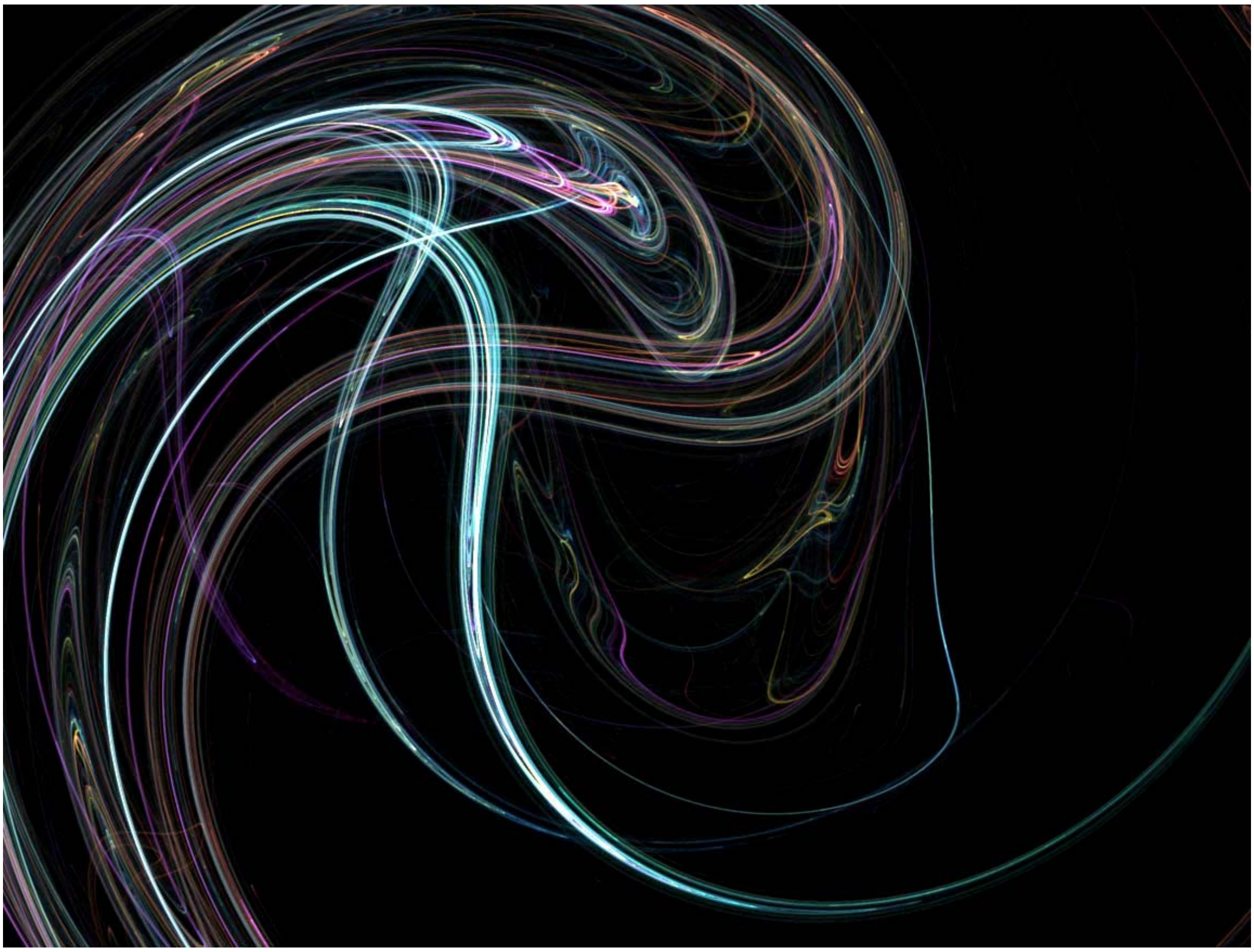

Smarter Smart Lights

Project Inception Report

IC The Light Group

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2. Introduction

The need to augment energy-efficiency measures in the foreseeable future has been rendered inevitable due to a combination of environmental and economic factors. The economic factors include the need to tackle the current trend of rising energy costs due to alarming rates of resource depletion as well as globalization which has spurred austere levels of competition between companies compelling them to continuously rethink formerly accepted practices and methods to curb costs. On the environmental front the relentlessly growing rates of carbon dioxide emissions are posing a grave long-term threat towards global climate change and governments are only now beginning to implement energy-saving directives specifically targeted at energy usage by businesses.

Although appreciable steps have been employed in recent years to reduce power dissipation in heating, cooling, ventilation and hot water systems in commercial buildings, the inadequacies in lighting control systems have seen relatively lacklustre development despite being responsible for almost a quarter of electricity wastage in a typical office. The most significant source of lighting power wastage in offices with conventional installations stems from lights being left on needlessly with no one being present in the illuminated area. Therefore quite accordingly lighting control aims to alleviate this energy dissipation by automating the control of illumination based on occupancy or vacancy of an area, independently of occupant control.

Most motion detection systems incorporate a combination of microwave, passive infrared (PIR) and ultrasonic sensor technologies to coordinate lighting. Although such systems are effective in illuminating an area upon detection of entry or other motion without manual user intervention, the occupant of the area is restricted to minimally moving once in the time-frame that the detector keeps lighting active after the last motion detection. This is clearly implausible in modern offices where employees may work unvaryingly at their designated locations for several hours at a stretch.

The different types of detection mechanisms considered for use in the system included; thermal sensing with PIR sensors, X-band microwave sensors for human heartbeat detection, visual image processing camera with microprocessor, mobile phone detection, computer-access controlled lighting, swipe in and out cards and laser/ultrasound sensor technology. These various options were evaluated and juxtaposed with one other in light of their cost and ease of installation, reliability upon operation and cost of maintenance according to customer needs as outlined in the market research. The final combination of sensors for the system was chosen to best meet the needs of the customers.

This report commences by presenting the results of a market research conducted to obtain a gist of the main customer needs, then a technical specifications development based on the identified needs, the different considered sensors are discussed and compared with one other to finally yield the high-level design with the chosen combination of sensors for the final product to best satisfy the customer needs.

3. Executive Summary

The central objective of this project was to set in place the foundations of a potential technical solution to cater to the needs of an office lighting control market niche. The identified niche is the office lighting control installations relying on presence detection and exists due to reasons determined through a conducted local market survey as well as general market research.

These reasons include:

- A general trend of going ‘green’, energy-efficiency and cost-cutting amongst companies.
- Concerns regarding climate change caused by excessive energy consumption.
- Resulting upsurge in stringent governmental directives targeted at companies with regard to their energy usage.
- Office buildings account for 40 % of energy usage within the European Union.

- Unused lighting accounts for 25 % of energy wastage in offices with conventional electrical installations without lighting control.
- Most Lighting Control products currently available in market rely on motion detection sensors (as opposed to presence detection), not suitable for modern office work-places where people work unvaryingly for long times.
- From market survey a demand (i.e. potential commercial viability) has been identified for presence detection lighting control technology, given that it is acceptably reliable, technically sound and cost-effective.

The technical solution developed would have to be such as to best fulfil the customer needs identified through the survey. The needs were determined to be plausible pricing and good reliability and were then applied to the technical specifications development for the top-level design of the solution.

