and ethical permission in the study country?
Is the research compliant with Data Protection legislation in the country concerned or is it compliant with the UK Data Protection Act 1998?

The study will be conducted at the homes of participants.

B4 **Have collaborating departments whose resources will be needed been informed and agreed to participate?**
Attach any relevant correspondence.

N/A

B5 **How will the results be disseminated, including communication of results with research participants?**

Results will be presented in a MEng dissertation and may be presented in academic publications and/or conferences, workshops, and/or teaching material. Participants' names will not be disclosed, and childrens' faces will not be shown. Raw material will only be accessible to the student researcher, principal researcher, and potentially examiners. Research participants will be invited to request a copy of the dissertation if desired, contact details of the researchers will be provided on the information sheets given to each participant.

B6 **Please outline any ethical issues that might arise from the proposed study and how they are be addressed.** *Please note that all research projects have some ethical considerations so do not leave this section blank.*

Informed consent: When conducting interviews, participants will be briefed regarding the study purpose, given an information sheet for them to keep with details of the study and contact information for the researchers, and asked to sign a consent form. Participants will be informed that their participation is completely voluntary, and that no harm will arise if they do not wish to participate. Informed consent will be obtained by adults 18-64, except where they are unable to give consent due to mental health problem or incapacity. Consent for child participants will be obtained from their parents or legal guardian.

Protection from harm: All interaction will be conducted at the homes of participants, with the parent or guardian present at all times. The student researcher has been CRB approved.

Right to withdraw: Participants will be informed that they have the right to withdraw from the study at any time, without explanation. This will be reinforced with the information sheet and consent form. Video recording will only be conducted once the study starts, if the participant has any concerns regarding filming, it will immediately stop and any footage of them will be destroyed.

Storage of data, confidentiality and anonymity: Behaviour and responses to the prototype will be recorded using video and observational field notes. All data will be stored on a password-protected computer, and any data stored on an external hard disc will be encrypted. Participants will be informed that the study is confidential and anonymous, and will be given an information sheet detailing the study to keep.

SECTION C DETAILS OF PARTICIPANTS

C1 **Participants to be studied**

C1a. Number of volunteers:	10 families in total. 10-20 children and 10-20 parents.
Upper age limit:	64
Lower age limit:	4

C1b. Please justify the age range and sample size:

The study is primarily focused on evaluating the prototype for children aged between 4-9, as the technology will not be as effective for children outside this age range. Parents will also be involved in the study, hence the upper age limit.

The sample size was chosen in order to obtain a relevant range of data within the constraints of time for the study.

C2 **If you are using data or information held by a third party, please explain how you will obtain this. You should confirm that the information has been obtained in accordance with the UK Data Protection Act 1998.**

N/A

C3 **Will the research include children or vulnerable adults such as individuals with mental health problems or with learning disabilities, the elderly, prisoners or young offenders?** ☒ Yes ☐ No

How will you ensure that participants in these groups are competent to give consent to take part in this study? *If you have relevant correspondence, please attach it.*

Children asked to participate in interviews will be granted consent from their parents or legal guardians who are present. Consent forms and information sheets will be sent to the parents and guardians. As prototypes are designed for children, child participation is necessary for this study.

C4 **Will payment or any other incentive, such as gift service or free services, be made to any research participant?**

☒ Yes ☐ No

If yes, please specify the level of payment to be made and/or the source of the funds/gift/free service to be used.

A Tesco food voucher will be given to each family who participates in the study. Value of voucher to be confirmed with principal researcher.

Please justify the payment/other incentive you intend to offer.

A food voucher is a suitable gift for a study which focusing on meals and healthy eating. A voucher will be offered as a thank you for taking part in the study.

C5 **Recruitment**

(i) Describe how potential participants will be identified:

Potential participants will be identified if they have children between the age of 4-9, who may have fussy eating problems.

(ii) Describe how potential participants will be approached:

Participants will be approached if there are no obvious impediments to doing so. The researcher will identify and introduce themselves and provide a quick summary of their research purposes. They will then be asked if they would be interested in participating, and if they agree, they will be briefed on the study, the information sheet will be explained, and will be asked to sign the consent forms for themselves and their children, the researcher will then arrange a suitable time for the participant to conduct the study.

(iii) Describe how participants will be recruited:

Participants will be recruited through emails circulated via UCL.

See attached 1) Recruitment Email for Participants

Attach recruitment emails/adverts/webpages. A data protection disclaimer should be included in the text of such literature.

C6 **Will the participants participate on a fully voluntary basis?** ☒ Yes ☐ No

Will UCL students be involved as participants in the research project? ☒ Yes ☐ No

if yes, care must be taken to ensure that they are recruited in such a way that they do not feel any obligation to a teacher or member of staff to participate.

Please state how you will bring to the attention of the participants their right to withdraw from the study without penalty?

A right to withdraw at any time will be stated on the consent forms and information sheets, and will be mentioned in the brief of the study.

C7 **CONSENT**

Please describe the process you will use when seeking and obtaining consent.

Consent will be sought to participate in the study. After being briefed regarding the purpose of the study, and the parent or legal guardian approves, and are capable of approving for themselves, they will be given an information sheet for them to keep with details of the study and contact information for the researchers. The study will be explained to them and they will be asked to sign consent forms for themselves and for the child participant.

A copy of the participant information sheet and consent form must be attached to this application. For your convenience proformas are provided in C10 below. These should be filled in and modified as necessary.

In cases where it is not proposed to obtain the participants informed consent, please explain why below.

C8 **Will any form of deception be used that raises ethical issues? If so, please explain.**

N/A

C9 **Will you provide a full debriefing at the end of the data collection phase?** ☒ Yes ☐ No

If 'No', please explain why below.

C10 **Information Sheets And Consent Forms**

A poorly written Information Sheet(s) and Consent Form(s) that lack clarity and simplicity frequently delay ethics approval of research projects. The wording and content of the Information Sheet and Consent Form must be appropriate to the age and educational level of the research participants and clearly state in simple non-technical language what the participant is agreeing to. Use the active voice e.g. "we will book" rather than "bookings will be made". Refer to participants as "you" and yourself as "I" or "we". An appropriate translation of the Forms should be provided where the first language of the participants is not English. If you have different participant groups you should provide Information Sheets and Consent Forms as appropriate (e.g. one for children and one for parents/guardians) using the templates below. Where children are of a reading age, a written Information Sheet should be provided. When participants cannot read or the use of forms would be inappropriate, a description of the verbal information to be provided should be given. Please ensure that you trial the forms on an age-appropriate person before you submit your application.

SECTION D DETAILS OF RISKS AND BENEFITS TO THE RESEARCHER AND THE RESEARCHED

D1 **Have UCL's Risk Assessment Procedures been followed?** ☒ Yes ☐ No

If No, please explain.

D2 **Does UCL's insurer need to be notified about your project before insurance cover can be provided?** ☐ Yes ☒ No

The insurance for all UCL studies is provided by a commercial insurer. For the majority of studies the cover is automatic. However, for a minority of studies, in certain categories, the insurer requires prior notification of the project before cover can be provided. For example, you will need to complete an insurance registration form for the following types of studies: clinical trials which use drugs or vaccines; trials of medical devices; studies which use radiation, surgery or anesthesia as the intervention; studies which will enroll over 5000 subjects.

If Yes, please provide confirmation that the appropriate insurance cover has been agreed. *Please attach your UCL insurance registration form and any related correspondence.*

D3 **Please state briefly any precautions being taken to protect the health and safety of researchers and others associated with the project (as distinct from the research participants).**

Mobile Phones: The researcher must carry a mobile phone to the session and leave it on at all times. The researcher must notify an emergency contact or the supervisor upon entering and leaving the house. The supervisor and emergency contact must hold the full name and mobile phone number of the researcher. The supervisor or emergency contact must be prepared for action if the researcher does not call at a reasonable end time for a study, for example if it is a lunch session starting at 1.00pm and the researcher does not call by 3.30pm. In this case the supervisor or emergency contact should call the researcher, then the house phone, then must be prepared to phone the police.

Conducting the study. The researcher must conduct the study in a public room i.e dining room or lounge not bedroom, and preferably nearest the front door. The parent or legal guardian should be present at all times with researcher when the child is in the room. The researcher must let the participant know when they are due to leave, and the supervisor must be informed beforehand of the address and telephone number of where the study is taking place. The researcher must take their student card along with the name and contact number of the supervisor, to authenticate to the participant who the researcher is.

House Visits: The researcher must assess the layout and quickest route out of the house.

The researcher must inform the supervisor if they do not feel adequately protected by these guidelines.

D4 **Will these participants participate in any activities that may be potentially stressful or harmful in connection with this research?** ☐ Yes ☒ No

If Yes, please describe the nature of the risk or stress and how you will minimise and monitor it.

D5 **Will group or individual interviews/questionnaires raise any topics or issues that might be sensitive, embarrassing or upsetting for participants?**

If Yes, please explain how you will deal with this.

No

D6 **Please describe any expected benefits to the participant.**

The benefit to the participant will be contributing to research of digitally enhancing food for children, and influencing the future direction of the design of technologies for eating related behaviour change.

D7 **Specify whether the following procedures are involved:**

Any invasive procedure(s) ☐ Yes ☒ No

Physical contact ☐ Yes ☒ No

Any procedure(s) that may cause mental distress ☐ Yes ☒ No

Please state briefly any precautions being taken to protect the health and safety of the research participants.

The study will be conducted in the home of the participant during normal supper times. The parent or legal guardian will always be present during the study with the child participant.

D8

Does the research involve the use of drugs? ☐ Yes ☒ No

If Yes, please name the drug/product and its intended use in the research and then refer to Appendix I

Does the project involve the use of genetically modified materials? ☐ Yes ☒ No

If Yes, has approval from the Genetic Modification Safety Committee been obtained for work? ☐ Yes ☒ No

If Yes, please quote the Genetic Modification Reference Number:

D9

Will any non-ionising radiation be used on the research participant(s)? ☐ Yes ☒ No

If Yes, please refer to Appendix II.

CHECKLIST

Please submit ether 12 copies (1 original + 11 double sided photocopies) of your completed application form for full committee review or 3 copies (1 original + 2 double sided copies) for chair's action, together with the appropriate supporting documentation from the list below to the UCL Research Ethics Committee Administrator. You should also submit your application form electronically to the Administrator at: ethics@ucl.ac.uk

Documents to be Attached to Application Form (if applicable)	Ticked if attached	Tick if not relevant
Section B: Details of the Project		
• Questionnaire(s) / Psychological Tests	☐	☒
• Relevant correspondence relating to involvement of collaborating department/s and agreed participation in the research.	☐	☒
Section C: Details of Participants		
• Parental/guardian consent form for research involving participants under 18	☒	☐
• Participant/s information sheet	☒	☐
• Participant/s consent form/s	☒	☐
• Advertisement	☒	☐
Section D: Details of Risks and Benefits to the Researcher and the Researched		
• Insurance registration form and related correspondence	☐	☒
Appendix I: Research Involving the Use of Drugs		
• Written signed statement from the pharmaceutical/industrial company stating their agreement to abide by the guidelines on compensation of the Association of British Pharmaceutical Industry (ABPI)		
or other insurance certificate	☐	☒
• Proposed volunteer contract	☐	☒
• Full declaration of financial or direct interest	☐	☒
• Copies of certificates: CTA etc…	☐	☒
• Relevant correspondence relating to agreed arrangements for dispensing with the pharmacy	☐	☒
Appendix II: Use of Non-Ionising Radiation		

Please note that correspondence regarding the application will normally be sent to the Principal Researcher and copied to other named individuals.

E Approval Letter

Dr Yvonne Rogers
Director of UCL Interaction Centre
Malet Place Engineering Building (8th Floor)
UCL

29 January 2013

Dear Dr Rogers

Notification of Ethical Approval
Project ID: 4337/001: Play with your food

I am pleased to confirm that your study has been approved by the UCL Research Ethics Committee for the duration of the project i.e. until January 2014.

Approval is subject to the following conditions:

1. You must seek Chair's approval for proposed amendments to the research for which this approval has been given. Ethical approval is specific to this project and must not be treated as applicable to research of a similar nature. Each research project is reviewed separately and if there are significant changes to the research protocol you should seek confirmation of continued ethical approval by completing the 'Amendment Approval Request Form'.

The form identified above can be accessed by logging on to the ethics website homepage: http://www.grad.ucl.ac.uk/ethics/ and clicking on the button marked 'Key Responsibilities of the Researcher Following Approval'.

2. It is your responsibility to report to the Committee any unanticipated problems or adverse events involving risks to participants or others. Both non-serious and serious adverse events must be reported.

Reporting Non-Serious Adverse Events
For non-serious adverse events you will need to inform Helen Dougal, Ethics Committee Administrator (ethics@ucl.ac.uk), within ten days of an adverse incident occurring and provide a full written report that should include any amendments to the participant information sheet and study protocol. The Chair or Vice-Chair of the Ethics Committee will confirm that the incident is non-serious and report to the Committee at the next meeting. The final view of the Committee will be communicated to you.

Reporting Serious Adverse Events
The Ethics Committee should be notified of all serious adverse events via the Ethics Committee Administrator immediately the incident occurs. Where the adverse incident is unexpected and serious, the Chair or Vice-Chair will decide whether the study should be terminated pending the opinion of an independent expert. The adverse event will be considered at the next Committee meeting and a decision will be made on the need to change the information leaflet and/or study protocol.

On completion of the research you must submit a brief report (a maximum of two sides of A4) of your findings/concluding comments to the Committee, which includes in particular issues relating to the ethical implications of the research.

With best wishes for the research.

Yours sincerely

Professor John Foreman
Chair of the UCL Research Ethics Committee

Cc: Sangita Ganesh

UCL Research Ethics Committee, c/o The Graduate School, North Cloisters, Wilkins Building
University College London Gower Street London WC1E 6BT
Tel: +44 (0)20 7679 7844 Fax: +44 (0)20 7679 7043
ethics@ucl.ac.uk
www.ucl.ac.uk/gradschool

F CRB Check

Enhanced Disclosure

Page 1 of 2

disclosure

Disclosure Number 001385290004

Date of Issue: 10 NOVEMBER 2012

Applicant Personal Details

Surname: GANESH

Forename(s): SANGITA

Other Names: NONE DECLARED

Date of Birth: 08 MAY 1991

Place of Birth: MADRAS INDIA

Gender: FEMALE

Employment Details

Position applied for:
STUDENT MSC RESEARCH

Name of Employer:
UCL

Countersignatory Details

Registered Person/Body:
UNIVERSITY COLLEGE LONDON

Countersignatory:
JEANETTE PHILLIPS

Police Records of Convictions, Cautions, Reprimands and Warnings

NONE RECORDED

Information from the list held under Section 142 of the Education Act 2002

NONE RECORDED

ISA Children's Barred List information

NONE RECORDED

ISA Vulnerable Adults' Barred List information

NONE RECORDED

Other relevant information disclosed at the Chief Police Officer(s) discretion

NONE RECORDED

Enhanced Disclosure

This document is an Enhanced Criminal Record Certificate within the meaning of sections 113B and 116 of the Police Act 1997.

