Vision Inspection System

Josh Grundmann, Sarah Rowland, Ashley Oulds

Advisor: Dr. Paul Weckler

Prepared for Lopez Foods

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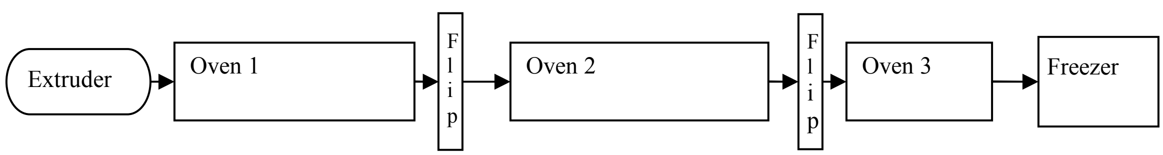
Mission Statement

GRO Engineering is a consulting group dedicated to assisting clients in solving food design and control problems. The solutions developed will increase overall production efficiency to further the client in customer satisfaction and profit.

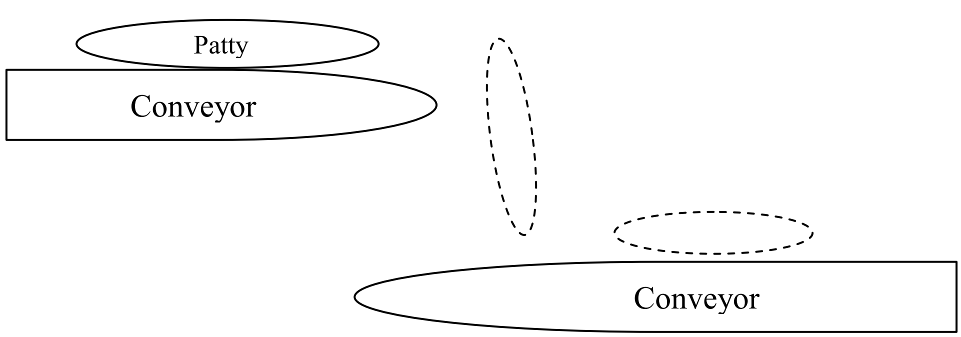
Introduction to the Problem

Lopez Foods, Incorporated provides frozen, cooked sausage patties to many large food corporations. The cooking lines for the sausage patties consist of a conveyor belt beginning at an extruder and running through three ovens to a blast freezer (see Figure 1). The patties are extruded onto a conveyor belt and proceed down the conveyor belt to be cooked then stored in the freezer until shipping.



- Figure 1 – Flowchart of sausage patty production line.

During the cooking process, patties are flipped twice to allow them to be cooked evenly by the ovens which radiate heat towards the top of the patty. Flipping is achieved by running the patties off the end of one conveyor onto another conveyor (see Figure 2).



- Figure 2 – Diagram of patty flip procedure. For a picture of flip, see Appendix 2.

The flipping method intermittently causes the delicate patties to overlap, break, or fold onto themselves (for pictures of non-satisfactory patties, see Appendix 1). If these patties are folded or overlapped, their effective thickness is twice the design thickness the oven was programmed to cook. This means the patties do not cook long enough for the center temperature to be raised enough for the meat to be considered safe for consumption. These patties must be located and removed from the cooking line before the patties are transferred into the freezer so that any bacterium which may remain in the undercooked meat is not allowed into the sterile freezer.

The current method of ensuring only quality patties enter the freezer consists of three employees stationed on each oven line to remove any defective patties from the conveyors. Two employees are located inside the oven room inspecting patties before each flip and one is in the transition room to the blast freezer to inspect the patties a final time. The working conditions for these employees can be very harsh. Previous work by Thermal Solutions showed the oven room can reach temperatures of 120°F, but it is much warmer next to the ovens. The transition room is about 40°F, but it is much cooler next to the openings to the blast freezer. Lopez Foods, Inc. hopes by installing a computer-operated vision inspection system it will be unnecessary to have employees working in such conditions.