To create an acceptably flawless control system a combination of presence and motion detection, the detection systems initially considered for use included:

- Motion Detection methods such as Ultrasonic, Microwave and Passive Infrared sensors (PIR).
- Presence Detection methods such as computer-access control for lighting (CALS), image Processing camera with microprocessor, pressure Sensors, Laser/Ultrasonic and mobile Phone detection.

The final choice of sensors for the top-level design was decided upon by comparing each of them in light of their fulfilment of the decent price and reliability criteria of above.

- According to our evaluation, the combination of CALS, PIR and mobile phone detection best satisfies the aforementioned requirements.
- No current presence detection technology incorporates mobile phone detection or CALS, potentially providing our proposed product a competitive edge.

The advantages over conventional lighting management (no lighting control) we aim to provide our customers with our proposed solution include:

- Significant reductions in power wastage and energy bills (up to 25 %) than without lighting control.
- Low chance of breakdowns due to localized control structure of presence detection systems with no central control unit unlike conventional centralized switching systems.
- More flexibility and cost-effective during refurbishments and alterations of offices due to localized structure unlike expensive electrical wiring restructuring associated with conventional centralized structures.

4. Market Research

The Market research is concerned with the analysis of sample (quantitative and qualitative) data collected from several companies to tackle two main issues. Firstly it serves to reinforce the expected commercial viability of the product with real customer response data and secondly to deduce the fundamental customer needs to be later addressed in the specifications development planning.

The first step towards identifying the market needs was the conduction of a market survey. Two separate surveys were conducted. The first survey’s task was to find out the employees’ habits while working in an office. The second one was mainly used to investigate the infrastructure of the offices.

4.1 Survey A

Identifying typical sounds, movements and patterns would lead us to conclusions on what sensors our lighting system should use. Therefore we visited several offices of various sizes in Imperial

College and completed a survey which is shown in Appendix A. The market survey was conducted for all the offices during normal office hours (09:00 – 17:00) and after office hours.

Generally, in small offices (of size of about 10 – 15 people) the results recorded did not deviate a lot from their average. One important fact that was observed was that although some of the offices had entry and exit points which were exclusive, most of them had a single door for both entrance and exit. In addition it was noted that the doors were large enough for maximum of two people crossing them at a time.

It was recorded that more than 70% of the workforce was logged in on computers during their working hours. Another observation made was that only 10% of employees continued to work during after hours. Finally the majority of small offices had an existing lighting system which in all cases was based on the passive infrared sensors (PIR).

Medium and large offices were also considered. The average number of people working in the medium sized and large sized offices investigated where 25 and 50 people respectively.

In both the medium sized and the large sized offices the typical sounds produced where the mouse clicks, the pressed keyboard keys, phones ringing, people either talking or whispering and some machinery noise. During after working hours in medium sized offices there was not much change, but in the large sized offices there was less noise than the standard working hours.

There was constant movement in both the medium and the large offices, but in the large offices the frequency of the movements was higher. There were also some minor movements observed such as chair movements. Only a third of people didn’t move at all for a specific period of time (thirty minutes). It was observed that during after office hours in medium sized workplaces there was not a significant change, whereas in large ones the movement of people was less than before.

In all offices investigated, the doors were crossed usually by a single person but sometimes (10% of the time) two people were entering the room at the same instant. Most offices had two doors for entrance and exit which makes systems that use the principle of counting of people entering and leaving more difficult to control.

Important information was also extracted about the use of computers. In all offices all the employees have a computer to work. In the medium sized offices, during office hours 67% of computers were logged in but only 47% of the computers were actually used. 13% of people were working on paper and 7% of people were using laptops. At any given time, on average, only 7% of people were actually using mobile phones and another 7% were using landlines. After the standard office hours, the data did not significantly change except that less people were present in the office. In the large sized offices during office hours around 50% of computers were logged in and only 20% were actually used. 3% of the workforce was working on laptops. 10% of people were working on paper and another 10% were using mobile phones at any instant. 5% of people were using landlines. In these large sized offices, during after office hours we found that only a small proportion of people continued to work (7%), but 10% of the computers were logged in! 5% of computers where actually used and a very small proportion (less than 5%) were using mobile phones and landlines.

For all offices of any size it was calculated that more than 80% of the people had mobile phones with them at work. In some medium sized offices people where having problems by the existing motion detectors, because some people in the corners had to move towards the centre of the office so that the lights would switch back on. In almost all offices when we asked who switches off the lights, almost all said that they switch off “automatically”.

It is obvious that there is a need for automated solution since people are not concerned with minimizing the energy spent. The first point to note is that although there are various sounds produced there is no one single one that is always and constantly made when people are there and that is not made when people are not there. So from a single sound we cannot have a definite yes or no answer for the presence of a human being. Also since it was found there is constant movement of employees in an office it is a good indicator that a motion detector seems to be required. Computers are also widely used. So, a sophisticated program may also be a good way to control presence of people. Lastly, more than 80% of the workforce has mobile phones which suggest that checking on presence of mobile phones may be a good indicator of whether a human being is present in the office.

People where not concerned about minimizing the energy spent. Thus a robust and sophisticated lighting system is required to minimize the energy wasted which should not rely on people's actions.

4.2 Survey B

The second survey conducted was consisted of 8 questions to be answered by the appropriate representative of each office. The survey questions are included in Appendix B. The survey was conducted on 30 companies in person. The results of this survey are best demonstrated in the form of graphs which are shown in Appendix C.

4.2.1 Analysis of Survey B results

Graph 1 - What (approximate) proportion of your work-force has access to a computer?
The result here suggests the prevalence of computers in modern offices, no offices in our sample had computer access proportion lower than 50 % of their staff. 24 out the 30 offices (80 %) surveyed had computer access for more than 70 % of their staff, while a minority of 6 offices (20 %) reported less than or equal to 70 % computer access rate.

Graph 2 - At any given time are there more employees working on computers (or similar items such as PDAs) than non-electronic items?
The result here embodies the dominance of computer usage in modern offices and reinforces the suggestion of the computer access rates from above. All the offices reported a majority of their staff work on computers and similar electronic items at any given time. Therefore computers play an extremely important role in the time spent by the average employee in a modern office.

Graph 3 - What (approximate) proportion of your work-force own mobile phones?
The result here is analogous to computer access rates and suggests that the likelihood of the average office employee owning a mobile phone is quite high. 28 out of the 30 offices (93 %) reported mobile phone ownership to exceeding 70 % of their work-force, whereas 2 out of 30 (7 %) reported this at minimum half of their staff and no offices reported more than half of their work-force to not owning any mobile phones.

Graph 4 - What (approximate) proportion of your work-force work after-hours?
The result here suggests most offices have between 1 to 10 % of their staff working over-time and with few reporting over-time rates of over 10 %. 24 out of the 30 offices (80 %) reported 1-10 % of their staff working over-time whereas only 6 out of 30 offices (20 %) reported 10-20 % of their staff to doing so and no offices reported over-time staff rates beyond this.

Graph 5 - Does your office currently have any lighting control system installed?
The result here suggests that about half of the companies surveyed do currently have lighting control systems installed in their offices. 18 out of 30 offices (60 %) reported having some form of lighting-management system installed whereas 12 reported not having any form of such technology.