THIS DISCLOSURE IS NOT EVIDENCE OF IDENTITY

Continued on page 2

Application for inclusion of a research project Form 2

A. APPLICATION DETAILS

A1	**Project Title:** **Play With Your Food**	
	Date of Submission: 26/04/2013	Proposed Start Date: 26/09/2012
	UCL Ethics Project ID Number: 4337/001	Proposed End Date: 26/04/2013

A2	**Principal Researcher** *(Please note that a student – undergraduate, postgraduate or research postgraduate cannot be the Principal Researcher for Ethics purposes).*	
	Full Name: Yvonne Rogers	
	Position Held: Director of UCL Interaction Centre	
	Address: University College London Malet Place Engineering Building (8th Floor), UCL, Gower Street, London, WC1E 6BT, UK	
		Email: y.rogers@ucl.ac.uk
		Telephone: +44 20 7679 7843

A3	**Data Collector(s) Details** *(if Applicant is not the Principal Researcher e.g. student details):*	
	Full Name: Sangita Ganesh	
	Position Held: 4th Year MEng Computer Science	
	Address: 31 Tindale Close, South Croydon, CR2 0RT	
		Email: sangita.ganesh.09@ucl.ac.uk
		Telephone: 07969018057

B. DETAILS OF THE PROJECT

B1 Please provide a brief summary of the project

This study will be conducted as part of a dissertation project to meet the requirements for the MEng Computer Science, it will involve video recording responses to a novel prototype. This research project explores the potential of using technology to enhance meals and in particular as a behavioral nudge to encourage fussy eating children to eat their food. Many parents and guardians have trouble with persuading young children to eat their vegetables, and children in hospitals often tend to lose their appetites. However, as a means to get better they must eat healthy, nutritious food. To solve this issue, we present a prototype that digitally augments vegetables on a plate, and provides virtual rewards for eating the meal. The prototype involves a small camera that tracks the food on the plate, with the projector then shining multicoloured lights onto the food as it moves, with virtual badges being earned and displayed around the plate, once half or all the vegetables have been finished.

C. DETAILS OF PARTICIPANTS

C1 **Data subjects**

Data will be collected from 10 families, who have consented to participate in the study.

C2 **What data will be collected**

Names of participants, address, home telephone number and the ages of the children involved will be collected from the participants, as studies will be conducted in homes.

Responses to the technology by the parent and child will be noted using video recordings and observational field notes.

All data will be stored on a password protected computer, and any data stored on an external hard drive will be encrypted. Participants can withdraw their data up until it is transcribed for use in the dissertation on 01/03/2013.

C3 **Disclosure**

Results will be presented in a MEng dissertation and may be presented in academic publications and/or conferences, workshops, and/or teaching material. Participants' names, addresses and home telephone numbers will not be disclosed, and childrens' faces will not be shown. Raw material will only be accessible to the student researcher, principal researcher, and potentially examiners. Research participants will be invited to request a copy of the dissertation if desired, contact details of the researchers will be provided on the information sheets given to each participant.

D. CONSENT

D1 **Consent**

See attached Information Sheet, Verbal Information, Consent form for adult and Consent form for child.

E. INTERNATIONAL TRANSFER

E1 **International Transfer**

	The eighth principle of the Data Protection Act 1998 prohibits the transfer of personal data to countries or territories outside the European Economic Area (which consists of the 27 EU member states, Iceland, Liechtenstein and Norway). At the time of writing the following countries have also been deemed adequate for the purposes of the 8th principle Argentina, Canada, Guernsey, Isle of Man, Jersey and Switzerland. N/A

F. PUBLICATION

Will the results of your research be published in an academic journal or other publication? **YES**

Please note that published results must not contain data by which an individual can be identified.

G. NOTIFICATION

G1	**Notification** *(Please note that notification is a prerequisite for registration)* Have you informed your department's Data Protection Coordinator about your project? **YES**

G2	**Notification** *(Please note that notification is a prerequisite for registration)* Have you informed your department's computer representative about your project? **YES**

H. ETHICS

H1	Are you applying to the UCL Research Ethics Committee? **YES** Date of Ethics meeting: 28/01/2013

I. REGISTRATION

I1	**Registration:** *Office use only.*	
	UCL Data Protection Registration Number:	Data issued:

Further information

For more information and guidance on the UCL Research Committee, please visit
http://ethics.grad.ucl.ac.uk/

When all essential documents are ready to archive, contact the UCL Records Office by email at records.office@ucl.ac.uk to arrange ongoing secure storage of your research records unless you have made specific alternative arrangements with your department, or funder.

For information on the UCL Records Management Service, please visit
http://www.ucl.ac.uk/efd/recordsoffice/policy/records-transfer

H Recruitment Email and Information Sheet For Participants

Calling all parents! Do you ever have problems getting your children to eat? We're looking for parents with children aged between 4-9 to help us test out a new technology that digitally enhances food! We'll be projecting lights onto food and awarding virtual badges for you child to finish their vegetables. If you would like further information and may be interested in taking part, contact Sangita Ganesh (4th Year MEng Computer Science) at sangita.ganesh.09@ucl.ac.uk. All data will be collected and stored in accordance with the Data Protection Act 1998.

Information Sheet for Evaluating a Prototype to Improve Eating Habits in Young Children

You will be given a copy of this information sheet.

Title of Project: **Play With Your Food**

This study has been approved by the UCL Research Ethics Committee (Project ID Number): 4337/001

Name	Student Researcher: Sangita Ganesh Principal Researcher: Yvonne Rogers Other Researchers: Paul Marshall
Work Address	University College London Interaction Centre, Malet Place Engineering Building (8th Floor), Gower Street – London WC1E 6BT
Contact Details	sangita.ganesh.09@ucl.ac.uk y.rogers@ucl.ac.uk paul.marshall@ucl.ac.uk

We would like to invite you and your children participate in this research project.

Details of Study: The aim of this project is to evaluate a novel prototype that encourages fussy eating children to eat their food. The focus of the investigation is to understand how well the prototype works in nudging behaviour and getting children to try and/or finish disliked foods. The findings of the study will help us to understand the user experience with the technology, and outline the effectiveness of its purpose and ways in which it could possibly be improved in the future to help children to eat better. The prototype itself consists of a simple camera and projector, which track the movement of the food and project animations down on the plate. The animation shows different coloured lights projecting on to the vegetables, with the lights following the food around the plate as your child moves their food. There are also virtual badges awarded if half then all the lit up vegetables have been eaten, which will be displayed around the outside of the plate.

If you agree to participate, we will arrange a convenient time to conduct the study in your home. You will be asked to prepare a normal supper for your child, on preferably a white plate, with a side of vegetables of your choice, which they may or may not dislike. You will also be asked to notify the child of winning virtual badges if they eat half and all their vegetables. You are encouraged to interact with the child as they eat their meal.

The study will last for the duration of the meal, and will be video recorded; I will be taking notes during the study. If you do not wish to have the study video recorded, please let me know beforehand. Participation in this study is voluntary and you are free to withdraw at any time during the study without having to give an explanation. You may withdraw your data from the project at any time up until it is transcribed for use in the final report on 01/03/2013. You and your child's names or addresses will not be disclosed anywhere, and videos will not be published publicly and will solely be used for research purposes in this project.

If you decide to take part you will be given this information sheet to keep and be asked to sign two consent forms for yourself and on behalf of your child. A final copy of the report from this study can be requested via the contact details above if desired. You will also receive a Tesco Voucher as a gift for taking part.

Please discuss the information above with others if you wish or ask us if there is anything that is not clear or if you would like more information. It is up to you to decide whether to take part or not; choosing not to take part will not disadvantage you in any way. If you do decide to take part you are still free to withdraw at any time during the study without giving a reason. **All data will be collected and stored in accordance with the Data Protection Act 1998.**

Informed Consent Form for Participation in Research Study: Evaluating a Prototype to Improve Eating Habits in Young Children

Please complete this form after you have read the Information Sheet and/or listened to an explanation about the research.

Title of Project: **Play With Your Food**

This study has been approved by the UCL Research Ethics Committee (Project ID Number): 4337/001

Thank you for your interest in taking part in this research. Before you agree to take part, the person organising the research must explain the project to you.

If you have any questions arising from the Information Sheet or explanation already given to you, please ask the researcher before you to decide whether to join in. You will be given a copy of this Consent Form to keep and refer to at any time.

Participant's Statement

I _____ **(Participants name)**

- have read the notes written above and the Information Sheet, and understand what the study involves.
- understand that if I decide at any time that I no longer wish to take part in the study, I can notify the researchers involved and withdraw immediately.
- understand that my participation will be video taped, unless I ask otherwise, and consent for the material to be used as part of the project
- understand I can withdraw my data at any time up until it is transcribed for use in the final report on 01/03/2013
- consent to the processing of my personal information for the purposes of this research study.
- understand that the information I give will be used in a dissertation and may be published at a later date, and that I may request a copy, and that my non-personal research data may be used by others for future work. Confidentiality and anonymity will be maintained and it will not be possible to identify me from any publications.
- understand that such information will be treated as strictly confidential and handled in accordance with the provisions of the Data Protection Act 1998.
- agree that the research project named above has been explained to me to my satisfaction and I agree to take part in this study.

Signed: Date:

Informed Consent Form for Participation in Research Study: Evaluating a Prototype to Improve Eating Habits in Young Children

Please complete this form after you and the child participant have read the Information Sheet and/or listened to an explanation about the research.

Title of Project: **Play With Your Food**

This study has been approved by the UCL Research Ethics Committee (Project ID Number): 4337/001

Thank you for your interest in taking part in this research. Before you agree to let the child for whom you are parent or guardian take part, the researcher will explain the project to you.

If you have any questions arising from the Information Sheet or explanation already given to you, please ask the researcher before you to decide whether to join in. You will be given a copy of this Consent Form to keep and refer to at any time.

Participant's Statement

I _____ **(Participants name)**

- have read the notes written above and the Information Sheet, and understand what the study involves. The child participant has also either read the information sheet or had the study explained to them
- understand that if we decide at any time that we no longer wish to take part in this project, we can notify the researchers involved and withdraw immediately.
- consent to the processing of our personal information for the purposes of this research study.
- understand that my participation will be videotaped, unless we ask otherwise, and consent for the material to be used as part of the project
- understand I can withdraw my data at any time up until it is transcribed for use in the final report on 01/03/2013
- understand that the information I give will be used in a dissertation and may be published at a later date, and that I may request a copy, and that my non-personal research data may be used by others for future work. Confidentiality and anonymity will be maintained and it will not be possible to identify me or the child participant from any publications.
- understand that such information will be treated as strictly confidential and handled in accordance with the provisions of the Data Protection Act 1998.
- agree that the research project named above has been explained to me to my satisfaction and I agree for the child of whom I am the parent or legal guardian to take part in this study.

Signed: Date:

J Questions for Semi-Structured Interview

Family No.:	Child's Age/Food Preferences:

Children	
Did you see anything differently about your meal today?	
What did you think of the colours?	
What is your favourite colour/ What colours did you see?	
Did the colours/badges help you eat your food?	
Why do you think you got a badge?	
What other rewards do you want?	
Parents	
How did you feel about the prototype?	
How do you think the prototype affected the dynamics of the meal?	
Do you think it helped your children's eating?	
Would you suggest any changes or anything it should do differently?	

Play With Your Food

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Abstract

This paper describes an ongoing research project to explore the potential of using technology to enhance meals, and in particular as a behavioral nudge to encourage fussy eating children to eat their food. Many parents and guardians have trouble with persuading young children to eat their vegetables, and children in hospitals often tend to lose their appetites. However, as a means to get better they must eat healthy, nutritious food.

We report our initial ideas and sketches, and our findings from three preliminary studies conducted with various families. Based on these results, we present our initial system design for a prototype that digitally augments vegetables on a plate, and provides virtual rewards for eating the meal.

Author Keywords
Behavioral Nudges; Fussy Eating; Children; Digitally Augmented Food;

Figure 1. Guided eating. A number appears on the food you have to eat next. Once this is done the next number appears.

Figure 2. Monkey on a banana. Here is a character interacting with the food, in this case climbing up a banana.

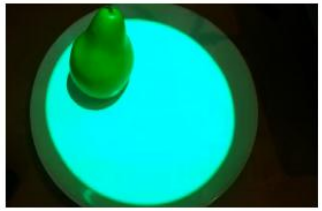

Figure 3. The colour of the plate changes according to the colour of the food you eat. Here the green matches the green of the pear.

ACM Classification Keywords
H.5.m [Information Interfaces and Presentation (e.g., HCI)]: Miscellaneous; K.8.0 [Personal Computing]: Games;

General Terms
Design; Human Factors

Introduction

Persuading children to eat healthily has always been a challenging issue. The World Cancer Research Fund (WCRF) reported that four out of five children are eating less than the recommended five portions of fruits and vegetables a day [3]. In particular it is found that vegetable consumption is 10% lower than fruit consumption [4]. Various schemes have been introduced to recognize this issue. Jamie Oliver is trying to raise attention for this problem by organizing a challenge together with open IDEO to "raise kids' awareness of the benefits of fresh food so they can make better choices" [13]. However, such concepts are primarily targeted at adolescents, whereas food choices are influenced as children enter school and enjoy more social experiences with friends [7], thus children should be stimulated to eat healthily from a young age.

Currently, there are various techniques being used to deal with fussy eaters. These include disguising problem foods within liked foods (e.g grating carrots into sauces or mashing cauliflower into mashed potatoes), making food fun by giving dishes appealing names such as 'Cowboy Chicken', making the cutlery talk and singing to the child [2] and presenting food in colourful, cute ways with characters and objects the child can relate to, such as in the case of the Japanese bento boxes [1]. Given that much of these techniques are performed manually, there is scope for technology to be used in such a context to augment meals. Digitally enhancing food has been explored in other situations rather than with picky eating [14]. Heston Blumental's "Sounds of the Sea" dish involves the diner listening to sea sounds whilst eating the meal, thus enhancing it's taste. The creation of this dish is based on research which has shown that sounds affect the perceptions of food [15]. Additionally, visual and olfactory information can be manipulated through the use of technology. The Meta cookie [12], combines a head-mounted display (HMD) with an olfactory display to present different kinds of cookies (strawberry, chocolate, tea etc), the visual effects makes the user perceive that they are eating different varieties but in fact it is a plain cookie.