Statement of Work

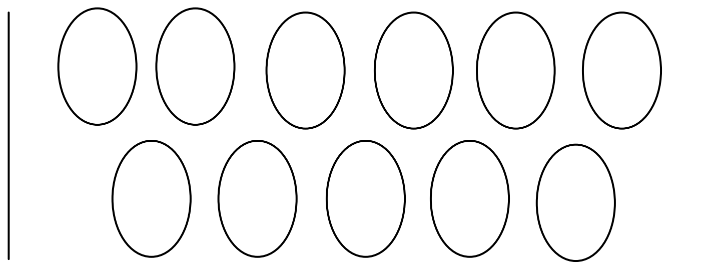
Project Definition

GRO Engineering should provide to Lopez Foods, Inc. an inspection system which will identify all products which are defective in perimeter, shape, and color. This system should be easily cleaned, able to withstand the environment of oven and freezer transition rooms, work in the space allotted, and adapt to various situations and products. A vision system will increase safety to consumers, accuracy of removal, and create better working conditions for employees.

Software

For this project, we must obtain a software package capable of identifying from an image patties of different shapes and sizes and locating the position of the patties on the conveyor (see Figure 3). This software should be provided by a company with a reputation of good quality assurance and technical support to assure that Lopez will be able to run the program effectively in the future. In choosing the software, we must consider the compatibility to the image capturing hardware. To implement this system, we will program all of the steps needed to capture and analyze an image of each row of patties including quality tolerances for each patty. We also will determine a way to trigger the camera to take an image of the randomly placed patties.

The software we choose must be able to connect images from as many cameras as necessary to "see" the whole width of the conveyor. The program must be able to discern the location of as many patties as may appear in that section of the belt at any one time and their shape. Software will also need to have the capability to pinpoint and communicate the location of patties on the moving conveyor to a controller to remove defective patties.



- Figure 3 – Ideal Patty Placement on the conveyor

Hardware

The camera(s) we choose for the system must be compatible with the purchased software package. Because of the necessary washing of the production area and the harsh conditions, it will probably be necessary to design a shield for the camera.

Implementation of the camera system includes determining the amount of space available to implement our system and constructing a bracket to hold the camera with an acceptable view of the conveyor. We will determine the material type for the conveyor which provides the clearest image while maintaining oven safety standards. Additionally, we will investigate the requirements for illumination.. This system should also include a controller for a rejection system to remove the non-satisfactory patties from the line based on the information given from the software. Because there are several oven lines in the Lopez Foods plant, these vision inspection systems should be easily reproduced and fitted for each cooking line in the factory.

Market Research Review

GRO Engineering reviewed many types of software and hardware while researching prospective suppliers. In this record were software providers, hardware manuals, and an overview of the BAE vision lab, Vision Systems Design Magazine, and presentations by sales representatives from Banner Engineering Corporation, Texonics, and Omron. These methods are the most effective in obtaining information about the ever-changing vision inspection industry. Patents and research papers were consulted and searched at length, but because of the specific nature of vision systems, there were no resources found in these sources which will be of use to us on this project.

Banner Engineering Corporation Presentation

On October 23, 2006, we were able to have a workshop in the BAE computer lab pertaining to all the software and hardware from Banner for vision inspection. We were presented with software and hardware possibilities and were interested to see a vision system programmed to run. A Banner representative, Mr. Glenn Haueter, presented the workshop where he constructed a system to analyze several aspects of a target that was much like a piece of cooked sausage.

The P4 Omni hardware system is made by Banner Engineering and is capable of working in the conditions in our problem statement because it will only have to work at about 1.5

Hz, according to our measurements of the speed of the conveyor. At this rate the system will have enough time to make a full analysis of each patty to obtain a pass or a fail signal from the machine. Mr. Haueter brought to our attention that a huge issue with any vision analysis is the lighting system. He said the lighting accounts for about 70% of the success of any vision system, and colors of emitted light are also important to the success of the machine. Mr. Haueter mentioned that a triggering mechanism would be required so that the computer would know when to grab an image and not continuously take pictures.

Banner's software seems very easy to program and to use, and it would not be necessary to write code with this program. Specific image analysis tools in the software will be most important to analyze a sausage patty for roundness and size. The first is a "locate tool", which finds the target in the field of view of the camera. In our case it might look for the left edge of the patty, and when found, it will find the bottom edge relative to the left edge. Everything in the analysis will be relative to the edge it is programmed to find first rather then to a specific place in the picture so that the patty can be found no matter where it appears in the image. The locate tool finds an object in the picture, but the object still needs to be analyzed.