Graph 6 - Would you be interested in investing in a new and efficient lighting control technology which employs presence detection sensors for operation
The turnout here hints most offices in favour of installing the technology or at least considering the option, with an overwhelming minority expressing direct disinterest. 8 out of 30 offices (27 %) expressed direct interest in investing in a presence detection solution whereas 17 out of 30 (57 %)

expressed possible interest. Therefore collectively a majority of 25 out of 30 offices (83 %) expressed possible interest in the adoption of the technology whereas only 5 out of 30 offices (17 %) showed no interest whatsoever. This helps highlight the possible expected demand and commercial viability of the final product.

Graph 7 - If interested in investing in aforementioned technology, how much would you be willing to pay for the installation of such technology?

The distribution of data here suggests that offices interested in buying presence detection technology are willing to pay in the vicinity of £200-400 for its installation. 3 out of the 25 offices (12 %) are willing to invest, given the installation costs are bounded by £ 150, 7 out of 25 offices (28 %) are willing to pay £ 150-200, the majority of 13 out of 25 offices (52 %) are prepared to pay between £ 200-350, 2 out of the 25 offices (8 %) are prepared to pay between £ 350-500 and no offices are willing to pay any more than £ 500 in installation costs. This suggests that cost is definitely a factor for investment however there is a certain expectation upon installation of the lighting control technology that pushes customers to pay higher than the minimum price provided in the range. This result also reinforces the suggestion of projected demand and commercial viability of the final product.

Graph 8 - How many days of the week are the lights left on the whole night? (Please allow for 3 days when lights are forgot in Fridays)

When conducting the survey, the company was asked to include weekends in their estimation.

From this graph it can be seen that the majority of companies leave their lights on overnight 3 times a week.

The average can be worked out using the formula:

$$E\{N\} = \sum_{n=1}^{7} pdf_N N$$, where *N* is the number of days

$$E\{N\} = (1\times0.05) + (2\times0.15) + (3\times45) + (4\times0.2) + (5\times0.09) + (6\times0.04) + (7\times0.02) = 3.33 days$$

Collectively the outcomes for the various questions imply the possibility of a potential customer base for the proposed product and strongly encourage an acknowledgement of mobile phone detection and CALS as possible technologies to include in the final solution. Moreover the results of survey aid in invigorating general market research which suggests the uniqueness of employing CALS and mobile phone detection technologies in the final product as a means of differentiating from existing competing products in the market to prospectively gain a competitive edge.

4.3 Investigation of energy saving in terms of money

An important aspect of the market research is to find out how much money a typical company is likely to save by introducing a new lighting system which can control correctly the operations associated with switching on and off the lights when a person is not present in a room.

Let us consider an office with working hours from 9:00 to 17:00. Assume that people stay until 21:00 in the evening. Therefore the lights need to operate for a total of 12 hours. If we assume that an office does not have any kind of automatic lighting system then it means that if the last person that leaves forgets the lights on, then it means that energy will be wasted for 12 hours which is 50% of the total energy used. Using graph 8 of the appendix C, it can be calculated (shown above) approximately 47% of the days the lights are left on overnight. This means that we can save over a whole year around 23% of the energy spent.

More efficiency can be achieved through day-time light dimming or turning by using photosensitive detectors. This is consistent with the "Modern Building Services" journal where it was observed that it is possible to save up to 25% of the electricity bill by using smart lights.

4.4 Existing presence detector products

In an attempt to evaluate whether a price competitive solution can be produced, we will consider a range of existing presence detectors. The most commonly used products in the market up to date are the passive infra red motion detectors. In some products the infra red detector is combined with a microwave detector to safeguard against false alarm from moving curtains, heating vents, even animals. In other cases it is also combined with ultra sound receivers to correct wrong judgement of no human presence due to no or very little motion. In such a case, sounds from a mouse or keyboard click indicate presence. Their price ranges from less than £20 to about £80, the more expensive ones being those combining two sensors, giving higher accuracy. More expensive and accurate thermal imaging systems are mainly used in military and industry.

Active detectors also exist, where usually they emit microwaves or ultrasounds and receive their reflection from a human entering in their range. These are more commonly used at door entrances to allow for an automatic door opening system. Such products are relatively cheap to buy, £25 - £45, but don’t operate as an ideal presence detector. More sophisticated systems use infra red cameras or simple cameras and complex image processing software but prices exceed £250.

Having considered the existing technology, we are aiming to build an accurate illumination control device that can be effectively marketed in the £20 - £80 price range.

5 Specification Development

The market research conclusions give important parameters to define the specifications of the product. The other important parameter is the technical limitations and expense of solutions. In order to decide on how to solve the task technically, all the available methods of sensing had to be considered. Towards that end, a review of all these methods considered is provided.

5.1 Motion detectors

There are various ways to implement a motion detector. The three motion detectors considered here are the ultrasonic, the microwave and the infrared motion sensors.

5.1.1 Ultrasonic motion sensors

The ultrasonic motion sensors detect motion using sound waves. They are divided into active and passive sensors depending on how they operate. Active sensors emit sound waves at a higher frequency a human ear can hear. A movement disrupts the sound waves and this change is picked by the receiver. Depending on the sensitivity of the sensor, the control unit of the system decides if the movement is big enough to trigger any mechanism connected to it. Passive ultrasonic sensors have predetermined settings identifying the sounds which will trigger the sensor.

The ultrasonic sensors detect any movement within their range, but the area of detection weakens with distance. Motion can be detected for a distance of, generally, up to twelve meters. Ultrasonic sensors have a lifespan of approximately twelve to fifteen years. Extreme conditions such as high temperatures and humidity decrease the sensors’ life.

Ultrasonic sensors suffer from sensitivity problems. If the sensitivity is set too high then it might produce false alarms. Wind or noise outside the required detection area may also trigger the sensor. Ultrasound cannot penetrate through solid objects and this causes alterations in the detection field. Passive ultrasonic motion sensors may produce false detection when a telephone rings, although this can be avoided by proper calibration.

5.1.2 Microwave motion sensors

Microwave motion sensors emit microwaves to detect movement. It uses the same principle as an active ultrasonic motion sensor. Movement produces disruption in the detection field which the receiver senses. There are two different types of microwave motion sensors, called monostatic and bistatic. In monostatic sensors both the receiver and the emitter are contained in a single unit. Bistatic sensors have different units for the two components.

Monostatic units have a beam that can detect motion up to a distance of 120 metres whereas bistatic units can detect motion up to a distance of 450 metres. Although microwaves penetrate most types of solid objects, they cannot penetrate metal and hence any area located behind a metal is outside the detection zone. Also microwave sensors can detect motion behind walls and as a result may detect motion in areas which are not required to be monitored and hence bias the results. They also give some false readings because they are too sensitive. For example microwave motion sensors may be triggered even by fluorescence lighting.

5.1.3 Infrared motion sensors

Infrared motion sensors detect heat changes in a given area. There are two types of infrared motion sensors called active and passive sensors. Active sensors emit invisible light lying in the infrared range of the electromagnetic spectrum.

Passive infrared motion sensors work by detecting the heat emitted by living objects. If the temperature in the detection area is changed and is above a certain threshold then motion is detected, otherwise any small variation of temperature is ignored.