However, current research has been primarily targeted at adults and in restaurant settings. We would like to shift the focus towards children and consider the applications of technology for behaviour change in eating habits. By using nudging techniques, which have been highlighted in several frameworks such as MINDSPACE [11], we intend to alter the context of 'playing' with food, through the use of persuasive technologies.

Initial Ideas and Design

By using the design processes highlighted by Buxton [9], we created a number of sketches using stop motion and Adobe Flash animations to explore ways of digitally augmenting food for children. These can be seen in the figures and included guided eating through numbering, characters interacting with the meal, and the colour of the plate changing according to the colour of the food you are eating. Within the wealth of ideas,

Figure 4. Multicoloured lights projecting down onto peas. The lights have been created using a Flash animation.

Figure 5. As we eat the peas the lights disappear. This figure shows the peas and lights remaining as we finish the meal.

we filtered down to two animations that focused on the gameification and disguise aspects of food.

The first involved shining multicoloured lights onto peas, this created the effect of the peas looking like Smarties or other coloured sweets, these colours would often change, as children are found to be attracted to a variety of bright colours [2], and foods they can identify with sweetness [6,8].

Gamifaction is a notion that can be used in non gaming contexts [10]. In addition, researchers have shown that games are effective ways for health-related behaviour change, as they provide an immersive environment based on goal setting [5]. Consequently, in our second animation, we played a game with our food. The participant was given certain portions of the meal to finish within a time limit, with the incentive of earning a virtual badge projected on the plate. This is similar to the reward systems used in schools, in which children obtain a sticker for doing well. These ideas are used to encourage children to eat more quickly and award them for their successes.

Figure 6. A game has been created for guided eating of the food using Flash. The instructions say 'Eat 3 pieces of broccoli in 10 seconds to win a badge'. On the top right hand corner you can see a timer counting down how much time you have left to finish the instruction.

Figure 7. If you successfully eat the target portion of food within the given time, you earn a virtual badge. Badges you have already won are displayed around the top of the plate

Figure 8. This figure shows what happens if you do not complete your food according to the instructions. The text says 'Better luck next time. You didn't manage to finish your broccoli on time. Try again another day to get your Broccoli Master badge! Next badge Nimble Nibbler!'.

Wizard of Oz Studies

To observe and evaluate the animations, we conducted Wizard of Oz studies with three different families, each with two children. For each study we used a standard meal of pasta with a side of peas, a typical supper the family would have. The studies were split into two parts, so each child could participate with one of the animations, the first involved projecting the colours onto peas, without the disappearing lights for purposes

of difficulty manually tracking, and the second projected the game (adapted for a meal of pasta and peas), without the timer, onto the plate.

Equipment

We used a pico projector held up by a tripod to project the animations down onto the plate. The meals had to be staggered between the two children as we only had one set of equipment.

Participants

The study was done in the homes of the participants, to ensure a natural, comfortable setting for all those involved. This also ensured that we were able to observe the reaction of the parents/guardians as well as the children.

We had three families involved. Family 1 had two young boys aged 4 and 6. As the game required a little understanding of instructions and some reading ability, we employed it with the older child, and used the multicoloured peas animation for the younger boy. The children were supervised by their mother, who was present during the meal. Family 2 had two girls aged 2 and 4. We used the game animation with the 4 year old, who required a large amount assistance with the reading from the parent, and we used the multicoloured peas with the 2 year old. During the meal, both parents were present. Family 3 had a boy aged 7 ½ and a girl aged 5. In this study we projected the game onto the plate for the boy, and the multicoloured peas for the girl. During this study, both parents, and an older brother aged 14 were present.

Results

With the multicoloured peas, we found that in all cases, sampling was done from the coloured area of the plate, with children placing food in these regions. The 4 year old boy from Family 1 said he preferred pasta to peas, but we observed him finishing all the peas first; and then pushing the pasta into the glowing area of the plate. In Family 2, we saw the 2 year old, placing the peas on the lighted dots and eating from these areas. The 5 year old from Family 3, also responded in a similar manner, and pushed the food into the coloured parts. The children from Families 1 and 3, with exception of the 2 year old from Family 2, who was too young to fully articulate, also seemed keen on the notion of the colours following the food on the plate. The 4 year old from Family 1 liked the idea and said he also wanted it to 'disappear once [he] ate it'. Similarly, in Family 3, the 5 year old said that she prefers brighter colours and 'want[ed] the colours to stay on the food when [she] move[d] it around'. There was also a lot of conversation created by the parents in all the families, to focus the child's attention on the glowing dots. In Family 1 the parent hinted they were 'magic' and asked the child 'do you think you will glow if you eat glowing food?'. In addition, with Families 1 and 2, the parents suggested that the peas 'taste yummier when it's glowing'. This illustrates that the technology was used as a cue to support parents' own persuasive techniques.

Another key finding in the case of the multicoloured peas, was with the elder sister in Family 2, who disliked peas. Although she was not taking part in this animation, she was intrigued by the colours and was motivated to try some. Thus, confirming the nudging effect of this technology.

With the game, we found it had an unexpected educational quality as the child, and in some cases with the help of the parent, tried to read the instructions. This shifted the attention from the meal, which may be beneficial in breaking up the task of eating. We also observed the parents creating stories out of the characters appearing next to the instructions, with phrases such as 'Oh look who it is! It's Bernie the bowl!' and 'you won't be making the characters happy if you don't eat your food'. With each family, once the child was told they would earn a virtual badge if they followed the instructions, they promptly abided. The effectiveness of this incentive can be illustrated in each case. In Family 1 we asked the participant if they would like a timer counting down the time they had left to finish the food in order to win a badge, they said 'no, because I won't win badges'. In Family 2 the participant did not like peas. There was a stage in the meal where the parent said 'you don't have to finish all those peas if you don't want to', to which she responded 'but then I won't get the badge' and continued eating her peas. Finally, in Family 3 the participant disliked pasta, at the end of the meal he said, 'I hate eating pasta, but I did it because I wanted the badges'.

Discussion and Future Work

From the results of these studies, we saw children being stimulated to try, and finish, foods they may usually dislike, as particularly evident in the case of the 4 year old from Family 2 and the 7 ½ year old from Family 3. By creating this immersive environment, there is a shift in attention from the food to the animation or game. This enables the children to engage in fun rather than focus on their meal, which motivates them to eat better.

Our next steps are to further our investigations through building a prototype that uses similar animations to create a fun, immersive environment to encourage eating behavioural change. Our current animations worked very well, and subsquently, we intend to build on them to enhance the purpose it is trying to serve.

From these studies we observed several factors that has led to our design decisions in our prototype. Firstly, with the multicolours there was a lot of interest from the children, in the lights 'following' the vegetables around the plate, as a result motion tracking and object detection should be implemented in the system. With the game, although the children followed the instructions, they did so with the incentive of winning badges. We also saw that the badges took up a lot of space when projected on the plate, thus, we propose to project them around the outside of the plate. Concerns that were raised by the parents, was regarding the novelty value of the system, and that the children may lose motivation to eat from this on a frequent basis. As a result, we suggest that such a system should be deployed primarily in hospitals, to encourage children who may be there for a relatively short period of time and who are having problems eating well.

Based on our results and design decisions, our prototype will track the movement and project coloured lights on vegetables on the plate, as these are generally problem foods amongst children. The light corresponding to each vegetable switches off once it has been eaten, and virtual badges are earned at certain points of completion, for example, after eating all or half the vegetables. Once the prototype has been built and tested, we intend to carry out a user study

with several children, and discuss the possibility of incorporating such a system in hospitals with dieticians and pediatricians.

Acknowledgements
We would like to thank all the families that participated in our study, the researchers at University College London and at Microsoft Research, Cambridge.

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L Use Cases

Use Case: View Help

ID	UC.01
Case Description	The software operator views the help feature in the system
Primary Actors	Software Operator
Secondary Actors	None
Preconditions	None
Main Flow	1. The software operator opens the application 2. The software operator presses the 'Select Food' button 3. The system loads the selection screen 4. The software operator presses the 'Help' button 5. The system displays the help window
Post Conditions	The software operator has viewed the help screen
Alternative Flow	None

Use Case: Select First Food

ID	UC.02
Case Description	The software operator selects the first food to track
Primary Actors	Software Operator
Secondary Actors	None
Preconditions	None
Main Flow	1. The software operator opens the application 2. The software operator presses the 'Select Food' button 3. The system loads the selection screen 4. The software operator presses the radio button next to 'Colour 1' 5. The software operator selects the range in which the colour of the food to be tracked falls using the Hue/Saturation/Brightness track bars and/or the colour presets 6. The system displays the minimum and maximum colour in the range specified in the colour boxes, and shows a live thresholded image of the particular food being selected
Post Conditions	The software operator has successfully selected the first food or exited
Alternative Flow	None

Use Case: Select Second Food

ID	UC.03
Case Description	The software operator selects the second food to track
Primary Actors	Software Operator
Secondary Actors	None
Preconditions	The software operator has opened the application and selected the first food to track
Main Flow	1. The software operator presses the radio button next to 'Colour 2' 2. The software operator selects the range in which the colour of the food to be tracked falls using the Hue/Saturation/Brightness track bars and/or the colour presets 3. The system displays the minimum and maximum colour in the range specified in the colour boxes, and shows a live thresholded image of the particular food being selected
Post Conditions	The software operator has successfully selected the second food or exited
Alternative Flow	None

Use Case: Select Third Food

ID	UC.04
Case Description	The software operator selects the third food to track
Primary Actors	Software Operator
Secondary Actors	None
Preconditions	The software operator has opened the application and selected the first and second foods to be tracked
Main Flow	1. The software operator presses the radio button next to 'Colour 3' 2. The software operator selects the range in which the colour of the food to be tracked falls using the Hue/Saturation/Brightness track bars and/or the colour presets 3. The system displays the minimum and maximum colour in the range specified in the colour boxes, and shows a live thresholded image of the particular food being selected
Post Conditions	The software operator has successfully selected the third food or exited
Alternative Flow	None

Use Case: Select Fourth Food

ID	UC.05
Case Description	The software operator selects the fourth food to track
Primary Actors	Software Operator
Secondary Actors	None
Preconditions	The software operator has opened the application and selected the first, second and third foods to be tracked
Main Flow	1. The software operator presses the radio button next to 'Colour 4' 2. The software operator selects the range in which the colour of the food to be tracked falls using the Hue/Saturation/Brightness track bars and/or the colour presets 3. The system displays the minimum and maximum colour in the range specified in the colour boxes, and shows a live thresholded image of the particular food being selected
Post Conditions	The software operator has successfully selected the fourth food or exited
Alternative Flow	None

Use Case: Select Fifth Food

ID	UC.06
Case Description	The software operator selects the fifth food to track
Primary Actors	Software Operator
Secondary Actors	None
Preconditions	The software operator has opened the application and selected the first, second, third and fourth foods to be tracked
Main Flow	1. The software operator presses the radio button next to 'Colour 5' 2. The software operator selects the range in which the colour of the food to be tracked falls using the Hue/Saturation/Brightness track bars and/or the colour presets 3. The system displays the minimum and maximum colour in the range specified in the colour boxes, and shows a live thresholded image of the particular food being selected
Post Conditions	The software operator has successfully selected the fifth food or exited
Alternative Flow	None

Use Case: Select Projection Colours

ID	UC.07
Case Description	The software operator selects the colours to be projected onto the food
Primary Actors	Software Operator
Secondary Actors	None
Preconditions	The software operator has opened the application and selected up to 5 foods to be tracked
Main Flow	1. The software operator selects a colour box next to 'Tar' 2. The system displays a shadow to show the box has been selected 3. The software operator selects a colour to be projected using the Hue/Saturation/Brightness track bars and/or the colour presets 4. The system displays the colour selected in the colour boxes and shows a live stream of the colour superimposed on the particular food 5. The software operator repeats steps 1-3 to select up to 5 projection colours for each food selected 6. The software operator selects 'Save Colours' 7. The system returns to the main screen
Post Conditions	The software operator has selected and saved the colours to be projected onto the food or has exited
Alternative Flow	None

Use Case: Clear Colours

ID	UC.08
Case Description	The software operator clears the selected colours
Primary Actors	Software Operator
Secondary Actors	None
Preconditions	The software operator has opened the application and selected colours of the food to be tracked and/or projection colours
Main Flow	1. The software operator selects the radio button next to the colour they want to stop tracking 2. The software operator presses the 'Clear' button 3. The system removes the colours in the associated colour boxes and deactivates the 'Clear' button to say 'Undefined' 4. The system removes the superimposed colour image on the live stream if projection colours have been selected
Post Conditions	The software operator has cleared the colours of a selected food
Alternative Flow	None

Use Case: Run Projection

ID	UC.09
Case Description	The software operator runs the projection
Primary Actors	Software Operator
Secondary Actors	None
Preconditions	The software operator has opened the application and selected colours of the food to be tracked and/or projection colours, and saved the colours
Main Flow	1. The software operator presses 'Run' on the main screen 2. The system displays the projection screen 3. The software operator selects 'Hide Controls' to hide the projection displacement controls 4. The software operator clicks on the screen and selects 'Stop Run' to exit the projection screen once they have finished using the system
Post Conditions	The software operator has successfully run and exited the projection screen
Alternative Flow	Adjust Projection

Use Case: Adjust Projection

ID	UC.09.01
Case Description	The projection does not exactly overlay on the food
Primary Actors	Software Operator
Secondary Actors	None
Preconditions	The software operator has opened the application and selected colours of the food to be tracked and/or projection colours, saved the colours and run the projection screen
Main Flow	1. The alternative flow starts at step 2 of the main flow 2. The software operator adjusts the projection using the 'up', 'down', 'left', 'right' button until it overlays on the food 3. The control returns to step 3 of the main flow
Post Conditions	The software operator has successfully run and exited the projection screen
Alternative Flow	None

Use Case: Exit Program

ID	UC.10
Case Description	The software operator exits the program
Primary Actors	Software Operator
Secondary Actors	None
Preconditions	The software operator has opened the application
Main Flow	1. The software operator selects the 'Exit Application' button 2. The system exits
Post Conditions	The software operator has successfully exited the application
Alternative Flow	None

Use Case: Move Lighted Food

ID	UC.11
Case Description	The child moves a lighted portion of food
Primary Actors	Child
Secondary Actors	Software Operator
Preconditions	The software operator is running the projection screen and has selected the food to be tracked and chosen the projection colours
Main Flow	1. The child moves a portion of the lighted food around their plate 2. The system projects one of the selected projection colours onto this portion of food
Post Conditions	The system successfully tracks the food around the plate
Alternative Flow	None

Use Case: Eat Lighted Food

ID	UC.12
Case Description	The child eats a portion of the lighted food
Primary Actors	Child
Secondary Actors	Software Operator
Preconditions	The software operator is running the projection screen and has selected the food to be tracked and chosen the projection colours
Main Flow	1. The child eats a portion of the lighted food 2. The system detects the piece has been disappeared and no longer projects light over that piece of food
Post Conditions	The system has successfully detected when food has been eaten
Alternative Flow	None