The "edge tool" is the fastest way to analyze an object. This tool finds where the lighter background stops and where the darker patty begins. It can also be used to find where the patty stops on the other side, and, using this information, calculates the diameter of the patty. While this is not useful in one dimension, when several edge tools are used to find multiple diameters at various angles, it gives an idea of the roundness of the object.

A second tool for analyzing the patty object is the “BLOB tool”, short for Binary Large Object. It essentially finds the object, changes each pixel into a black or a white one, based on programmed tolerances of lightness and darkness, then counts the black pixels within the space. This count can be compared to programmed tolerances to determine if the patty is large enough to be a whole patty (not torn or folded over) and if the patty is small enough to not be two overlapping or touching patties.

The third useful analysis tool for this system is the “geo tool”, which will actually recognize the shape of a circle and then analyze both the diameter and area along with other constraints. The geo tool takes longer to run than the edge or BLOB tools, but the speed of the conveyor belt would probably allow us to use it. In this application it is probably feasible to use the BLOB and edge tools together to analyze the patty.

The total Banner package is about $2500 per camera system, and we may need two or three of them at each inspection point due to the width of the conveyor belt and the flow rate of the patties. Our main concern with the Banner package is the system’s apparent lack of ability to conjoin pictures from multiple cameras.

Texonics Presentation

On November 9, 2006, Mr. Chaital Shah, a graduate of the BAE department of Oklahoma State University, met with us to discuss hardware and software available through Texonics, Inc. We received many pamphlets with products including hardware and software packages. The pertinent software from Texonics is NetSight, a basic program with similar tools to the Banner software. We have received trial versions of these programs, but in testing them have discovered that they are not very user friendly which is crucial to our final design. Texonics is also a supplier of hardware such as laser triggers.

Omron – F-series Vision Sensors

There are several packages in this line of vision automation products. The F150-2 Vision Sensor looks like a program that could fit our software needs. It uses drop-down menus to set up functions including filtering; adjusting the shutter speed; background suppression; X, Y, and Theta position compensation; and image calibration. Measurement tools include area, edge position, edge pitch, degree of defect, and more. With this program, there are options for 16 setup scenes and up to 16 measurements per scene. The F160 is one step above the F150 and allows for two cameras.

Omron Presentation

On November 14, 2006, our group met with Mr. Louis Watts of Omron Electronics. During this meeting, we were able to explain our problem and our goals for our project to Mr. Watts. He explained the vision inspection tools available through Omron including their F-series packages. From previous research, we determined the F150-2 Vision

Sensor may supply a solution to this problem. During our discussion with Mr. Watts, we were informed there may be a more appropriate system available through Omron. Our group provided Mr. Watts with information he could take to his engineers so they could determine whether or not Omron had a software package capable meeting our requirements.

National Instruments – Vision Builder for Automated Inspection

This software works with analog, digital, or FireWire cameras which means we are free to connect it to a camera which meets all of our specifications. There is no programming required. Vision Builder can be tested offline with a downloadable trial version of the software. The menu-based program can be used for color or black/white inspection. It is capable of locating and analyzing multiple objects. National Instruments is a well-known company and seems to be very user friendly. The price for this software is $1499.

FSI Automation – XCaliper

This system can be connected to outside image capture devices. Teach tools allow users to program calipers, various edge locators and blob analyzers, all of which could be compatible to the Banner software. It can locate several blobs on an image. The XCaliper program can also analyze patches of color on an image.

Vision Systems Design Magazine

Vision Systems Design Magazine is a publication that showcases up-to-date hardware and software of vision systems, and also shows practical applications of these systems.

Illustrations and name-brand advertisements gleaned from this resource are very useful. The pictures give us a view of what others have done with respect to design of vision systems, and the advertisements have allowed us to know the major hardware and software systems on the market with an idea of price ranges. The screenshots of the software are helpful in finding a suitable program with an easy interface that is robust enough to meet our needs. For the purposes of general knowledge and for gaining names of possible software and hardware distributors, Vision Systems Design Magazine is very useful. Reading the articles allows us to know that there is a solution to our problem, simply because others have applied this to very similar engineering problems.