Passive infrared sensors are considered as one of the most reliable sensors. They are also small and cheap. On the other hand, the detection area is a circular area around the sensor; hence there are areas between the units that are not covered. Passive infrared sensors are affected by direct sunlight and should not be put opposite a window. Hanging objects such as balloons may also cause false detection and walking towards the sensor instead of across it may result in not detecting the movement.

5.2 Detection of mobile signal

This sensor will utilise the signal that is constantly sent out by a mobile phone, even if it is not used to make or receive a call. The signal includes the ‘Mobile Identification Number’ and the ‘System Identification Code’ used by the mobile phone to identify its self and register on the network. Since it is in the 1800 MHz band, in order to detect it, a simple radio signal receiver is needed, tuned in this frequency band. The receiver’s sensitivity should be such that its range should be similar to the size of the room concerned, picking up signals from that room only. Then the presence of a signal would be interpreted that someone is in the room switching on the lights.

The advantages of this receiver include the fact that it is passive, meaning that it does not emit any radiation itself, keeping power consumption to negligible levels. Also, it is a simple and cheap detector to build, light, taking very little space. Considering also the fact that the number of mobile phones is increasing quickly to one-phone-per-person, and the very high number of young users, this could be the solution for the future.

Problems with this detector are the facts that not everyone has a mobile phone (yet) and that someone may forget his mobile phone in the office (or not bring it at all to work!). As a result this detector would be more effective if used with a combination of other sensors.

5.3 Computer-Access controlled lighting system (CALS)

As is evident from Graphs 2 and 3 of the Market Research Survey (Appendix C), the overwhelming majority of employees in an office have access to a computer and for the large part of their working hours use them. Therefore computer usage is an invaluable indicator of presence in a typical office and can thereby be reliably utilized to form part of the lighting control system under consideration.

CALS is optimally reliable and moderately cheap to implement and maintain as a secondary detection system (please see block diagram of system below). As a secondary detection system, CALS will have to wait till the primary detector(s) don't detect any presence in a localized lighting area and check for login status of computers in that area (if the office computers are operated by password-activated access), mouse and keyboard usage to detect presence that the primary detection may have missed. CALS employs software control through a microprocessor which is also in contact with the primary detection system.

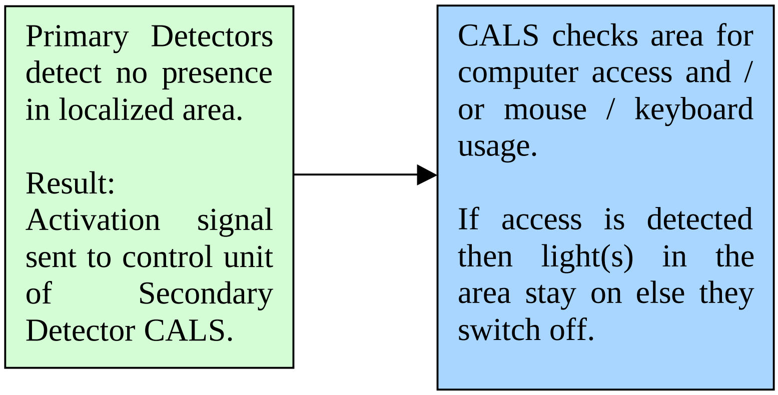

Figure 5.3.1: Block diagram of CALS

5.4 Image processing

Image processing is a process by which we can extract information from a real world image, obtained through an appropriate device (e.g. a digital camera), a frame grabber; a device to capture the images as a computer add-in board and using software to process this information into a useful function. An example of this is using algorithms for detection of the human shape to know if a person is within a given area.

Image processing in connection with presence detection for the particular application of automatic lighting control is a very accurate and reliable way of observing if and where an individual is present within a room. The cameras offer very high resolution and together with function-specific software this device can ensure human body detection for high ranges and various lighting configurations

However, image processing is not yet an option for commercially viable automatic lighting because of the price. Only the camera prices range from £1000 to £15000 per unit, and it is necessary of course to obtain suitable software on top of this. The cost of the software for a relatively simple presence detection starts at £1000 pounds. Because of this, image processing, although fascinating, is not an option for our project nowadays.

5.5 Heart beat detection

If heart beat detection could be accurately achieved, in the desired range and with low power consumption from the detector, then it would be the ultimate human presence detector and illumination control system. Nevertheless 'listening' to the heart with passive means is practically impossible, as noise in a normal office is well above the threshold which makes the sound made by the heart too weak to pick up.

Another mean to do this would be by sending a signal (possibly a microwave) and receive a reflection that is modulated by the vibrations of the human body that are caused by the heart beat. Yet due to the possibly high level of energy consumption by the device itself and the estimated lengthy period of testing needed (not feasible under this project), this solution will not be considered in building a prototype.

5.6 Laser sensors

Laser beams can be used to detect the number of people entering and leaving an office and therefore calculate the number of people in the room.

To make this method work each doorframe would be required to have two laser beams and detectors. The laser beams would be situated on one side of the doorframe adjacent to each other, with the detectors on the opposite side. Hence, if the laser path to the detector were to be broken, this would mean a person has either entered or left the office. The reason behind having two laser beams is to differentiate between a person entering and leaving a room. For example, if a person enters the office one of the lasers would be cut momentarily before the other one. The same concept would apply to someone leaving the room. A simple counter can be used to record the approximate number of people in the office. If this design were to be chosen, the lasers would need to be transparent so that they would not damage someone's eyesight.

This system would only give a rough estimation of the number of people in the office. If two people were to simultaneously leave the room side by side, the sensor would only record one person leaving the room. Also, this method alone could not be used to specify which parts of the office are being used, meaning that all the lights have to be switched on even if only one person was present in the room.

A possible alternative to lasers would be to use ultrasound transmitter (or piezo transducer). Piezo transducers (£0.5) and sensors (£2.50) are considerably cheaper than lasers (£10). Also, the power consumption for a typical laser transmitter (0.7mW) is significantly more than for ultrasound.

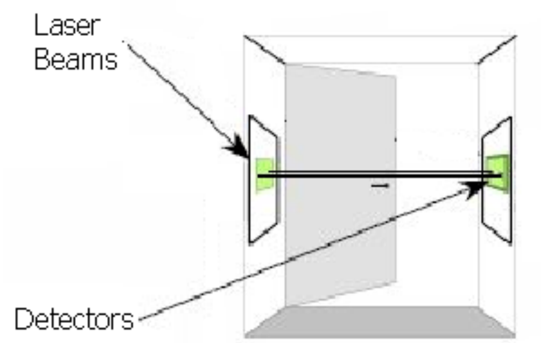

Figure 5.6.1: Layout of a laser sensor system

5.7 Pressure sensors

In an office, pressure sensors can be used to determine the number of people at any instant. This can be done by counting the number of individuals entering and exiting the office. The way this can be done is to place pressure sensors on the floor on both sides of each door i.e. inside and outside the office. When the sensors detect pressure from footsteps act as counters. Then when someone enters the room (pressure acted first on the sensor outside office and then on the inside one) it adds one to the counter and vice versa.

The main advantage of this type of sensor is the low cost of production. However, this method has many problems which include the issue when two people enter the office in the same instant through the same entrance. Another problem is that some features of human beings vary between people (e.g. weight and footsteps). Therefore this makes the product more complicated and thus more expensive.