Use Case: Finish Half Lighted Food

ID	UC.13
Case Description	The child eats half the lighted portion of food
Primary Actors	Child
Secondary Actors	Software Operator
Preconditions	The software operator is running the projection screen and has selected the food to be tracked and chosen the projection colours
Main Flow	1. The child eats half the lighted portion of food 2. The system detects half the food has disappeared and no longer projects light over that half 3. The system displays the 'Growing Star Badge' outside of the plate
Post Conditions	The system has successfully detected when half food has been eaten and the child has earned a virtual badge
Alternative Flow	None

Use Case: Finish All Lighted Food

ID	UC.14
Case Description	The child eats all the lighted portion of food
Primary Actors	Child
Secondary Actors	Software Operator
Preconditions	The software operator is running the projection screen and has selected the food to be tracked and chosen the projection colours. The child has already eaten half the lighted portion of food and the 'Growing Star Badge' has been displayed.
Main Flow	1. The child eats all the lighted portion of food 2. The system detects all the food has disappeared and no longer projects light over the food 3. The system displays the 'Growing Star Badge' and the 'Champion Muncher Badge' outside of the plate
Post Conditions	The system has successfully detected when all the food has been eaten and the child has earned two virtual badges
Alternative Flow	None

M Test Cases

Test Case: View Help

ID	TC.01
Case Description	View Help
Preconditions	None
Main Flow	1. Open the application 2. Select 'Select Food' 3. Select 'Help'
Expected Results	The 'Help' window should appear
Actual Result	The 'Help' window appears

Test Case: Select First Tracking Colour

ID	TC.02
Case Description	Select the colour of the first food to be tracked
Preconditions	None
Main Flow	1. Open the application 2. Select 'Select Food' 3. Select the radio button next to 'Colour 1' 4. Use the track bars and/or the presets to select maximum and minimum values of the range of which the colour to detect falls in
Expected Results	The maximum and minimum colours in the range should appear in colour boxes and the RGB and HSV values should change accordingly. A thresholded image of the selected food should be displayed as a live video stream.
Actual Result	The maximum and minimum colours in the range appears in colour boxes and the RGB and HSV values changes accordingly. A thresholded image of the selected food is displayed as a live video stream.

Test Case: Select Second Tracking Colour

ID	TC.03
Case Description	Select the colour of the second food to be tracked
Preconditions	The application must be open and user must have selected the colour of the first food to be tracked
Main Flow	1. Select the radio button next to 'Colour 2' 2. Use the track bars and/or the presets to select maximum and minimum values of the range of which the colour to detect falls in
Expected Results	The maximum and minimum colours in the range should appear in colour boxes and the RGB and HSV values should change accordingly. A thresholded image of the selected food should be displayed as a live video stream.
Actual Result	The maximum and minimum colours in the range appears in colour boxes and the RGB and HSV values changes accordingly. A thresholded image of the selected food is displayed as a live video stream.

Test Case: Select Third Tracking Colour

ID	TC.04
Case Description	Select the colour of the third food to be tracked
Preconditions	The application must be open and user must have selected the colours of the first and second foods to be tracked
Main Flow	1. Select the radio button next to 'Colour 3' 2. Use the track bars and/or the presets to select maximum and minimum values of the range of which the colour to detect falls in
Expected Results	The maximum and minimum colours in the range should appear in colour boxes and the RGB and HSV values should change accordingly. A thresholded image of the selected food should be displayed as a live video stream.
Actual Result	The maximum and minimum colours in the range appears in colour boxes and the RGB and HSV values changes accordingly. A thresholded image of the selected food is displayed as a live video stream.

Test Case: Select Fourth Tracking Colour

ID	TC.05
Case Description	Select the colour of the fourth food to be tracked
Preconditions	The application must be open and user must have selected the colours of the first, second and third foods to be tracked
Main Flow	1. Select the radio button next to 'Colour 4' 2. Use the track bars and/or the presets to select maximum and minimum values of the range of which the colour to detect falls in
Expected Results	The maximum and minimum colours in the range should appear in colour boxes and the RGB and HSV values should change accordingly. A thresholded image of the selected food should be displayed as a live video stream.
Actual Result	The maximum and minimum colours in the range appears in colour boxes and the RGB and HSV values changes accordingly. A thresholded image of the selected food is displayed as a live video stream.

Test Case: Select Fifth Tracking Colour

ID	TC.06
Case Description	Select the colour of the fifth food to be tracked
Preconditions	The application must be open and user must have selected the colours of the first, second, third and fourth foods to be tracked
Main Flow	1. Select the radio button next to 'Colour 5' 2. Use the track bars and/or the presets to select maximum and minimum values of the range of which the colour to detect falls in
Expected Results	The maximum and minimum colours in the range should appear in colour boxes and the RGB and HSV values should change accordingly. A thresholded image of the selected food should be displayed as a live video stream.
Actual Result	The maximum and minimum colours in the range appears in colour boxes and the RGB and HSV values changes accordingly. A thresholded image of the selected food is displayed as a live video stream.

Test Case: Select Projection Colours

ID	TC.07
Case Description	Select colours to be projected
Preconditions	The application must be open and user must have selected a food to be tracked
Main Flow	1. Select a colour box next to 'Tar' associated with the food that's being tracked 2. Use the track bars and/or the presets to select a colour to be projected on the chosen food 3. Repeat steps 1 and 2 to choose up to 5 projection colours for each food
Expected Results	The colours selected should appear in the associated colour box and the RGB and HSV values should change accordingly. The colour currently selected should overlay on the thresholded image of the selected food and be shown as a live stream in the video box.
Actual Result	The colours selected appear in the associated colour box and the RGB and HSV values change accordingly. The colour currently selected overlays on the thresholded image of the selected food and is shown as a live stream in the video box.

Test Case: Use Presets

ID	TC.08
Case Description	Select colours to track/project using the preset buttons
Preconditions	The application must be open
Main Flow	1. Click 'Select Food' 2. Select radio button next to 'Colour 1' if 'Colour 1' has already been defined select 'Colour 2' etc. 3. Click on 'Dark Green' 4. Click on 'Green' 5. Click on 'Yellow' 6. Click on 'Orange' 7. Click on 'Brown'
Expected Results	When 'Dark Green' is selected, the colour boxes should change to the colours specified for dark green and the HSV and RGB values should change accordingly. When 'Green' is selected, the colour boxes should change to the colours specified for green and the HSV and RGB values should change accordingly. When 'Yellow' is selected, the colour boxes should change to the colours specified for yellow and the HSV and RGB values should change accordingly. When 'Orange' is selected, the colour boxes should change to the colours specified for orange and the HSV and RGB values should change accordingly. When 'Brown' is selected, the colour boxes should change to the colours specified for brown and the HSV and RGB values should change accordingly.
Actual Result	When 'Dark Green' is selected, the colour boxes change to the colours specified for dark green and the HSV and RGB values change accordingly. When 'Green' is selected, the colour boxes change to the colours specified for green and the HSV and RGB values change accordingly. When 'Yellow' is selected, the colour boxes change to the colours specified for yellow and the HSV and RGB values change accordingly. When 'Orange' is selected, the colour boxes change to the colours specified for orange and the HSV and RGB values change accordingly. When 'Brown' is selected, the colour boxes change to the colours specified for brown and the HSV and RGB values change accordingly.

Test Case: Save Colours

ID	TC.09
Case Description	Save the colours to be tracked and projected
Preconditions	The application must be open and user must have specified the colours for a selected food
Main Flow	1. Click on 'Save Colours'
Expected Results	The system should exit and return to the main screen.
Actual Result	The system exits and returns to the main screen.

Test Case: Clear Colour Selection

ID	TC.10
Case Description	Clear a colour selection
Preconditions	The application must be open and user must have specified the colours for a selected food
Main Flow	1. Select the radio button next to the colour to be cleared 2. Click 'Clear'
Expected Results	The colour boxes for the selected colour should be greyed out and the 'Clear' button should now say 'Undefined'.
Actual Result	The colour boxes for the selected colour are greyed out and the 'Clear' button says 'Undefined'.

Test Case: Run Projection

ID	TC.11
Case Description	Run the projection
Preconditions	The application must be open and user must have specified the colours for a selected food and the projection colours
Main Flow	1. Select 'Save Colours' 2. Click 'Run'
Expected Results	The projection screen displaying a randomly changing projection colour from those specified for each food should appear.
Actual Result	The projection screen displaying a randomly changing projection colour from those specified for each food appears.

Test Case: Hide Displacement Buttons

ID	TC.12
Case Description	Hide the displacement buttons
Preconditions	The user must have chosen colours to track and project, and must run the projection screen
Main Flow	1. Click on 'Hide Controls'
Expected Results	The displacement buttons should disappear.
Actual Result	The displacement buttons disappear.

Test Case: Display Displacement Buttons

ID	TC.13
Case Description	Display Displacement Buttons
Preconditions	The user must have chosen colours to track and project, and must run the projection screen
Main Flow	1. Click anywhere on the projection screen
Expected Results	The displacement buttons should appear.
Actual Result	The displacement buttons appear.

Test Case: Use Displacement Buttons

ID	TC.14
Case Description	Use Displacement Buttons
Preconditions	The user must have chosen colours to track and project, and must run the projection screen
Main Flow	1. Click 'Up' 2. Click 'Down' 3. Click 'Left' 4. Click 'Right'
Expected Results	The projected image should move up, down, left and right, in that order.
Actual Result	The projected image moves up, down , left and right, in that order.

Test Case: Exit Projection Screen

ID	TC.15
Case Description	Exit the projection screen
Preconditions	The user must have chosen colours to track and project, and must run the projection screen
Main Flow	1. Click the projection screen to display the displacement buttons if necessary 2. Click 'Stop Run'
Expected Results	The system should return back to the main screen.
Actual Result	The system returns back to the main screen.

Test Case: Exit Application

ID	TC.16
Case Description	Exit application
Preconditions	The user must run the application
Main Flow	1. Click 'Exit'
Expected Results	The system should exit.
Actual Result	The system exits.

Test Case: Move Lighted Food

ID	TC.17
Case Description	The user moves a lighted piece of food around the plate
Preconditions	The user must run projection screen calibrated with the colour that should be tracked and projection colours
Main Flow	1. Move a piece of the lighted food
Expected Results	The system should project coloured light directly on the food when it is placed in a different area of the plate.
Actual Result	The system projects coloured light directly on the food when it is placed in a different area of the plate.

Test Case: Eat Lighted Food

ID	TC.18
Case Description	The user eats a lighted piece of food
Preconditions	The user must run projection screen calibrated with the colour that should be tracked and projection colours
Main Flow	1. Eat a piece of the lighted food
Expected Results	The light projecting on the piece that has been eaten should disappear.
Actual Result	The light projecting on the piece that has been eaten disappears.

Test Case: Eat Half Lighted Food

ID	TC.19
Case Description	The user eats half the lighted food
Preconditions	The user must run projection screen calibrated with the colour that should be tracked and projection colours
Main Flow	1. Eat half of the lighted food
Expected Results	The light projecting over half the food that has been eaten should disappear and the 'Growing Star' badge should appear outside the plate.
Actual Result	The light projecting half the food that has been eaten disappears and the 'Growing Star' badge appears outside the plate.

Test Case: Eat All Lighted Food

ID	TC.20
Case Description	The user eats all the lighted food
Preconditions	The user must run projection screen calibrated with the colour that should be tracked and projection colours.
Main Flow	1. Eat all the lighted food
Expected Results	The light projecting over all the food that has been eaten should disappear and the 'Champion Muncher' badge should appear outside the plate next to the 'Growing Star' badge.
Actual Result	The light projecting over all the food that has been eaten disappears and the 'Champion Muncher' badge appears outside the plate next to the 'Growing Star' badge.

N System Manual

Before running the application, ensure your computer meets the recommended specifications.

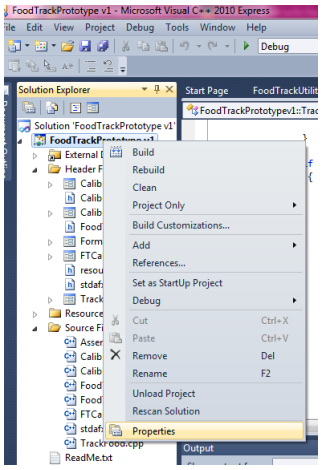
- Windows 7 edition
- Intel Core i5 Processor or above
- At least 6 GB RAM
- Screen Resolution of 1366 x 768

Instructions

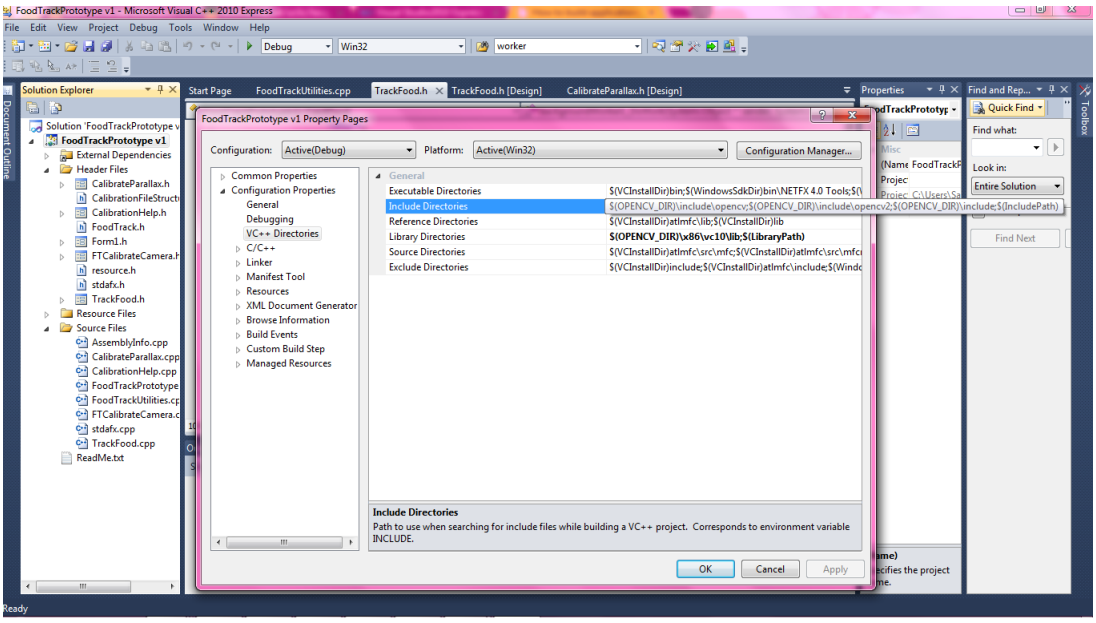
- Download Microsoft Visual C++ 2010 Express from: www.microsoft.com/visualstudio/en-gb/express
- Install OpenCV by following'Installation by Using the Pre-built Libraries' on this page:

  http://docs.opencv.org/doc/tutorials/introduction/windows_install/windows_install.html#windows-installation