Hardware Manuals

With a vision inspection system, it is necessary to have both a software package and compatible hardware. Edmund Optics publishes an optics and optical instruments catalog. This catalog includes various pieces of hardware that may be needed for a vision inspection system such as illumination systems and color or monochrome analog cameras. Not only does the catalog have pictures and descriptions of each piece of hardware, it also includes pricing information for most of the inventory displayed in the catalog.

BAE Vision Lab

In addition to presentations and magazine reviews, the facilities and equipment available in the Biosystems and Agricultural Engineering (BAE) Vision Inspection Laboratory at Oklahoma State University are available to us. On October 5, 2006, our group was able to schedule a time with Dr. Weckler to tour the BAE Vision Lab. During this tour, we were introduced to the hardware that the department has already purchased for research in the field of vision inspection. The BAE Vision Lab has many different cameras available for use in our preliminary testing of vision inspection software. The cameras available use both analog and digital output allowing our group to be able to customize our system to the specifications deemed necessary. Our tour concluded with a discussion on how digital images are transferred into binary numbers which in turn are outputted into the image that we see. From this tour, GRO Engineering decided to test our inspection system using the hardware found in the BAE Vision Lab and a software package purchased through a commercial vendor.

Customer Requirements

The vision system provided will need to meet many requirements as specified by Lopez Foods. These requirements include the following capabilities:

1. Determine the quality sausage patties from defective patties based on patty thickness, diameter, and eccentricity.
2. Locate multiple randomly placed patties on moving conveyor.
3. Track defective patties on moving conveyor.
4. Communicate with defective patty rejection mechanism.
5. Easily cleaned with water.
6. Resistant to large temperature and humidity ranges.
7. Have a very high success rate.
8. Be easily reprogrammed.

9. Fit into allocated space.

10. Possibly recognize color patterns of the patties.

11. Inspect patties at least at Oven 1 and Oven 2 positioning.

Engineering Specifications

The following are specifications for the system as required by Lopez Foods:

Target Diameter	3.75 +/- 0.25 inches
Target Thickness	0.400 +/- 0.05 inches
Conveyor Speed	1 row of patties per second
Conveyor Width	30 inches with 7 inch dead space on either side
Lens working distance	1 meter (42° of view)
Lens field of view	750 mm

The camera used should communicate with the processor via Firewire for fastest processing time. In addition, the camera will be mounted in the oven rooms where temperatures can reach up to 120°F. Because of this element, our camera needs to be able to operate at temperatures above 120°F to ensure accuracy and safety.

It is imperative that the camera lens stay clean. During our second trip to Lopez's facilities, the conveyor system, including grease splatter, was measured and photographed (see Appendix 2). In addition, the patties' positions on the lines were measured and photographed, and the environment inside the oven room was reassessed.

Measurements show grease splatters only a few inches above the conveyor belt height. For information on the space available for the camera and bracket, please see Appendix 2.

A second discussion with the quality control personnel at Lopez revealed that the most important inspection points are before the first flip located after Oven 1 and after the first flip to ensure the patties cook correctly in Oven 2. It is not required for the patties to be inspected on the Oven 3 conveyor since Oven 3 does not do imperative cooking.

Preliminary Design Concepts

The camera system for the design will include several components. A good image requires a good light source to illuminate the product's features and allow the picture that the camera receives to be bright and clear and without glare. An ideal camera will be able to look at the entire width of the conveyor line with a high enough resolution so that good product can be easily distinguished from bad. The lens should allow the camera to be a reasonable distance away from the product—far enough away to see the whole width but close enough that no photo distortion effects occur.

The processing system can be a personal computer with a monitor or it can be a control box that only contains the algorithm for pass/fail. This processing system, once it has determined quality, must then have outputs that convey the verdict to a rejection device further down the line. This system must be fast enough to process all patties before the next row passes the camera.