Another way to detect presence is by planting pressure sensors under the chairs. When a person sits on a chair the sensor detects the force due to the weight of the human body. Since in an office people are either moving or sitting, this kind of sensor can be used along with a motion detector. However, the cost to place pressure sensors on all chairs in an office would be high. Also wires will be running loose from the chairs to the control unit. This would cause a chaos in the office. This problem could be solved if we have wireless pressure sensors, but this would increase the product price even more.

5.8 Swipe IN/OUT system

At the entrance of an office, a swipe in/out system could be used to determine the number of people in the room and the parts of the office which are occupied.Every time an employee would enter/leave the office, he would be required to swipe in/out. The swipe card would contain all the required information about the person on magnetic strips. When it has been swiped, the information would be recorded onto a computer/microprocessor and the lights in the room switched on/off accordingly. The advantage of this is that it would be relatively cheap, with the most expensive equipment being the magnetic card readers (£55 → £200)

In an ideal world (where everyone remembers to swipe in and out), this system would be very reliable. However, inevitably this is very difficult to achieve and people will forget to do this. Also at peak times, cues are likely to appear at the swipe in/out machine, which could lower moral and possible make staff feel they are wasting their time.

Therefore, because this system relies on a significant amount of human interaction, we believe that this is an unsuitable solution.

5.9 Defining the specifications of the product

Having considered all the options available to detect human presence, we will now consider various combinations of sensors in an attempt to make a package that ultimately fails as little as possible.

5.9.1 Market research involvement in defining the specification, cost and time issues

The market research has defined a few parameters for our system that need to be followed. First of all, it was found that a motion detector is vital since there was almost always constant movement in an office. So using some kind of motion detector will take care of a large part of the detection process. Furthermore it was found that employees rely on the use of computers, so it would be important to use some kind of input information from PCs. Mobile phones are also widely used. According to the market research more than 80% have a mobile phone with them at work. This can be used to pick up the mobile signal and identify if someone is in the office.

On the other hand, according to the market research, there were occasions that people where entering the office two at a time. This means that the laser beam system counter would not work. In addition, a lot of offices have two access points, which makes the system installation more difficult. The system would also be faced with concurrency issues

It was also found that people are ignorant about how the lighting system works and this means that the proposed solution should minimise people’s involvement. This means that a swipe in/out system is not favoured. Pressure sensors and image processing were found to be expensive and the pressure sensor is also impractical to use.

Heart beat detection is still investigated at research level and hence in the time given to complete the project, a system based on this method could not be designed. Therefore a specification including this system would not have been realistic.

5.9.2 Solution 1: Passive Infra Red (PIR) – Mobile Phone Detector (MPD) – Personal Computer Monitoring (PCM)

This package will use the traditional passive infra red motion detector, the mobile phone detector and information from the PCM unit, all combined. It is generally accepted that the PIR is the most effective motion detector, and most widely used in the market today. This fails only in cases that someone is in the room, needing the light on, but due to no or very little and slow movement the lights go off. Using the mobile phone detector as well will solve the problem if that person has a mobile phone. So if there is no motion but there is a mobile phone in the room, the lights will go on/stay on. Further, the log-in information from the PCs (as well as any input from keyboards or mouse) in that room will help in the case that that person who is not moving and doesn't have a mobile phone is locked-in on a computer. The system fails only when there is somebody in the room, needing the lights on, not moving, not having a mobile phone and not using or being locked-in on a computer. We can see this graphically with the pie chart in figure 5.9.2.1

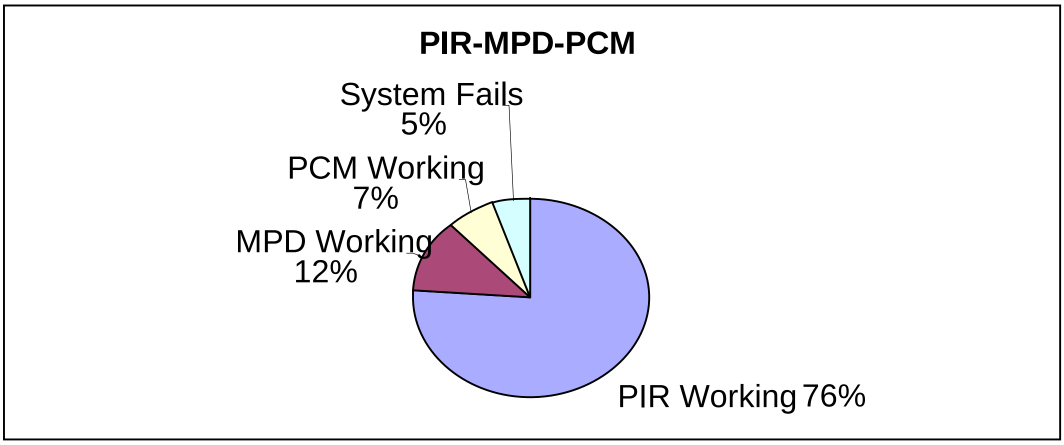

Figure 5.9.2.1: Pie chart of system reliability

The total pie chart area represent the total time that the lights are needed to be on. The PIR system fails 24% of the time but adding the MPD and PCM this drops to 5%. Numbers are an estimate, using observed behaviour from an average office. (Observed behaviour in an average office is derived by observations in a number of different sized offices.) As a result, numbers may well differ for different offices.

Based on this model, the performance of the traditional PIR motion detector is improved by about 20%. Yet this may result in considerably greater percentage of energy saved. This because, in the cases that PIR fails (for example when the movement of a person working in the corner of a room is not detected at all), the PIR may be by-passed turning lights on 'permanently' and then relying on someone to turn them off, which may never happen.

5.9.3 Solution 2: Ultrasound Counter + PIR

Fitting ultra sounds on every door to the room, to count people in and out, will fail if two or more people walk in or out the door simultaneously. If the counter fails to 'see' that there are people still in the room the PIR will correct it and leave the lights on (on the condition that there is enough motion to be detected). On the other hand, if the counter fails to see that there is nobody else in the room and we assume that PIR should but is not detecting motion, then the lights are going to be uselessly left on. This would be true in the case that the counter is used as the primary criterion. As it can be seen from the pie chart below (figure 5.9.3.1), this system has a larger probability of failure.

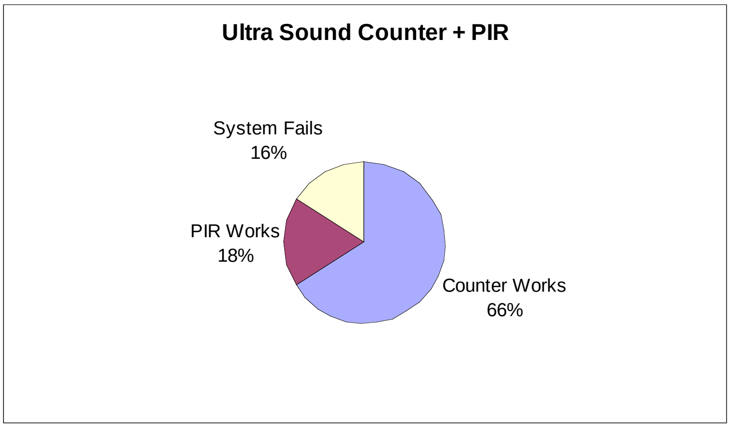

Figure 5.9.3.1: Pie chart of system reliability

The system fails 16% of the time which is a very small improvement to the PIR alone which fails 24% of the time. The problems mentioned above and the considerably large installation cost makes this solution less favourable than the PIR-MPD-PCM.