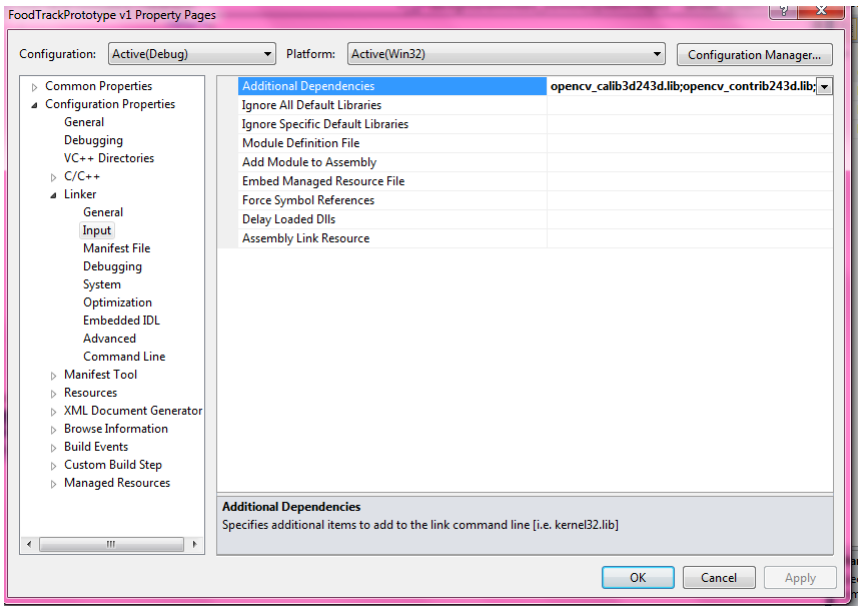
- Set the environment variables to finalize the installation by following the instructions on the above page
- In Microsoft Visual C++ 2010 Express open the application. Do File -> Open -> Project/Solution and navigate to 'FoodTrack Prototype v1.sln' on your computer.
- Right click on 'FoodTrack Prototype v1.sln' and select 'Properties'



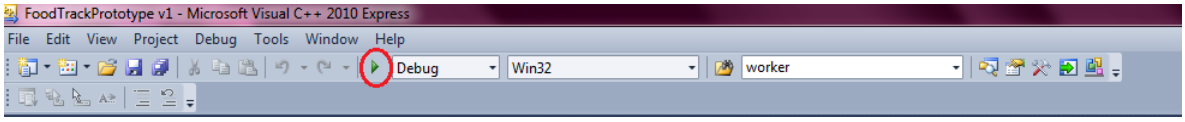
- In VC++ Directories, add the path to the OpenCV include files on your computer next to 'Include Directories', using the environment variables you set earlier. Similarly add the path to your OpenCV libraries by clicking next to 'Library Directories'. The following screenshot shows the paths entered.



- Next, go to 'Linker' -> 'Input' and under 'Additional Dependencies' enter the name of all the libraries. You can find the list of libraries under your build directory in opencv.



- Click 'OK' to save. Now run the application by pressing the green play button at the top.



- If you encounter any problems, refer to :

  http://docs.opencv.org/doc/tutorials/introduction/windows_visual_studio_Opencv/windows_visual_studio_Opencv.html#windows-visual-studio-how-to.

O User Manual

Running the Software In order to run FoodWorks! ensure your computer meets the recommended specification:

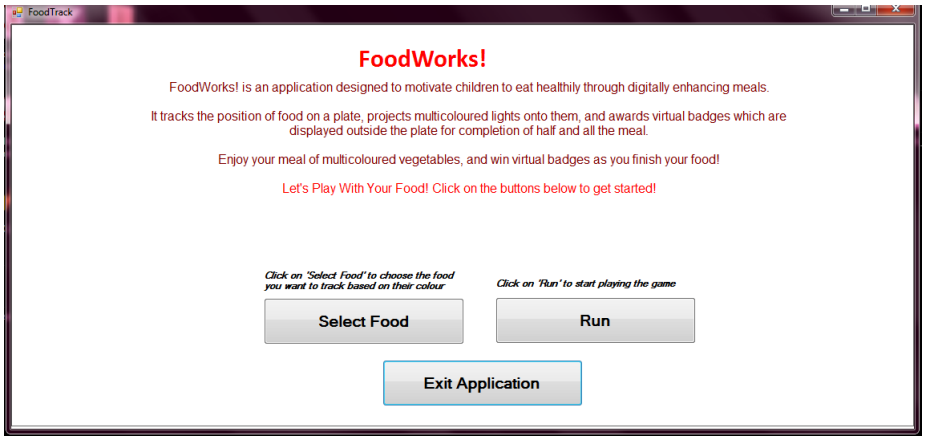
- Windows 7 edition
- Intel Core i5 Processor or above
- At least 6 GB RAM
- Screen Resolution of 1366 x 768

Open the application by clicking *FoodTrackPrototype v1.exe* from the *FoodTrackRelease Version* folder.

Hardware Setup Follow these instructions to ensure that the hardware is set up properly.

- Plug in the computer and projector to a power socket.
- Connect the projector to the computer using a VGA cable.
- Connect the camera to the computer using the USB cable.
- Clamp the projector and camera securely and attach it to the tripod. Adjust the height of the tripod until the camera can observe the whole plate.

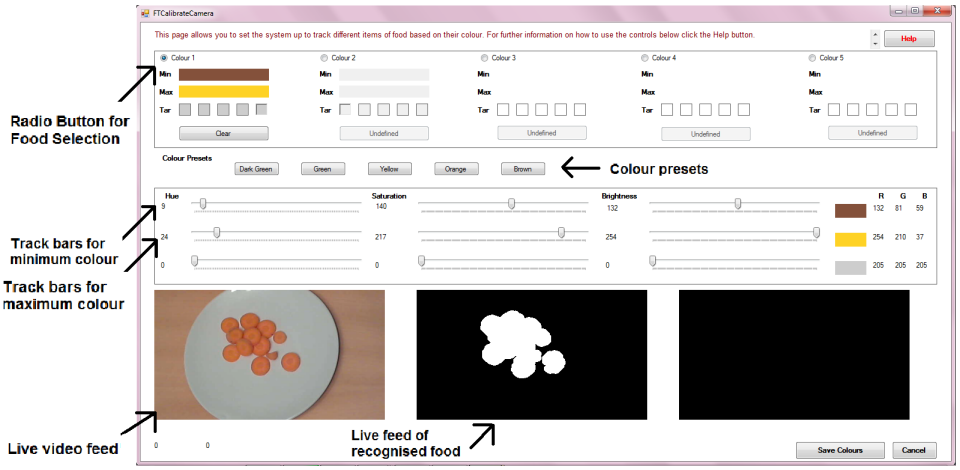
Home Screen The home screen of FoodWorks! has three buttons. *'Select Food'*, *'Run'* and *'Exit Application'*. Clicking on *'Select Food'* allows you to select the food you want to track based on its colour. *'Run'*, runs the projection screen that will be displayed on the plate, if *'Run'* is clicked without selecting food first, the system picks up the colours saved the last time the application was used. *'Exit Application'* allows you to close and exit the system.



Select Food

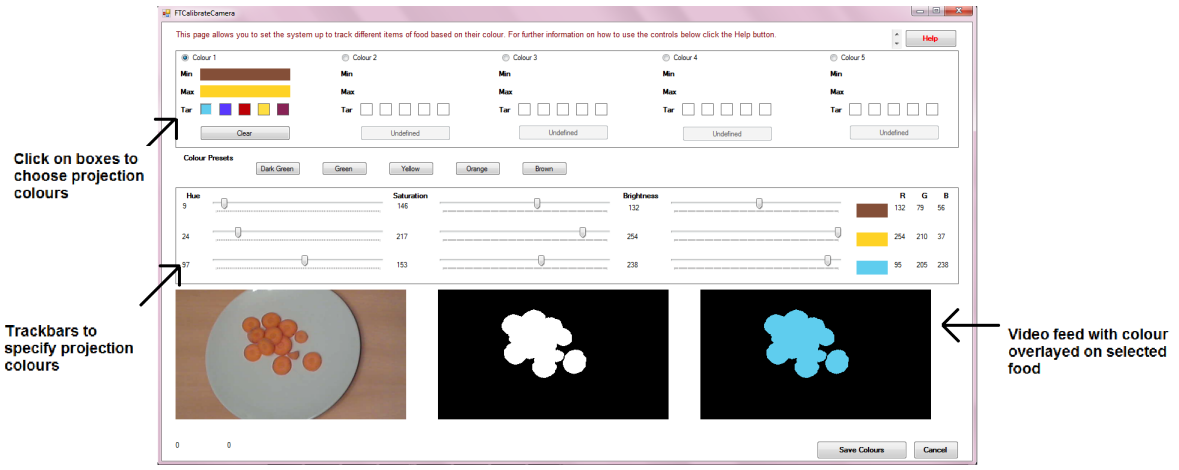
- Click *'Select Food'*
- Click the radio button next to *'Colour 1'*

- Use the track bars to select the range in which the colour of your food falls in. The top track bars indicate the HSV values for the minimum value of the colour in the range, the middle track bars indicate the HSV values for the maximum value of the colour in your range. The Hue track bar specifies the colour, Saturation specifies the shade of colour while the Value track bar specifies the brightness.
  - Alternatively you can select a colour using the *'Colour Presets'* and adjust accordingly using the trackbars
- The colour boxes indicate the minimum and maximum colours you have selected
- You can see whether your selected food is being picked up by observing the black and white feed in the bottom and comparing it to the live video stream. The food that is being recognised will appear as white
- Repeat the procedure to select up to 5 different foods to be tracked on your plate



Select Projection Colours You can select up to 5 different colours to be projected on each chosen food

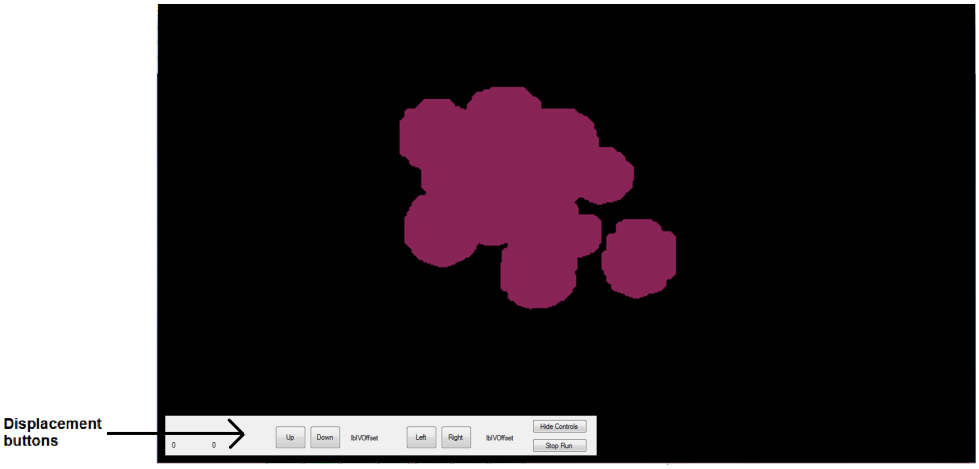
- Select one of the square colour boxes under your chosen colour of food
- Use the last row of track bars to select the colour you want to project, the colour boxes should change accordingly
- You will see the colour overlayed on your selected food in the third video feed box
- Repeat for each projection colour you want to set
- Click *'Save Colours'*



Clear Selected Colours If you are not happy with your colour selection for your food or for the projection, you can reset all the colours by selecting the radio button for the colour and clicking *'Clear'* or you can exit the colour selection screen by clicking *'Cancel'*.

Run Projection

- After selecting your colours to be tracked and projected through 'Select Colours' click on 'Run' from the main screen. The projection screen will then appear, this will display the colours to be projected and the badges on your computer. The window has been set to occupy a screen resolution of 1366 x768.
  - If you find your projection does not exactly overlay with the food on your plate click once on the projection to show the displacement buttons. Click 'Up', 'Down', 'Left' or 'Right' to adjust the projection image accordingly. Click 'Hide Controls' to hide the displacement buttons.
- Once you have finished click 'Stop Run'



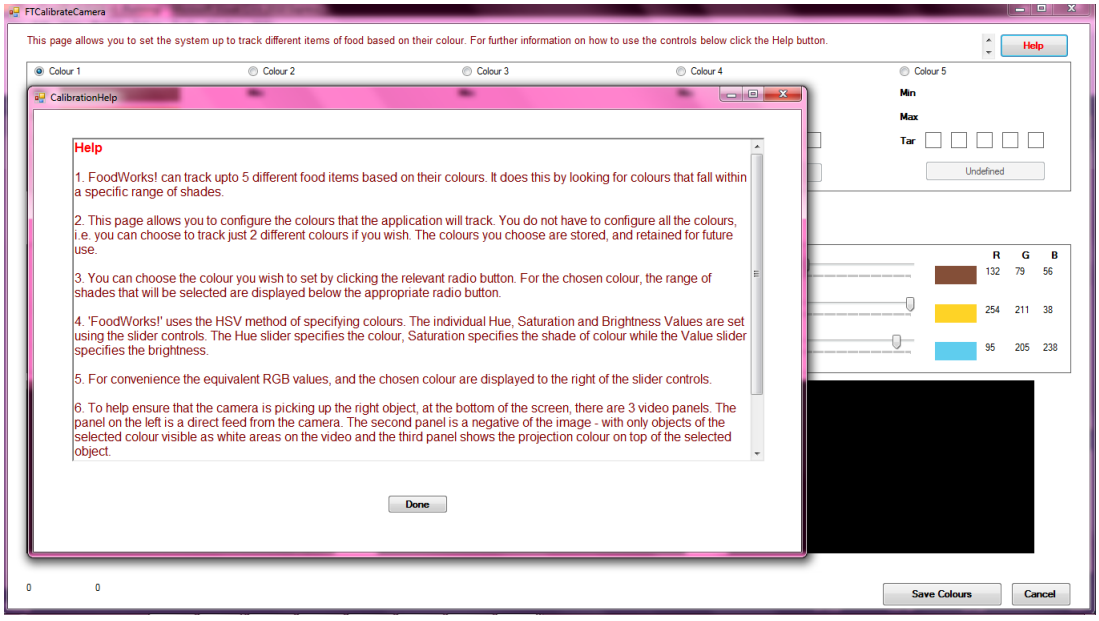
Eating Your Food

- Colours on the food being tracked will disappear once it has been eaten or has disappeared from the scene observed by the camera

- Colours will follow the food as you move it around the plate
- A virtual badge will appear outside your plate once you eat half the lit up food

- A second virtual badge will appear outside your place once you finish the lit up food

Help If you need further assistance to use the system, you can view the help screen by clicking *'Select Food'* -> *'Help'*.