The guidelines or algorithm for the processor are custom to the job, but basically all include product location, some kind of measurement, and a pass/fail statistic. The location part depends on the processor finding the product's edges on the image and creating a reference point from there. A measurement then takes place, where the computer either calculates the area, the diameter, or the aspect ratio of the product to make sure that it is within the specified bounds. Lastly, it will give each product a pass or fail rating based on the measurements and location and will deliver the coordinates of the product to the rejection system. Our processor unit will likely be positioned outside the oven room, so heat and humidity tolerance need only be assessed for the connecting cables.

The inspection surface is also very important. It must be kept clean because debris will confuse the algorithm which cannot distinguish debris from patties. In the Lopez situation, a clean surface is also necessary for health inspections. The surface should also be an appropriate color so that the product can be easily distinguished from the background.

Evaluation of Designs

Several options exist for the actual design of the vision inspection system, one of the most important being software selection. Through the internet, magazines, and advice from professors and industry experts, we narrowed the vast field of vision inspection software to a few products which seemed suitable for our application. Please see the information in the Market Research Review section of this paper for information about the products we considered in depth including packages from Banner, Texonics, Omron, FSI, and National Instruments.

The first question in the design was whether or not to add a new conveyor to the system. This would be expensive and require a rearrangement of the ovens, but would also allow for a consistent background color and speed for the patties. With a proper cleaning mechanism, it would ensure an environment that is in the best interests of successful product inspection. The alternative to this would be to capture images of the patties on the wire rack belt without adding a new conveyor. The wire rack is a difficult hurdle for a vision system, and the darker background underneath makes it even more difficult for the patties to be found against the shadows. The third option is a solid color background very close to the wire conveyor to minimize background noise and make it unnecessary to add a conveyor to the system.

We considered several methods for triggering the camera. A trigger allows the camera to take a picture only when the patties are passing in the field of view, making sure the patties are always in the same place for the camera. Laser triggers could be incorporated so that the camera snaps an image a certain time delay after a laser beam is broken. An alternative to this is a mechanical trigger, with plastic or metal "fingers" touching the conveyor surface and being deflected by a patty moving down the line. A third alternative is to set the trigger on a time lag with the extruder's signal. Every time the extruder makes patties, a time delay occurs and the camera takes a picture after a time depending on the speed of the conveyor. A final alternative is to set the camera rate at a high speed, and allow it to find the patties on its own. This will require much more processing power.

The next decision is the positioning of the controller. Since the oven room is very hot when in operation, the controller's vulnerability to heat was in question. One alternative is to place the controller in a climate-controlled box or to have plenty of cooling around it. The other option is to extend the wires to the controller and to place it outside the oven room in a moderate temperature and humidity environment.

Finally the question of where to place the cameras arises. There will be more than one camera so the patties can be inspected on both sides. There may also be a camera in the transition room en route to the freezer to check the second flip. The guiding factors in the placement decision are the placement of a future rejection device and available space.

Final Design

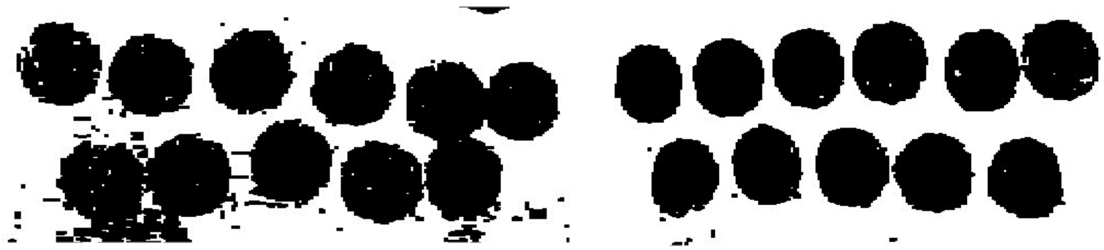
With the alternatives for each design decision in mind, the issues were addressed. After using trial versions of several software packages, meeting with representatives from several software companies, and not receiving replies from several companies, we decided that NI Vision Builder AI 3.0 will be the best fit for the Lopez system. The company has a good reputation for being competitive and having good customer service. The system can do everything we have specified above including connecting to a variety of different cameras and connecting to multiple cameras at once. It is robust enough to handle the job and carries a reasonable price tag (see Proposed Budget).