We therefore decided to use solution 1 since the system was estimated to work better.

6. Top level design

6.1. Block Diagram

The top level design block diagram (diagram 6.1.1) which is shown below contains all the main parts of the system proposed in solution 1.

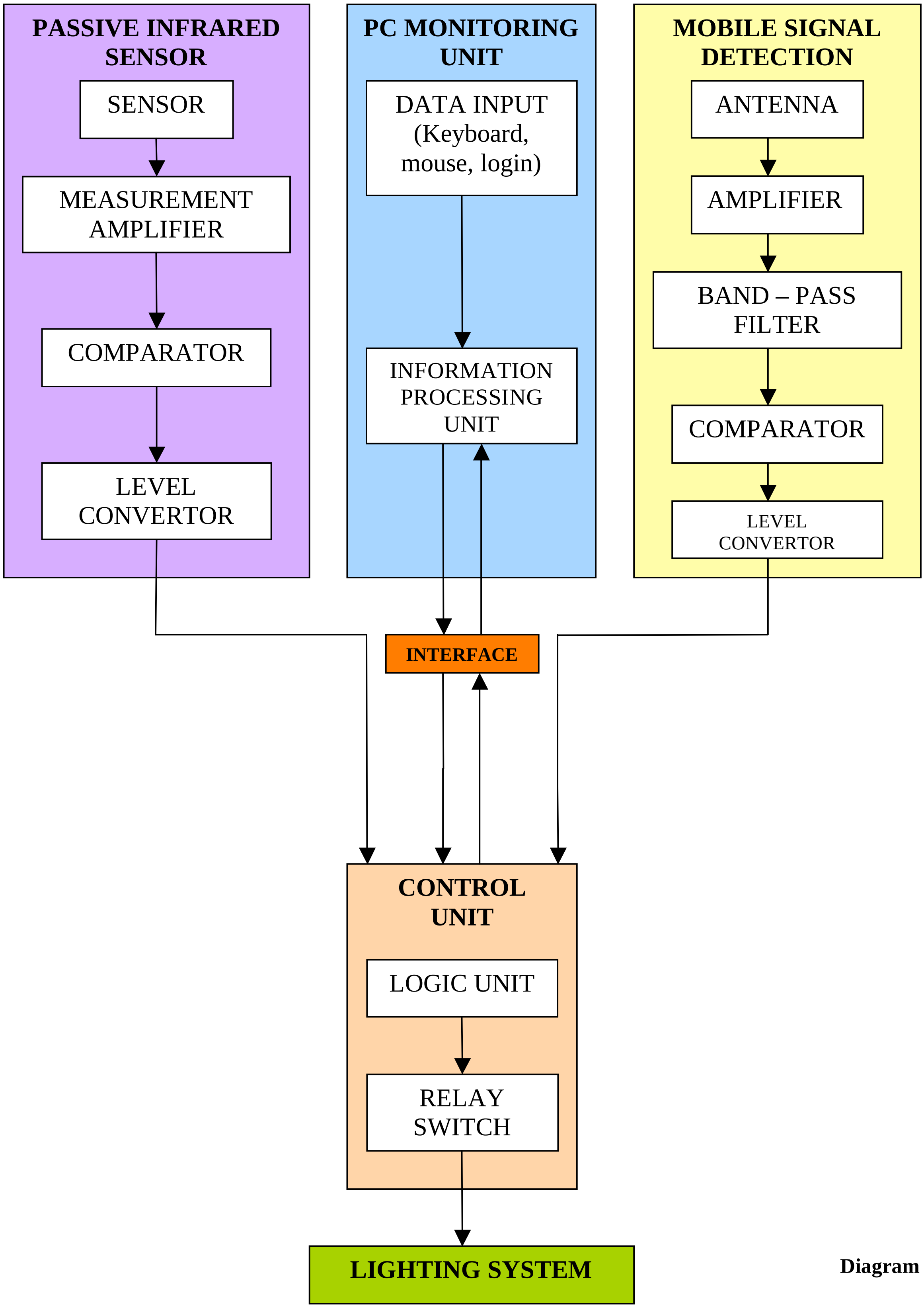

Diagram 6.1.1

6.2 Top Level Design Analysis

6.2.1 Passive infrared sensor (PIR)

The Passive infrared sensor (PIR) is composed of a sensor which receives an input signal and sends it to the measurement amplifier. The amplifier is typically bandwidth limited to below 10Hz to reject high frequency noise. The amplified signal is fed into a comparator. This circuit is used to compare our signal with a predetermined threshold level to determine between logic levels zero and one. This is completed with the help of a level converter which will determine a standardized voltage level for logic one and zero. Finally the output of the PIR circuit will be send to the control unit.

6.2.2 Mobile Signal Detection (MSD)

The MSD circuit is made up of an antenna, an amplifier, a band pass filter, a comparator and finally a level converter. Firstly the antenna receives the transmitted analogue signal of mobile phones along with some noise. Then we amplify this signal and pass it through a band pass filter centred at the desired frequency, so we remove all the additional noise received and amplified. Now we are left with only the signal transmitted by the mobile phones. As in the PIR a comparator and a level converter is also used to conclude between logic levels one and zero.

6.2.3 PC Monitoring Unit

In the PC monitoring unit the data input system records all computer usage. The parts that our system will store are mouse clicks, keyboard keys usage and logins. All this will be saved in the log files. The log file will also include the time of each event. This information is kept for the last half hour.

The information processing unit is enabled only if the control unit permits it via the interface. This processing unit is a software which will be based on a simple algorithm. It will start by fist finding the number of users that are logged in. If no one is logged in then the lights are turned off. Otherwise, the program will enter a loop which checks the log files of the last half hour. If the log files contain information about keys that were pressed or mouse buttons clicked then the system will stay idle and wait another half hour from the time of the last event (i.e. from the time of the last mouse or keyboard action). On the other hand if log files are empty then the system will send a message to the logged in computers asking if the users are in the office. If the person answers yes within 10 minutes then the control unit will wait for half an hour and then it will repeat the loop. If the program receives no reply it will assume the user is not in and the lights will switch off after assuming all users are not in the office. In the case that the lights are switched off and the user makes any action on the PC, the lights will switch on automatically.

The interface translates the output of the Information processing unit into voltage and then sends this voltage to the Control unit.

6.2.4 Control Unit

The logic unit contains a hardware algorithm. The control unit begins by checking if the PIR or mobile signal detector identifies presence of any employees in the office. If either of them identifies a human being present then it will send a signal to the relay switch to turn on the lights. If both do not detect any presence then the control unit will enable the PC monitoring system through the interface.

An important feature of the algorithm is that if at any instant the PIR and the mobile signal detector sense any presence then the control unit will override the operations of the PC monitoring unit and will have the lights switched on.

Finally the relay switch takes information from the control unit and is used to turn on or off the lighting system of the office.