P FoodWorks! Video

Below is a link to a video which shows FoodWorks! in operation. Please view in either 1080pHD or 720pHD for clarity.

http://www.youtube.com/watch?v=5ENVYpgd4wc&list=HL1365777890&feature=mh_lolz

CalibrationFileStructure.h

```
struct CalibratedColourValue
{
	int lowerHue;
	int upperHue;
	int lowerSaturation;
	int upperSaturation;
	int lowerValue;
	int upperValue;
	int targetHue;
	int targetSaturation;
	int targetValue;
};

struct TargetColour
{
	int targetHue;
	int targetSaturation;
	int targetValue;
};


struct newCalibratedColourValue
{
	int lowerHue;
	int upperHue;
	int lowerSaturation;
	int upperSaturation;
	int lowerValue;
	int upperValue;
	struct TargetColour TC[5];
};

struct pixelsOnPlate
{
	int initialCount;
	int currentCount;
	int initFlag;

};

const int LH = 1;
const int UH = 2;
const int LS = 3;
const int US = 4;
const int LV = 5;
const int UV = 6;
const int TH = 7;
const int TS = 8;
const int TV = 9;

//declare badge names
const std::string HALFBADGE = "HalfWayBadge.jpg";
const std::string FULLBADGE = "CompletionBadge.jpg";

const int MAX_COLOUR_TO_TRACK = 5;

///declare RTF file names that have content to fill in
Rich Text Boxes on various forms.

#define NEWCALIBFILE L"newcalibratedvalues.txt"
#define CALIBMSG L"CalibrateCamera.rtf"
#define HOMEPAGE L"FoodTrack.rtf"
#define HELPFILE L"Help.rtf"

#define LAPTOP_RES_COLS 1366
#define LAPTOP_RES_ROWS 768
#define WEBCAM_RES_COLS 1280
#define WEBCAM_RES_ROWS 720
#define LAPTOP_RES_COLS_MARGIN 6
#define LAPTOP_RES_ROWS_MARGIN 12
#define LAPTOP_RES_COLS_RATIO 1.7777
#define HOR_INCREMENT 10
```

```
#define VER_INCREMENT 10
#define CALIB_RESIZE_RATIO 0.6
#define MAGNIFICATION_ADJUSTMENT 2
#define BADGE_MAGNIFICATION_ADJUSTMENT 2
#define CROP_RATIO 0.5

#define MAX_LOOP_BEFORE_OBJECT_COUNT 3 //this specifies how
many scans are undertaken before baseline pixel count is
established
#define HALFWAY_LOOP_LIMIT   5     //this specifies for how
many loops the halfway threshold has to be crossed before
badge is displayed
#define FULL_LOOP_LIMIT 5     //this specifies for how many
loops the full threshold has to be crossed before badge is
displayed
```

CalibrationHelp.h

```
#pragma once

namespace FoodTrackPrototypev1 {

      using namespace System;
      using namespace System::ComponentModel;
      using namespace System::Collections;
      using namespace System::Windows::Forms;
      using namespace System::Data;
      using namespace System::Drawing;

      /// <summary>
      /// Summary for CalibrationHelp
      /// </summary>
      public ref class CalibrationHelp : public
System::Windows::Forms::Form
      {

      private: System::Windows::Forms::Form^  callingForm;

      public:
            CalibrationHelp(void)
            {
                  InitializeComponent();
                  //
                  //TODO: Add the constructor code here
                  //
            }

            public:
            CalibrationHelp(System::Windows::Forms::Form^
parentForm)
            {
                  callingForm = parentForm;
                  InitializeComponent();
                  //
                  //TODO: Add the constructor code here
                  //
            }

      protected:
            /// <summary>
            /// Clean up any resources being used.
            /// </summary>
            ~CalibrationHelp()
            {
                  if (components)
                  {
                        delete components;
                  }
            }
      private: System::Windows::Forms::RichTextBox^
richTextBox1;
      private: System::Windows::Forms::Button^  button1;
      protected:
```

```
        private:
            /// <summary>
            /// Required designer variable.
            /// </summary>
            System::ComponentModel::Container ^components;

#pragma region Windows Form Designer generated code
            /// <summary>
            /// Required method for Designer support - do
not modify
            /// the contents of this method with the code
editor.
            /// </summary>
            void InitializeComponent(void)
            {
                this->richTextBox1 = (gcnew
System::Windows::Forms::RichTextBox());
                this->button1 = (gcnew
System::Windows::Forms::Button());
                this->SuspendLayout();
                //
                // richTextBox1
                //
                this->richTextBox1->BorderStyle =
System::Windows::Forms::BorderStyle::FixedSingle;
                this->richTextBox1->Location =
System::Drawing::Point(48, 35);
                this->richTextBox1->Name =
L"richTextBox1";
                this->richTextBox1->Size =
System::Drawing::Size(865, 405);
                this->richTextBox1->TabIndex = 0;
                this->richTextBox1->Text = L"";
                //
                // button1
                //
                this->button1->Font = (gcnew
System::Drawing::Font(L"Microsoft Sans Serif", 8.25F,
System::Drawing::FontStyle::Bold,
System::Drawing::GraphicsUnit::Point,
                    static_cast<System::Byte>(0)));
                this->button1->Location =
System::Drawing::Point(442, 481);
                this->button1->Name = L"button1";
                this->button1->Size =
System::Drawing::Size(75, 23);
                this->button1->TabIndex = 1;
                this->button1->Text = L"Done";
                this->button1->UseVisualStyleBackColor =
true;
                this->button1->Click += gcnew
System::EventHandler(this,
&CalibrationHelp::button1_Click);
                //
                // CalibrationHelp
                //
                this->AutoScaleDimensions =
System::Drawing::SizeF(6, 13);
                this->AutoScaleMode =
System::Windows::Forms::AutoScaleMode::Font;
                this->BackColor =
System::Drawing::SystemColors::ControlLightLight;
                this->ClientSize =
System::Drawing::Size(958, 552);
                this->Controls->Add(this->button1);
                this->Controls->Add(this->richTextBox1);
                this->FormBorderStyle =
System::Windows::Forms::FormBorderStyle::FixedSingle;
                this->Name = L"CalibrationHelp";
                this->StartPosition =
System::Windows::Forms::FormStartPosition::CenterScreen;
                this->Text = L"CalibrationHelp";
                this->Load += gcnew
System::EventHandler(this,
```

```
&CalibrationHelp::CalibrationHelp_Load);
                this->ResumeLayout(false);

            }
#pragma endregion
      private: System::Void
CalibrationHelp_Load(System::Object^  sender,
System::EventArgs^  e)
                 {
                      richTextBox1-
>LoadFile("Help.rtf",RichTextBoxStreamType::RichText);
//loads help file into rich text box
                 }
      private: System::Void button1_Click(System::Object^
sender, System::EventArgs^  e)
                 {
                      callingForm->Focus();
                      callingForm->Show();
                      this->Close();
                 }
      };
}
```

FoodTrack.h

```
// Global variables

#ifndef MY_HEADER_FILE_
#define MY_HEADER_FILE_

#include "CalibrationFileStructure.h"

#endif

extern int threshHValue, threshSValue, threshVValue;

extern int selectedColor;

extern int selectedTargetColor;

extern int numOfColoursToTrack;

extern int vertOffset, horOffset;

extern struct newCalibratedColourValue
newCalibratedValues[];
extern struct pixelsOnPlate pOP;


extern cv::Mat resizedCapturedFrame, resizedThreshFrame,
resizedTargetFrame, trackingThresholdedFrame;

extern bool stopCalibCap;

extern bool calibDispThreadFinished,
calibCaptThreadFinished, PBUpdating,
DispThreadFinished,captThreadFinished;

void
dispCVImageinPictureBox(System::Windows::Forms::PictureBox
^ pbTargetPictureBox, cv::Mat& colorImage, bool
bGrayScale);

void dispCalibFrames(System::Windows::Forms::PictureBox^
pCapturedFrame, System::Windows::Forms::PictureBox^
pThresholdedFrame,System::Windows::Forms::PictureBox^
pTargetFrame);

void dispTrackingFrame(System::Windows::Forms::PictureBox^
pTrackingFrame);

cv::Mat getThresholdedFrame(cv::Mat inputFrame);

void convertHSVValuesToRGB (uchar hue, uchar saturation,
uchar brightness, uchar *rValue, uchar *gValue, uchar
```

```
*bValue);

cv::Mat getTrackingThresholdedFrame(cv::Mat inputFrame);

cv::Mat addBadges(cv::Mat inputFrame);

cv::Mat calibrateFrameInTargetColour(cv::Mat inputFrame,
uchar targetHue, uchar targetSaturation, uchar targetValue);
```

Form1.h

```
#pragma once

#include "FTCalibrateCamera.h"
#include "TrackFood.h"

namespace FoodTrackPrototypev1 {

	using namespace System;
	using namespace System::ComponentModel;
	using namespace System::Collections;
	using namespace System::Windows::Forms;
	using namespace System::Data;
	using namespace System::Drawing;

	/// <summary>
	/// Summary for Form1
	/// </summary>
	public ref class Form1 : public
System::Windows::Forms::Form
	{
	public:
		Form1(void)
		{
			InitializeComponent();
			//
			//TODO: Add the constructor code here
			//
		}

	protected:
		/// <summary>
		/// Clean up any resources being used.
		/// </summary>
		~Form1()
		{
			if (components)
			{
				delete components;
			}
		}
	private: System::Windows::Forms::Panel^  panel1;

	private: System::Windows::Forms::Button^
btnCalibrate;
	private: System::Windows::Forms::Button^  btnRunApp;
	private: System::Windows::Forms::Button^
btnExitApp;
	private: System::Windows::Forms::Label^  label1;
	private: System::Windows::Forms::RichTextBox^
rtbAppDesc;
	private: System::Windows::Forms::TextBox^  textBox2;
	private: System::Windows::Forms::TextBox^  textBox1;

	protected:

	private:
		/// <summary>
		/// Required designer variable.
		/// </summary>
		System::ComponentModel::Container ^components;

#pragma region Windows Form Designer generated code
```

```
            /// <summary>
            /// Required method for Designer support - do
not modify
            /// the contents of this method with the code
editor.
            /// </summary>
            void InitializeComponent(void)
            {
                  this->panel1 = (gcnew
System::Windows::Forms::Panel());
                  this->textBox2 = (gcnew
System::Windows::Forms::TextBox());
                  this->textBox1 = (gcnew
System::Windows::Forms::TextBox());
                  this->rtbAppDesc = (gcnew
System::Windows::Forms::RichTextBox());
                  this->label1 = (gcnew
System::Windows::Forms::Label());
                  this->btnExitApp = (gcnew
System::Windows::Forms::Button());
                  this->btnCalibrate = (gcnew
System::Windows::Forms::Button());
                  this->btnRunApp = (gcnew
System::Windows::Forms::Button());
                  this->panel1->SuspendLayout();
                  this->SuspendLayout();
                  //
                  // panel1
                  //
                  this->panel1->BackColor =
System::Drawing::SystemColors::ControlLightLight;
                  this->panel1->BorderStyle =
System::Windows::Forms::BorderStyle::FixedSingle;
                  this->panel1->Controls->Add(this-
>textBox2);
                  this->panel1->Controls->Add(this-
>textBox1);
                  this->panel1->Controls->Add(this-
>rtbAppDesc);
                  this->panel1->Controls->Add(this-
>label1);
                  this->panel1->Controls->Add(this-
>btnExitApp);
                  this->panel1->Dock =
System::Windows::Forms::DockStyle::Top;
                  this->panel1->Location =
System::Drawing::Point(0, 0);
                  this->panel1->Name = L"panel1";
                  this->panel1->Size =
System::Drawing::Size(1126, 501);
                  this->panel1->TabIndex = 0;
                  this->panel1->Paint += gcnew
System::Windows::Forms::PaintEventHandler(this,
&Form1::panel1_Paint);
                  //
                  // textbox above run button
                  //
                  this->textBox2->BorderStyle =
System::Windows::Forms::BorderStyle::None;
                  this->textBox2->Font = (gcnew
System::Drawing::Font(L"Microsoft Sans Serif", 8.25F,
static_cast<System::Drawing::FontStyle>((System::Drawing::
FontStyle::Bold | System::Drawing::FontStyle::Italic)),

      System::Drawing::GraphicsUnit::Point,
static_cast<System::Byte>(0)));
                  this->textBox2->Location =
System::Drawing::Point(603, 315);
                  this->textBox2->Multiline = true;
                  this->textBox2->Name = L"textBox2";
                  this->textBox2->Size =
System::Drawing::Size(228, 24);
                  this->textBox2->TabIndex = 7;
                  this->textBox2->Text = L"Click on \'Run\'
```

```
to start playing the game";
                  //
                  // textbox above select food button
                  //
                  this->textBox1->BorderStyle =
System::Windows::Forms::BorderStyle::None;
                  this->textBox1->Font = (gcnew
System::Drawing::Font(L"Microsoft Sans Serif", 8.25F,
static_cast<System::Drawing::FontStyle>((System::Drawing::Fo
ntStyle::Bold | System::Drawing::FontStyle::Italic)),

      System::Drawing::GraphicsUnit::Point,
static_cast<System::Byte>(0)));
                  this->textBox1->Location =
System::Drawing::Point(314, 305);
                  this->textBox1->Multiline = true;
                  this->textBox1->Name = L"textBox1";
                  this->textBox1->Size =
System::Drawing::Size(250, 34);
                  this->textBox1->TabIndex = 6;
                  this->textBox1->Text = L"Click on \'Select
Food\' to choose the food you want to track based on their
colour"
                        L"";
                  //
                  // rtbAppDesc
                  //
                  this->rtbAppDesc->BackColor =
System::Drawing::SystemColors::ControlLightLight;
                  this->rtbAppDesc->BorderStyle =
System::Windows::Forms::BorderStyle::None;
                  this->rtbAppDesc->Location =
System::Drawing::Point(169, 68);
                  this->rtbAppDesc->Name = L"rtbAppDesc";
                  this->rtbAppDesc->ReadOnly = true;
                  this->rtbAppDesc->Size =
System::Drawing::Size(804, 187);
                  this->rtbAppDesc->TabIndex = 5;
                  this->rtbAppDesc->Text = L"";
                  //
                  // label1
                  //
                  this->label1->AutoSize = true;
                  this->label1->Font = (gcnew
System::Drawing::Font(L"Calibri", 24,
System::Drawing::FontStyle::Bold,
System::Drawing::GraphicsUnit::Point,
                        static_cast<System::Byte>(0)));
                  this->label1->ForeColor =
System::Drawing::Color::Red;
                  this->label1->Location =
System::Drawing::Point(483, 26);
                  this->label1->Name = L"label1";
                  this->label1->Size =
System::Drawing::Size(184, 39);
                  this->label1->TabIndex = 4;
                  this->label1->Text = L"FoodWorks!"; //
displays title on home screen
                  //
                  // btnExitApp - button to exit
application
                  //
                  this->btnExitApp->Anchor =
System::Windows::Forms::AnchorStyles::None;
                  this->btnExitApp->Font = (gcnew
System::Drawing::Font(L"Microsoft Sans Serif", 14.25F,
System::Drawing::FontStyle::Bold,
System::Drawing::GraphicsUnit::Point,
                        static_cast<System::Byte>(0)));
                  this->btnExitApp->Location =
System::Drawing::Point(462, 417);
                  this->btnExitApp->Name = L"btnExitApp";
                  this->btnExitApp->Size =
System::Drawing::Size(250, 58);
```

```
                this->btnExitApp->TabIndex = 3;
                this->btnExitApp->Text = L"E&xit
Application";
                this->btnExitApp->UseVisualStyleBackColor
= true;
                this->btnExitApp->Click += gcnew
System::EventHandler(this, &Form1::btnExitApp_Click);
                //
                // btnCalibrate - button to navigate to
select colours screen
                //
                this->btnCalibrate->BackColor =
System::Drawing::SystemColors::ControlLightLight;
                this->btnCalibrate->FlatStyle =
System::Windows::Forms::FlatStyle::System;
                this->btnCalibrate->Font = (gcnew
System::Drawing::Font(L"Microsoft Sans Serif", 14.25F,
System::Drawing::FontStyle::Bold,
System::Drawing::GraphicsUnit::Point,
                      static_cast<System::Byte>(0)));
                this->btnCalibrate->Location =
System::Drawing::Point(315, 341);
                this->btnCalibrate->Name =
L"btnCalibrate";
                this->btnCalibrate->Size =
System::Drawing::Size(250, 58);
                this->btnCalibrate->TabIndex = 1;
                this->btnCalibrate->Text = L"Select Food";
                this->btnCalibrate-
>UseVisualStyleBackColor = false;
                this->btnCalibrate->Click += gcnew
System::EventHandler(this, &Form1::btnCalibrate_Click);
                //
                // btnRunApp - button to run projection
screen
                //
                this->btnRunApp->Font = (gcnew
System::Drawing::Font(L"Microsoft Sans Serif", 14.25F,
System::Drawing::FontStyle::Bold,
System::Drawing::GraphicsUnit::Point,
                      static_cast<System::Byte>(0)));
                this->btnRunApp->Location =
System::Drawing::Point(604, 340);
                this->btnRunApp->Name = L"btnRunApp";
                this->btnRunApp->Size =
System::Drawing::Size(250, 58);
                this->btnRunApp->TabIndex = 2;
                this->btnRunApp->Text = L"&Run";
                this->btnRunApp->UseVisualStyleBackColor
= true;
                this->btnRunApp->Click += gcnew
System::EventHandler(this, &Form1::btnRunApp_Click);
                //
                // Form1
                //
                this->AutoScaleDimensions =
System::Drawing::SizeF(6, 13);
                this->AutoScaleMode =
System::Windows::Forms::AutoScaleMode::Font;
                this->BackColor =
System::Drawing::SystemColors::ControlLightLight;
                this->ClientSize =
System::Drawing::Size(1126, 504);
                this->Controls->Add(this->btnRunApp);
                this->Controls->Add(this->btnCalibrate);
                this->Controls->Add(this->panel1);
                this->Name = L"Form1";
                this->StartPosition =
System::Windows::Forms::FormStartPosition::CenterScreen;
                this->Text = L"FoodWorks!";
                this->Load += gcnew
System::EventHandler(this, &Form1::Form1_Load);
                this->panel1->ResumeLayout(false);
                this->panel1->PerformLayout();
```

```
            this->ResumeLayout(false);

        }
#pragma endregion

private: System::Void Form1_Load(System::Object^  sender,
System::EventArgs^  e)
         {
              rtbAppDesc-
>LoadFile(HOMEPAGE,RichTextBoxStreamType::RichText);

         }
private: System::Void btnExitApp_Click(System::Object^
sender, System::EventArgs^  e)
         {
              Application::Exit();
         }
private: System::Void btnCalibrate_Click(System::Object^
sender, System::EventArgs^  e)
         {
              FTCalibrateCamera ^ calibrateForm = gcnew
FTCalibrateCamera(this);
              calibrateForm->Show();
         }
private: System::Void btnRunApp_Click(System::Object^
sender, System::EventArgs^  e)
         {
              TrackFood ^ trackForm = gcnew
TrackFood(this);
              trackForm->Show();
         }
private: System::Void panel1_Paint(System::Object^  sender,
System::Windows::Forms::PaintEventArgs^  e) {
         }
};
}
```