The design uses a Sony XCD-X710CR Camera . This new digital camera can work at up to 30 frames per second, has 1024 x 768 resolution, and can handle color processing. It can be triggered externally and connected by Firewire (IEEE 1394) to the processor. The durable design has high shock and vibration resistance and is quite small. The C mount makes it easily attachable to the frame. It is compatible with most lens and works in a wide range of light. (For more about the camera, please see the specification sheet in Appendix 5.)

The downside to the Sony XCD-X710CR Camera is that, like most digital cameras, it has a maximum operating temperature is 113°F. The cameras on the oven lines need to be able to operate continuously at ambient temperatures of over 120°F. From conversations with Lopez managers, we feel it is necessary for the system components to be operable to 150°F in order to perform well at 120°F. Since we could not find a suitable camera that operated in the oven room temperature range, we were forced to determine a way to cool the camera. A refrigeration system, circulating cooled air, and thermoelectric coolers were three methods considered for use in cooling our camera. The chosen cooling method is expanding compressed air. Compressed air will run through a filter and regulator then a vortex tube cooler into a small Plexiglas box. Baffles will cause the air to circulate around the camera then exit into the room through openings around the lens. The outflow of air will help to whisk away from the lens humidity and grease particles in the ambient air. (For more about the cooler, please see the specification sheet in Appendix 5.)

The lens is a Varifocal lens produced by Tamron (Model # 12VM412ASIR). This lens has an imager size of ½ inch, horizontal angle of view range of 31.2° to 93.7°, and has a C Mount. From our calculations, our lens needed an angle of view of approximately 42°. This angle of view is well within the Tamron (Model # 12VM412ASIR) lens' capability. (For more specifications of the lens, please see the specification sheet in Appendix 5.)
The light source is an ultra-bright, broad area flood, high-power LED linear array from Illumination Control, Inc. The company is easy to work with and constructed the array specifically to handle the high temperatures around the ovens. The 36 inch array has one row of white LEDs. One array will illuminate the entire width of the conveyor and the durable construction means it should perform well in the harsh environment. (For more specifications of the LED array, please see the specification sheet in Appendix 5.)

In our testing we determined a white background material just underneath the wire conveyor provides for enough clarity to allow the program to accurately process images. Images with and without a background were processed and shown in Figure 4. The conveyor should run as close to the background as possible to eliminate shadows. Using the white background eliminates the need for a separate section of conveyor to be installed. We recommend a white plastic background mounted as close to the wire rack as possible under the entire view of the camera.



No Background White Plastic Background

- Figure 4 – Comparison of Background Interference

The bracket designed to hold the camera and light source is shown in the User's Manual in Appendix 4. The bracket design will have to be modified by Lopez to fit the specific place where the camera system will be installed over a line. The bracket is designed to be removed at the end of the day for wash down. This will eliminate the risk of damage to electrical components from cleaning procedures.

The trigger for the camera shutter is connected to a photoelectric eye (Banner World Beam Q12). The eye is positioned so that a patty on the conveyor belt breaks the beam. The eye then sends a signal to the camera. The camera then sends the image to the processor. (For more detail about the photoelectric eye, please see the User's Manual in Appendix 4.)

The NI Vision Builder program written by GRO for patty inspection has several steps. The full program written by GRO to analyze patties can be found in the User's Manual in Appendix 4.

In considering placement of the processing unit, we determined the best place is outside the room. Research showed that time lag in the wires will not be an issue for this distance of only a few meters. Another positive outcome of placing the controller out of the room is it will be next to all other controllers for the rest of the facility. In addition, the processing unit will not be subjected to the high temperatures found in the oven rooms.

The placement and number of the cameras depends purely on necessity as determined by Lopez managers. Since cameras are expensive and will each require processing time, it is imperative to have as few as possible, while ensuring product quality. Our plan for now is to design a system with two cameras: one inspects the patties before the initial flip and one shortly afterward before the patties go into the second oven. This will allow space for a rejection mechanism on the other end of or in the middle of the second oven. Also, the system designed to work between the two large ovens can be reproduced and placed anywhere else deemed necessary.