7. Management Plan

The group members of this project are:

- Giorgos Georgiadis
- Kratinos Michaelides
- Ushnish Banerjee
- Andriy Gelman
- Matias Hernadez

Suitably selecting six individuals to make up the group was the first task towards organising the group. The first meeting of the group was done in the first week of the project for two reasons. First, it was a chance for group members to get to know each other and then decide what must be done before choosing any of the project topics provided. Once a brief research and reading was conducted on all the projects by all the individuals, we had another meeting and we decided to do the “Smarter Smart Lights” project. It was also decided to have regular meetings twice a week so that work could progress on. By the end of the first meeting we also decided to have two meetings a week and it was voted that Georgiadis Giorgios should be our group leader.

In the fourth week of the term, it was decided that everyone had to research about one type of sensor which could be used in our project. Meanwhile it was decided that a market survey would be required. For the eventuality that the questionnaire response time of the offices would exceed our deadline we conducted a back up survey to ensure we collected sufficient data for the market research. Therefore we made three groups of two to make the necessary researching. Two groups were assigned to do surveys at several offices during and after office hours to observe the behaviour of the employees. The other group had to find out about energy suppliers and the cost of existing presence detectors used. Gelman Andriy along with Hernandez Matias and Banerjee Ushnish were assigned to be the coordinators for the market research individual groups.

Michaelides Kratinos was designated as manager for the top level design. Georgiadis Giorgios was assigned as coordinator for the specification development. Finally Kassabian Ashot was assigned as human relation officer.

At this stage we also had two meetings with our supervisor to ask him any questions we had. After every member researching about the sensor they were assigned to, we had a meeting in order for each person to give a five minute presentation regarding the sensor they studied. After considering all the possible solutions we decided to have the necessary amount of sensor combinations with the highest efficiency to be used in our design.

All of us had to write about our sensors two weeks before the deadline and finally all parts were handed to the group leader a week before the deadline. These included the executive summary, market research, specification development and top level design.

Giorgios, Ashot, Matias and Kratinos were responsible to do the high level design. Editing was done by Giorgios, Andriy and Ashot while the market research report was done by Ushnish, Giorgios and Matias. Ushnish did the executive summary and in the end Ashot did the management plan (who was responsible of keeping meeting minutes). Finally everyone had a copy of the final report three days before the deadline so we could read it and then judge it. After some suggestions from almost all the members we improved and finalized the report.

In addition a mailing list was created in order to keep each member up to date. Uploads of sites which could be used in designing the solution were made. Help from communication professor and programming lecturer was sought.

Time plan

The time plan is briefly summarized in table 7.1:

Week	Session a	Session b
3	Select group members and decide to briefly research on all projects available. Voted for group leader.	Discussed the various project options and selected “Smarter Smart Lights”.
4	Split group members into smaller groups of 2. Design two different questionnaires. Assign market survey coordinators.	Decided on sensors and methods of input to research on. Preparation for market survey finalised.
5	Discuss first results of surveys. Gave 5 minute presentation of sensors. Set deadline for market surveys (end of week 6).	Brief meeting with Prof Green. Group given guidelines.
6	Meeting with Prof. Green. Discussed various solutions. Afterwards the proposed sensor combinations were chosen. Set deadline of write up of sensors (end of week).	Designed the specification development and the top level design. Divide work for the various other aspects of the project.
7	Top level design explanations were written and discussed. Alterations were made. Specification development report was also analysed.	Deadline of all parts of the project. Handed in to group coordinator. Editing of report was set to be done in the weekend.
8	Brief meeting to discuss report. Final changes on the structure.	Printing of project. Report handed in, in time.

Table 7.1

8. Conclusion

This report involved exploring the possibility of a lighting control solution based on presence detection mechanisms which would help curb energy wastage and expenditure in modern office buildings amongst other expected merits. The product was shown to be potentially marketable through the outcome of a locally conducted market survey in addition to research into the general market opportunities. These various opportunities justifying the impetus of pursuing the development of this project included several economic and environmental forces including a strong need to downsize power consumption in firms due to growingly stringent legislative measures towards energy wastage.

The market survey results suggestively demonstrated that considerable demand for presence detection based lighting management systems exist, however most potential customers will likely scrutinize the price, reliability and cost and ease of maintenance of the final product before opting to invest in it. Based on these findings, a specifications development was compiled, a number of detection sensors were considered, evaluated against one other to finally yield the best combination of sensors to fulfil the aforementioned requirements for the top-level design.

The final choice of sensors included mobile phone detection, CALS and PIR. Although the full technical description of the final design prototype is yet to be presented in subsequent reports, we hope to gain a competitive edge over existing companies in the lighting control market through our distinction of being the only one with CALS and mobile phone detection technologies in our final product. Moreover we hope to offer our potential clients a plethora of benefits from installing our product over competing lighting-management products and conventional lighting installations without lighting control.

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10. Appendix A

SURVEY A Questionnaire

Information about the office:
:

Observation time		Number of laptops used	
Observation duration		Number of people has mobile phones	
Total number of employees		Number of people using mobile phones an at given time	
Number of people present at given time		Number of people using landlines	
Total number of computers		Number of people working on paper	
Number of computers which are logged in		Number of access points of the office	

a) What sounds are produced (e.g. talking, music, keyboards, chairs moving, etc)?

b) Identify movement of people within the office (How many people move at a certain time? Do they move sitting on chairs? How often do they move? etc)

c) How often do people cross the doors 2 or more at a time (i.e. how many of them entered the door alone and how many of them entered the door at the same time for a given observation time)?

d) Identify existing lighting systems. What problems do they have?

e) How many people stay at the office after the normal office hours?

11. Appendix B

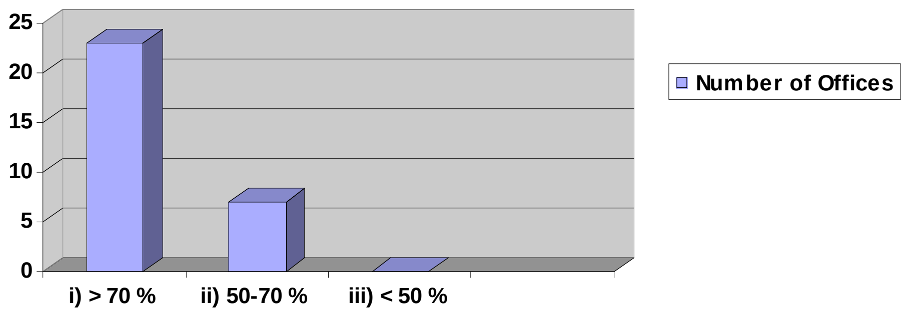
SURVEY B questionnaire

	Question	Possible answers
1	What (approximate) proportion of your work-force have access to a computer?	i) > 70 % ii) 50 - 70 % iii) < 50 %
2	At any given time are there more employees working on computers (or similar items such as PDAs) than non-electronic items?	i) Yes i) No
3	What (approximate) proportion of your work-force own mobile phones?	i) > 70 % ii) 50 - 70 % iii) < 50 %
4	What (approximate) proportion of your work-force work after-hours?	i) 1 - 10 % ii) 10 - 20 % iii) > 20 %
5	Does your office currently have any lighting control system installed?	i) Yes ii) No
6	Would you be interested in investing in a new and efficient lighting control technology which employs presence detection sensors to switch on and off (as opposed to current movement detection systems) to curb electrical power wastage (i.e. electricity bills) in your office?	i) Yes ii) Possibly iii) No, not interested
7	If interested in investing in aforementioned technology, how much would you be willing to pay for the installation of such technology?	i) < £ 150 ii) £ 150 - 200 iii) £ 200 - 350 iv) £ 350 - 500 v) > £ 500
8	How many days of the week are the lights left on the whole night? (Please allow for 3 days when lights are forgot in Fridays)	i) 1 day ii) 2 days iii) 3 days iv) 4 days v) 5 days vi) 6 days vii) 7 days