FTCalibrateCamera.h

Methods to scale and display images from webcam, with thresholding and target colours are described below. Most other methods in FTCalibrateCamera are displaying interface elements and event handling. For full implementation of FTCalibrateCamera.h see DVD

```
// differs from method in trackFood, scales and produces 3
images to be displayed at calibration
private: System::Void bw1_DoWork(System::Object^  sender,
System::ComponentModel::DoWorkEventArgs^  e)
         {
              Mat thresholdedFrame,
intermediateFrame,frameCaptured ;
              time_t start, end;
              double elapsedTime = 0.0;

              stopCalibCap = false;

              int xy, yz;

              xy = yz = 0;

              VideoCapture webcam_Cap(0);


webcam_Cap.set(CV_CAP_PROP_FRAME_WIDTH,WEBCAM_RES_COLS);


webcam_Cap.set(CV_CAP_PROP_FRAME_HEIGHT,WEBCAM_RES_ROWS);

     webcam_Cap.set(CV_CAP_PROP_CONVERT_RGB,1);


              int rem;
```

```
                int cropCols = (int)
(WEBCAM_RES_COLS*CROP_RATIO);
                if ((rem = (cropCols % 4)) != 0)
                {
                      cropCols = cropCols+ 4 - rem;
                }

                int cropXPoint = (int) ((WEBCAM_RES_COLS -
cropCols)/2);
                int cropRows = (int)
(cropCols/LAPTOP_RES_COLS_RATIO);

                if ((rem = (cropRows % 4)) != 0)
                {
                      cropRows = cropRows+ 4 - rem;
                }

                int cropYPoint = (int) ((WEBCAM_RES_ROWS -
cropRows)/2);

                Rect roi =
Rect(cropXPoint,cropYPoint,cropCols,cropRows);

                if (!webcam_Cap.isOpened())
                {
                      stopCalibCap = true;

                }

                while (!stopCalibCap)
                {
                      time(&start);
                      if (bw1->CancellationPending)
                      {
                            e->Cancel = true;
                            stopCalibCap = true;
                            webcam_Cap.release();
                            destroyAllWindows();
                            Sleep(10);
                            return;
                      }

                      if (calibDispThreadFinished && !
PBUpdating)
                      {

                            calibCaptThreadFinished =
false;
                            if (!
webcam_Cap.read(frameCaptured)) break;

                            waitKey(1); // allow openCV
to refresh its window

                            // resizes cropped image to
third of its size and displayed as seen by webcam



resize(frameCaptured(roi),resizedCapturedFrame,cv::Size(),
CALIB_RESIZE_RATIO,CALIB_RESIZE_RATIO,CV_INTER_AREA);

                            // image is thresholded
                            resizedThreshFrame =
getThresholdedFrame(resizedCapturedFrame);

                            //changed to target colour
                            resizedTargetFrame =
calibrateFrameInTargetColour(resizedThreshFrame, (uchar)
newCalibratedValues[selectedColor-
1].TC[selectedTargetColor-1].targetHue, (uchar)
newCalibratedValues[selectedColor-
1].TC[selectedTargetColor-1].targetSaturation, (uchar)
newCalibratedValues[selectedColor-
```

```
1].TC[selectedTargetColor-1].targetValue);

                              if (++xy > 1000000) //just
incase we need to pass values - also for debugging to check
in report progress that thread is running
                              {
                                    xy = yz = 0;
                              }
                              else
                              {
                                    ++yz;
                              }

                              calibCaptThreadFinished =
true;
                              time(&end);
                              elapsedTime =
difftime(end,start);
                              bw1-
>ReportProgress(xy,elapsedTime);
                        }
                        else
                        {
                              calibCaptThreadFinished =
true;
                              Sleep(10);
                        }
                  }
            }


// receives control from background thread each time an
image is ready to be displayed
private: System::Void bw1_ProgressChanged(System::Object^
sender, System::ComponentModel::ProgressChangedEventArgs^
e)
            {
                  time_t st,et;
                  double diff_disp_time;

                  time(&st);


                  PBUpdating = true;
                  calibCaptThreadFinished = true;
                  double elapTime = (double) e->UserState;
                  lblElapTime->Text = elapTime.ToString();
                  if (!PausePBDisplay)
                  {
                        // update picture boxes with
frames that have been resized and created
                        dispCalibFrames(this-
>pbCapturedFrame,this->pbThresholdedFrame,this-
>pbTargetFrame);
                  }
                  time(&et);
                  diff_disp_time = difftime(et,st);
                  lblDispElapTime->Text =
elapTime.ToString();

                  if(doIOwnLock(this->pbCapturedFrame))
calibDispThreadFinished = true;
                  PBUpdating = false;
            }
```

TrackFood.h

The method to run the background worker thread and crop the image is shown below, and also the method which calls the tracking image to be displayed. For full implementation of TrackFood.h see source code in DVD.

```
 // runs in background thread everything else runs in
foreground UI threads
private: System::Void
backgroundWorker1_DoWork(System::Object^  sender,
System::ComponentModel::DoWorkEventArgs^  e)
            {
                  Mat trackingFrameCaptured, croppedImage;;
                  time_t start, end;
                  double elapsedTime = 0.0;
                  int xy, yz;

                  xy = yz = 0;

                  stopCap = false;

                  VideoCapture webcam_Cap(0);

webcam_Cap.set(CV_CAP_PROP_FRAME_WIDTH,WEBCAM_RES_COLS);

webcam_Cap.set(CV_CAP_PROP_FRAME_HEIGHT,WEBCAM_RES_ROWS);
                  //crop image from camera to central 50%
                  int rem;
                  int cropCols = (int)
(WEBCAM_RES_COLS*CROP_RATIO);
                  if ((rem = (cropCols % 4)) != 0)
                  {
                        cropCols = cropCols+ 4 - rem;
                  }

                  int cropXPoint = (int) ((WEBCAM_RES_COLS
- cropCols)/2);
                  int cropRows = (int)
(cropCols/LAPTOP_RES_COLS_RATIO);

                  if ((rem = (cropRows % 4)) != 0)
                  {
                        cropRows = cropRows+ 4 - rem;
                  }

                  int cropYPoint = (int) ((WEBCAM_RES_ROWS
- cropRows)/2);

                  Rect roi =
Rect(cropXPoint,cropYPoint,cropCols,cropRows);


                  if (!webcam_Cap.isOpened())
                  {
                        stopCap = true;
                  }

                  while (!stopCap)
                  {
                        time(&start);
                        if (bw1->CancellationPending)
                        {
                              e->Cancel = true;
                              stopCap = true;
                              webcam_Cap.release();
                              destroyAllWindows();
                              waitKey(1);
                              return;
                        }

                        if (DispThreadFinished)
                         {
                               captThreadFinished = false;

                               if (!
webcam_Cap.read(trackingFrameCaptured)) break;


                               waitKey(1);//allow opencv to
```

```
refresh its window


                              trackingThresholdedFrame =
getTrackingThresholdedFrame(trackingFrameCaptured(roi)); //
get thresholded frame that identifies all colours we are
interested in

                              if (++xy > 1000000) //just
incase we need to pass values - also for debugging to check
in report progress that thread is running
                              {
                                    xy = yz = 0;
                              }
                              else
                              {
                                    ++yz;
                              }
                              captThreadFinished = true;

                              time(&end);
                              elapsedTime =
difftime(end,start);
                              bw1-
>ReportProgress(xy,elapsedTime); // reports what background
thread is doing
                              Sleep(750);
                        }
                        else
                        {
                              captThreadFinished = true;

                              Sleep(750);
                        }


                  }
            }

      //control returned from background thread to
display tracking image
private: System::Void bw1_ProgressChanged(System::Object^
sender, System::ComponentModel::ProgressChangedEventArgs^
e)
            {

                  time_t st,et;
                  double diff_disp_time;

                  time(&st);


                  DispThreadFinished = false;
                  captThreadFinished = true;
                  double elapTime = (double) e->UserState;
                  this->Focus();
                  this->pbTrackThresh->Focus();
                  lblElapTime->Text = elapTime.ToString();

                  dispTrackingFrame(this->pbTrackThresh);
// displays one image

                  time(&et);
                  diff_disp_time = difftime(et,st);
                  lblDispElapTime->Text =
elapTime.ToString();
                  DispThreadFinished = true;

            }
```

CalibrationHelp.cpp

```
#include "StdAfx.h"
#include "CalibrationHelp.h"
```

FoodTrackPrototypev1.cpp

```
// FoodTrackPrototype v1.cpp : main project file.

#include "stdafx.h"
#include "Form1.h"



using namespace FoodTrackPrototypev1;


[STAThreadAttribute]
int main(array<System::String ^> ^args)
{

	Application::EnableVisualStyles();
	Application::SetCompatibleTextRenderingDefault(false);
	threshHValue = 5;
	// Create the main window and run it
	Application::Run(gcnew Form1());
	return 0;

}
```

FTCalibrateCamera.cpp

```
#include "StdAfx.h"
#include "FTCalibrateCamera.h"
```

stdafx.cpp

```
// stdafx.cpp : source file that includes just the
standard includes
// FoodTrackPrototype v1.pch will be the pre-compiled
header
// stdafx.obj will contain the pre-compiled type
information

#include "stdafx.h"
```