Though the patties are flipped again on their way into the third oven, this oven is only for reheating uses to obtain a certain color and to guard against the problem that we will solve with the vision system. With the system in place and functioning, all failed patties that were overlapped or defective will have been removed by the time the product reaches the third oven.

Analysis of Design

In order to determine the accuracy of our design, we performed various statistical analyses. Type I errors for this analysis result only in loss of efficiency by increase in rework. Type II errors result in unsatisfactory, or partially uncooked, patties reaching the packaging section of the plant. First, we tested our program to determine if it could recognize and accept single satisfactory patties. Rows of five or six single acceptable patties were placed onto the running conveyor belt. The patties were then passed through the photoelectric eye which triggered the camera to snap an image of the patties. The image then ran through the program written by GRO in the NI Vision builder program. The program identified whether the patties were satisfactory or unsatisfactory. Out of 185 satisfactory patties, the program located and correctly identified 100% (185) of the satisfactory patties.

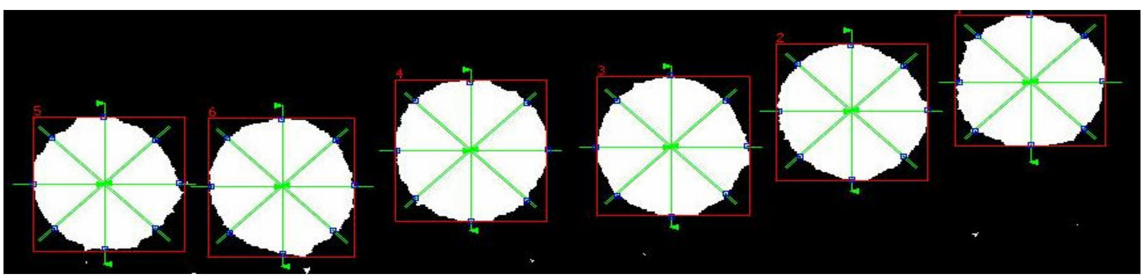


Figure 5: Correctly Identified Single Acceptable Patties

Next, the patties were arranged so that the edges of the patties were touching, but not overlapping. Sets of each of these patties were passed through the vision inspection system. Out of 109 sets of two satisfactory touching patties, the program located and identified 95.41% (105 sets) of the satisfactory patties. The program identified four sets of touching patties as unacceptable which was 4.59% of the sample size. This is Type 1 error and can easily be corrected by adding more examples of two touching patties to the classifier (see the User's Manual in Appendix 4 for more information about the classifier).

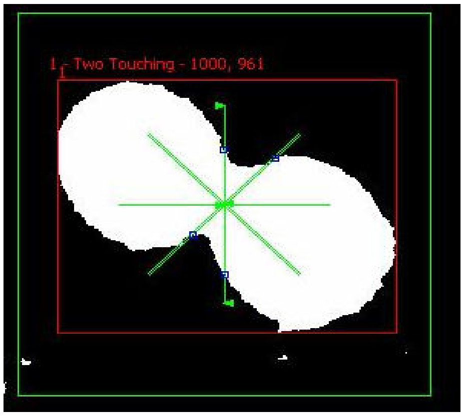


Figure 6: Two touching satisfactory patties identified by program

After testing two touching satisfactory patties, our group tested the program with overlapping patties. Out of 96 sets of unsatisfactorily overlapping patties, one set (1.04%) was passed. This is a Type II error which could be remedied by further training of the classifier.