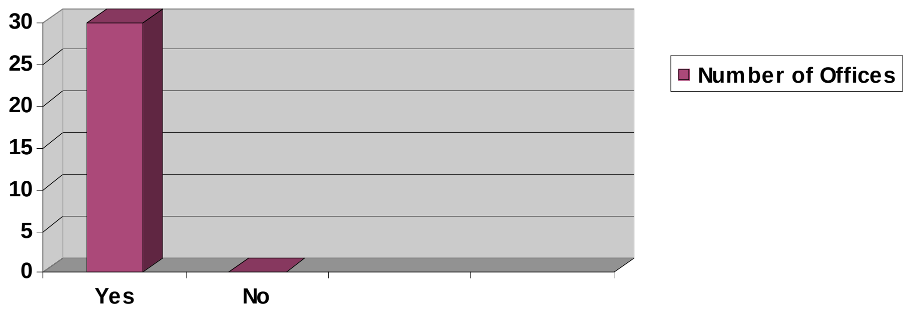
12. Appendix C

Results of Survey B

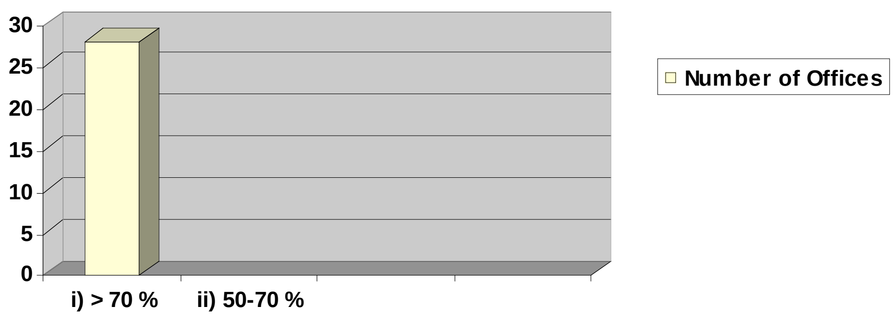
Graph 1: What (approximate) proportion of your work-force have access to a computer?



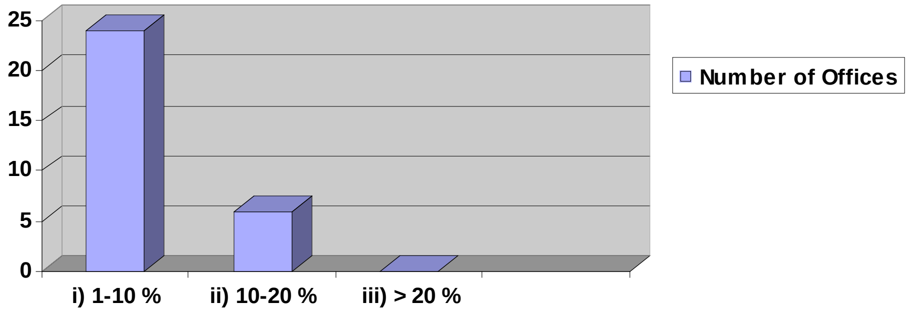
Graph 2: At any given time are there more employees working on computers (or similar items such as PDAs) than non-electronic items?



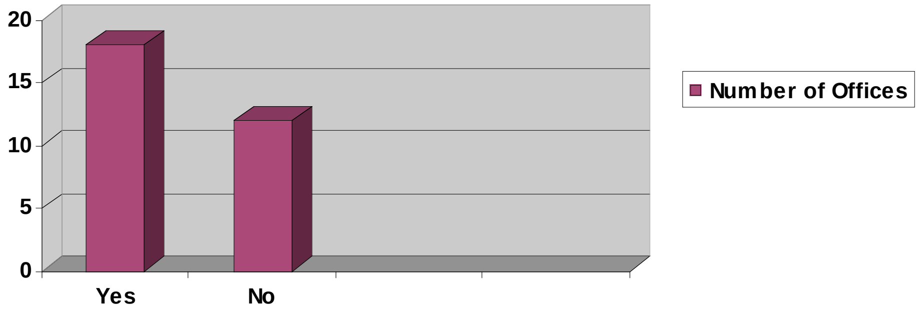
Graph 3: What (approximate) proportion of your work-force own mobile phones?



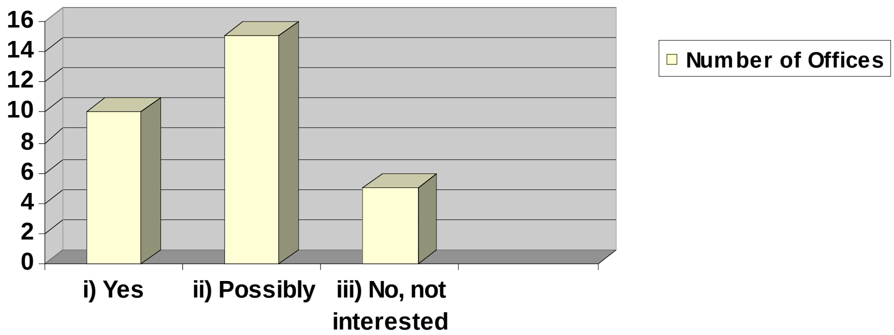
Graph 4: What (approximate) proportion of your work-force work after-hours?



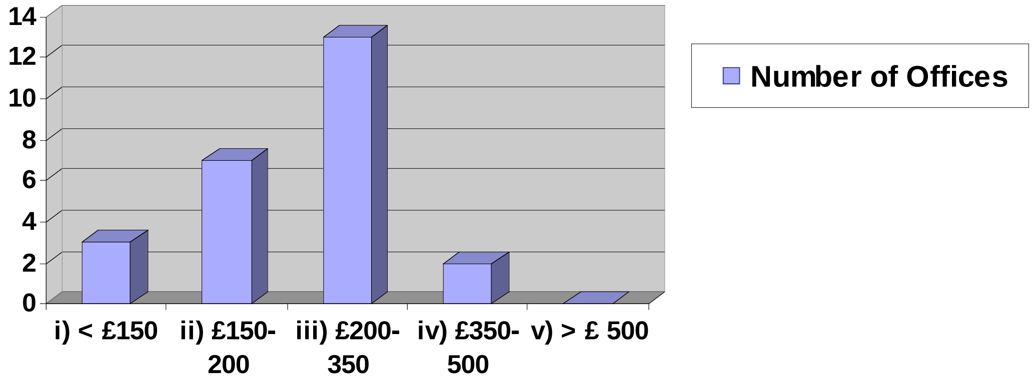
Graph 5: Does your office currently have any lighting control system installed?



Graph 6: Would you be interested in investing in a new and efficient lighting control technology which employs presence detection sensors for operation?



Graph 7: If interested in investing in aforementioned technology, how much would you be willing to pay for the installation of such technology?



Graph 8: How many days of the week are the lights left on the whole night? (Please allow for 3 days when lights are forgot in Fridays)