TrackFood.cpp

```
#include "StdAfx.h"
#include "TrackFood.h"
```

FoodTrackUtilities.cpp

The methods to convert HSV to RGB, add badges, thresholding and morphing, adding target colours, and displaying images during calibration and tracking are described below. For the full source code for this class refer to DVD.

```
void convertHSVValuesToRGB (uchar hue, uchar saturation,
uchar brightness, uchar *rValue, uchar *gValue, uchar
*bValue)
{
	const int WIDTH = 255;
	const int HEIGHT = 255;

	IplImage *imageHSV = cvCreateImage(cvSize(WIDTH,
HEIGHT), 8, 3);
	int h = imageHSV->height;			// Pixel
```

```
height
      int w = imageHSV->width;                  // Pixel
width
      int rowSize = imageHSV->widthStep; // Size of row in
bytes, including extra padding
      char *imOfs = imageHSV->imageData; // Pointer to the
start of the image HSV pixels.

      // Clear the image to grey (Saturation=0)
      cvSet(imageHSV, cvScalar(0,0,210, 0));

      // create a temp image with colour wheel for selected
hue
      for (int y=0; y<255; y++)
      {
            for (int x=0; x<255; x++)
            {
                  uchar h = hue;          // Hue (0 - 179)
                  uchar s = x;            // Saturation (0 -
255)
                  uchar v = (255-y);      // Value
(Brightness) (0 - 255)

                  // Set the HSV pixel components
                  *(uchar*)(imOfs + (y)*rowSize + x*3 + 0) =
h;
                  *(uchar*)(imOfs + (y)*rowSize + x*3 + 1) =
s;
                  *(uchar*)(imOfs + (y)*rowSize + x*3 + 2) =
v;
            }
      }



      IplImage *imageRGB = cvCreateImage(cvSize(imageHSV-
>width, imageHSV->height), 8, 3);
      cvCvtColor(imageHSV, imageRGB, CV_HSV2BGR);

      rowSize = imageRGB->widthStep;      // Size of row in
bytes, including extra padding
      imOfs = imageRGB->imageData; // Pointer to the start
of the image HSV pixels.
      *rValue = *(uchar*)(imOfs + (255-brightness)*rowSize
+ (saturation)*3 + 2); // Red
      *gValue = *(uchar*)(imOfs + (255-brightness)*rowSize
+ (saturation)*3 + 1); // Green
      *bValue = *(uchar*)(imOfs + (255-brightness)*rowSize
+ (saturation)*3 + 0); // Blue

      cvReleaseImage( &imageRGB );
      cvReleaseImage( &imageHSV );
}
Mat addBadges(Mat inputFrame)
{
      // add badges

      double HALF_THRESHOLD = 0.4;
      double FULL_THRESHOLD = 0.8;
      double initialObjectsOnPlate = (double)
pOP.initialCount;
      double currentObjectsOnPlate = (double)
pOP.currentCount;
      double completionPercentage = 0.0;
      Mat badge1, badge2, roiImg;
      Rect badgeRoi;

      if (pOP.initialCount == 0)
      {
            return inputFrame;
      }

      completionPercentage = (double) 1.0 -
(currentObjectsOnPlate/initialObjectsOnPlate);
```

```
	if (completionPercentage >= HALF_THRESHOLD)
	{
		halfWayCount++;
		if (halfWayCount > HALFWAY_LOOP_LIMIT)
		{

			halfWayFlag = true;

			badge1 = imread(HALFBADGE); //read image
file

			if(!badge1.data)
			{
				return inputFrame;
			}



resize(badge1,badge1,cv::Size(),BADGE_MAGNIFICATION_ADJUSTME
NT,BADGE_MAGNIFICATION_ADJUSTMENT,CV_INTER_CUBIC);

			//set region of interest
			badgeRoi = Rect(inputFrame.cols -
badge1.cols,inputFrame.rows-
badge1.rows,badge1.cols,badge1.rows);
			roiImg = inputFrame(badgeRoi);

	addWeighted(roiImg,0.0,badge1,1.0,0.0,roiImg); //add
the badge to the frame
		}
	}
	else
	{
		if(halfWayFlag)
		{
			halfWayCount--;
			if (halfWayCount < 0) halfWayCount = 0;
		}
	}

	if (completionPercentage > FULL_THRESHOLD)
	{
		fullCount++;
		if(fullCount > FULL_LOOP_LIMIT)
		{
			fullFlag = true;
			badge2 = imread((std::string)FULLBADGE);

			if(!badge2.data)
			{
				return inputFrame;
			}



resize(badge2,badge2,cv::Size(),BADGE_MAGNIFICATION_ADJUST
MENT,BADGE_MAGNIFICATION_ADJUSTMENT,CV_INTER_CUBIC);
			badgeRoi = Rect(0,inputFrame.rows-
badge2.rows,badge2.cols,badge2.rows); //set region of
interest
			roiImg = inputFrame(badgeRoi);

	addWeighted(roiImg,0.0,badge2,1.0,0.0,roiImg);
		}
	}
	else
	{
		if(fullFlag)
		{
			fullCount--;
			if (fullCount < 0) fullCount = 0;
		}
	}
```

```
	return inputFrame;}


//method used in FTCalibrateCamera, one colour is
thresholded and returned
Mat getThresholdedFrame(Mat inputFrame)
{


	Mat HSVFrame;

	Mat dilate_element;
	const int DILATE_SIZE = 6;

	//set up the dilating matrix.

	dilate_element = getStructuringElement( MORPH_ELLIPSE,
		cv::Size( 2*DILATE_SIZE + 1, 2*DILATE_SIZE+1 ),
		cv::Point( DILATE_SIZE, DILATE_SIZE ) );

	cvtColor(inputFrame,HSVFrame,CV_BGR2HSV,0);

	Mat threshFrame;

	inRange(HSVFrame,
Scalar(newCalibratedValues[selectedColor-
1].lowerHue,newCalibratedValues[selectedColor-
1].lowerSaturation,newCalibratedValues[selectedColor-
1].lowerValue),

Scalar(newCalibratedValues[selectedColor-
1].upperHue,newCalibratedValues[selectedColor-
1].upperSaturation,newCalibratedValues[selectedColor-
1].upperValue), threshFrame);

	dilate(threshFrame,threshFrame,dilate_element); //
smooths the image

	//Find contours and fill them in so we can see
objects

	vector<vector<cv::Point> > contours;
	vector<Vec4i> hierarchy;

	findContours( threshFrame, contours,
CV_RETR_EXTERNAL, CV_CHAIN_APPROX_SIMPLE, cv::Point(0,
0) );

	drawContours(threshFrame, contours, -1,
Scalar::all(255), CV_FILLED);

	return threshFrame;

}

// method used in tracking screen for thresholding
Mat getTrackingThresholdedFrame(Mat inputFrame)
{

	// remember input frame is cropped to the central
50% region of webcam so its a smaller image
	const int DILATE_SIZE = 20;

	const int MORPH_SIZE = 3;

	Mat TrackingHSVFrame,intermediateFrames,
intColourFrame,threshColourFrame,bigImage,roiImg;

	// set up the dilating matrix.

	Mat tracking_dilate_element = getStructuringElement(
MORPH_ELLIPSE,
```

```
cv::Size(DILATE_SIZE,DILATE_SIZE),
                                        cv::Point( -1,-1) );

      // set up the morphing matrix.

      Mat tracking_morphing_element = getStructuringElement(
MORPH_RECT,

cv::Size(MORPH_SIZE,MORPH_SIZE),
                                        cv::Point( -1,-1) );

      cvtColor(inputFrame,TrackingHSVFrame,CV_BGR2HSV,0);
//convert BGR image to HSV

      threshColourFrame =
Mat::zeros(inputFrame.size(),inputFrame.type());
//initialise as a black image

      // now threshold the image for each colour and combine
into single image

      noOfPixelsReplaced = 0;

      for(int i=0;i < numOfColoursToTrack; i++)

      {
            inRange(TrackingHSVFrame,
Scalar(newCalibratedValues[i].lowerHue,
newCalibratedValues[i].lowerSaturation,newCalibratedValues[i
].lowerValue),
                  Scalar(newCalibratedValues[i].upperHue,
newCalibratedValues[i].upperSaturation,newCalibratedValues[i
].upperValue), intermediateFrames);

            //remove noise

morphologyEx(intermediateFrames,intermediateFrames,MORPH_O
PEN,tracking_morphing_element);


dilate(intermediateFrames,intermediateFrames,tracking_dila
te_element,cv::Point(-1,-1),2); // smooths the image


            //Find Contours and fill them in

            vector<vector<cv::Point> > contours;

            findContours( intermediateFrames, contours,
CV_RETR_EXTERNAL, CV_CHAIN_APPROX_SIMPLE, cv::Point(0,
0) );

            drawContours(intermediateFrames, contours, -1,
Scalar::all(255), CV_FILLED);


            int rndnum = rand_num(MAX_COLOUR_TO_TRACK-1);

            intColourFrame =
calibrateFrameInTargetColour(intermediateFrames, (uchar)
newCalibratedValues[i].TC[rndnum].targetHue, (uchar)
newCalibratedValues[i].TC[rndnum].targetSaturation,
(uchar) newCalibratedValues[i].TC[rndnum].targetValue);


bitwise_or(threshColourFrame,intColourFrame,threshColourFr
ame);

      }
```

```
	//resize the image to allow for the distance effect of what the webcam sees. MAGNIFICATION_ADJUSTMENT is a constant that needs tuning dependening on distance of webcam from object
	//it should result in an imahge whose pixel counts in rows and columns are divisible by 4. else the convert to bitmap in Visual C++ fails


resize(threshColourFrame,threshColourFrame,cv::Size(),MAGNIFICATION_ADJUSTMENT,MAGNIFICATION_ADJUSTMENT,CV_INTER_CUBIC);

	bigImage = Mat::zeros((int) ((LAPTOP_RES_COLS-LAPTOP_RES_COLS_MARGIN)/LAPTOP_RES_COLS_RATIO), (LAPTOP_RES_COLS-LAPTOP_RES_COLS_MARGIN),threshColourFrame.type());

	// set Region of Interest in the big image so we can add the thresholded image

	int xPoint = (int) ((bigImage.cols - threshColourFrame.cols)/2) + horOffset;

	if (xPoint < 0) xPoint = 0;
	if (xPoint > (LAPTOP_RES_COLS-LAPTOP_RES_COLS_MARGIN - threshColourFrame.cols)) xPoint = (LAPTOP_RES_COLS-LAPTOP_RES_COLS_MARGIN - threshColourFrame.cols);

	int yPoint = (int)((bigImage.rows - threshColourFrame.rows)/2) + vertOffset;

	if (yPoint < 0) yPoint = 0;
	if (yPoint > ((int)((LAPTOP_RES_COLS-LAPTOP_RES_COLS_MARGIN)/LAPTOP_RES_COLS_RATIO) - threshColourFrame.rows))
	{
		yPoint= (int)((LAPTOP_RES_COLS-LAPTOP_RES_COLS_MARGIN)/LAPTOP_RES_COLS_RATIO) - threshColourFrame.rows;
	}

	Rect roi = Rect(xPoint,yPoint,threshColourFrame.cols,threshColourFrame.rows);

	roiImg = bigImage(roi);

	dispBlackImage = (dispBlackImage)?false:true;

	if(dispBlackImage)
	{
		Mat blackImage = Mat::zeros(threshColourFrame.rows,threshColourFrame.cols, threshColourFrame.type());

	addWeighted(roiImg,0.0,blackImage,1.0,0.0,roiImg);
	}
	else
	{


addWeighted(roiImg,0.0,threshColourFrame,1.0,0.0,roiImg);
// add the different images for each colour
	}

	countObjects(noOfPixelsReplaced);

	bigImage = addBadges(bigImage);

	return bigImage;

}
```

```
//convert white in thresholded image to target colour chosen
Mat calibrateFrameInTargetColour(Mat inputFrame, uchar
targetHue, uchar targetSaturation, uchar targetValue)
{
	Mat targetFrame;
	IplImage imageInput, imageTarget ;

	imageInput = inputFrame;

	int inRowSize = imageInput.widthStep;	// Size of
row in bytes, including extra padding
	char *imOfs = imageInput.imageData;
	int numRows = inputFrame.rows;
	int numCols = inputFrame.cols;

	targetFrame = inputFrame.clone();

	cvtColor(targetFrame, targetFrame,CV_GRAY2BGR);
//convert target image frame
	cvtColor(targetFrame, targetFrame,CV_BGR2HSV);
//convert target image frame

	imageTarget = targetFrame;

	char *imTFs = imageTarget.imageData;
	int outRowSize = imageTarget.widthStep;


	for (int y=0; y<numRows; y++)
	{
		for (int x=0; x<numCols; x++)
		{
			if ( * ((uchar *) imOfs + (y*inRowSize) +
x ) == 255)
			{
				// Set the HSV pixel components
				*(uchar*)(imTFs + (y)*outRowSize +
x*3 + 0) = targetHue;
				*(uchar*)(imTFs + (y)*outRowSize +
x*3 + 1) = targetSaturation;
				*(uchar*)(imTFs + (y)*outRowSize +
x*3 + 2) = targetValue;
				noOfPixelsReplaced++;
			}
			else
			{
				;
			}
		}
	}
	cvtColor(targetFrame, targetFrame,CV_HSV2BGR);
//convert target image frame
	return targetFrame;



}


// converts images to bitmap and assigns bitmap to
relevant picture box in calibration

void dispCalibFrames(System::Windows::Forms::PictureBox^
pCapturedFrame, System::Windows::Forms::PictureBox^
pThresholdedFrame,System::Windows::Forms::PictureBox^
pTargetFrame)
{


	if (calibCaptThreadFinished)
	{
		System::IntPtr
ptrRCF(resizedCapturedFrame.ptr());
```

```
            System::IntPtr ptrRTF(resizedThreshFrame.ptr());
            System::IntPtr
ptrRTgF(resizedTargetFrame.ptr());

            pCapturedFrame->Image = gcnew
System::Drawing::Bitmap(resizedCapturedFrame.cols,resizedCap
turedFrame.rows,resizedCapturedFrame.step,System::Drawing::I
maging::PixelFormat::Format24bppRgb,ptrRCF);
            pThresholdedFrame->Image = gcnew
System::Drawing::Bitmap(resizedThreshFrame.cols,resizedThres
hFrame.rows,resizedThreshFrame.step,System::Drawing::Imaging
::PixelFormat::Format8bppIndexed,ptrRTF);
            pTargetFrame->Image = gcnew
System::Drawing::Bitmap(resizedTargetFrame.cols,resizedTarge
tFrame.rows,resizedTargetFrame.step,System::Drawing::Imaging
::PixelFormat::Format24bppRgb,ptrRTgF);
      }

}

// displays single projection image
void dispTrackingFrame(System::Windows::Forms::PictureBox^
pTrackingFrame)
{
      if (captThreadFinished)
      {
            System::IntPtr
ptrRCF(trackingThresholdedFrame.ptr());
            pTrackingFrame->Image = gcnew
System::Drawing::Bitmap(trackingThresholdedFrame.cols,tracki
ngThresholdedFrame.rows,trackingThresholdedFrame.step,System
::Drawing::Imaging::PixelFormat::Format24bppRgb,ptrRCF);

      }
}
```

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