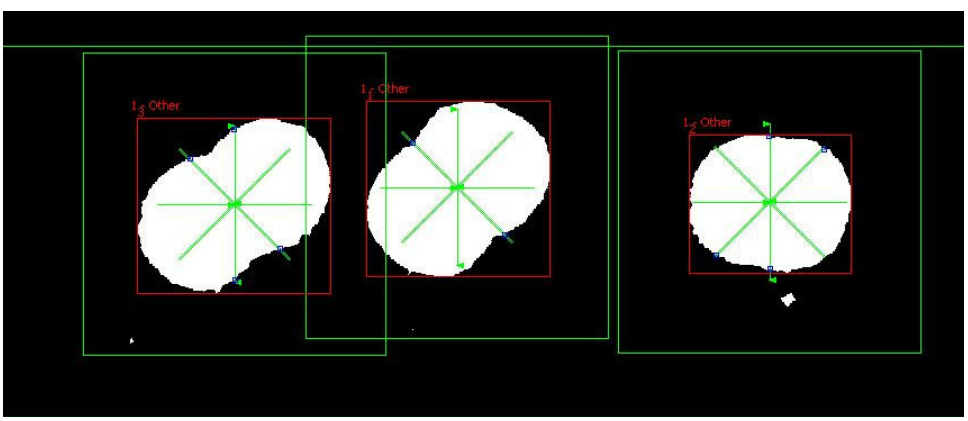


Figure 7 – Three sets of overlapping patties that were deemed bad by program

Bad patties such as those seen in Appendix 1 had a 97.80% correct rate. The patties causing the Type II errors were patties which would likely never occur in the production line. However, the percent correct could be increased by adding more diameters in the Measure Each Object state of the program.

Two touching bad patties caused a low percent correctly identified because when the bad sides are towards each other, it is difficult to distinguish them from two good touching patties. Further training of the classifier should remedy this unlikely problem.

Category	**Correctly Identified**
Single Acceptable Patty	100.00%
Two Touching Patties	95.41%
Overlapping Patties	98.96%
Single Unsatisfactory Patty	97.80%
Two Touching Unsatisfactory Patties	81.82%

Table 1: Program Accuracy Statistics

Budget

Proposed Budget	
Component	**Estimated Cost**
Processing Unit (for now we can use a desktop)	$2000
White Background	$100
2 Cameras	$2000
Software Package	$1500
Cables	$200
2 Lens	$400
Holding Bracket	$100
Laser Trigger	$200
Lucite Shielding Box	$100
Total	$6400

Our proposed budget for installing our system on a single conveyor line was approximately $6400. However, we did not take into consideration that the camera system would have to be cooled in order to operate properly in the oven room. Another consideration for our vision inspection system was lighting. In order for our system to work accurately, adequate lighting must be provided. With the addition of cooling and lighting systems, the actual cost of our project without the processing unit and white background is $5133 without the processor or background. This is shown in further detail in the table below.

Actual Budget	
Component	**Estimated Cost**
Processing Unit (for now we can use a desktop)	Variable
White Background	Provided by Lopez
Camera	$1624
Software Package	$1500
Lens	$153
Laser Trigger	$70
Lighting	$1388
Vortex Cooler	$149
Filter	$49
Bracket and Camera Housing (approximate)	$200
Total	**$5133 + Processor and Background**

Conclusions

The automated vision inspection system designed by GRO will meet the need of Lopez Foods, Inc. to take the burden of inspecting each patty off of the employees. With more training of the classifier upon installation of the system on the conveyor line, it should achieve nearly perfect accuracy. Further work in developing a rejecter mechanism will finish the solution.

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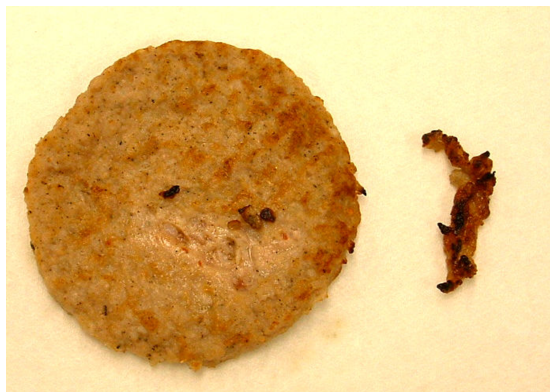
- Craig Trible – BAE Information Technology
- Mike Veldman – Electrical Support
- Wayne Kiner – BAE Laboratory Manager

Appendix 1 – Non-Satisfactory Patties

Overlapped patties causing undercooked crescent-shaped piece.



Meat scraps on patty. Scraps burn from being too close to oven and cause undercooked place on patty.

Patty folded over. When unfolded, reveals undercooked meat.

Bad patties used for statistical analysis.

Appendix 2 – Space for System

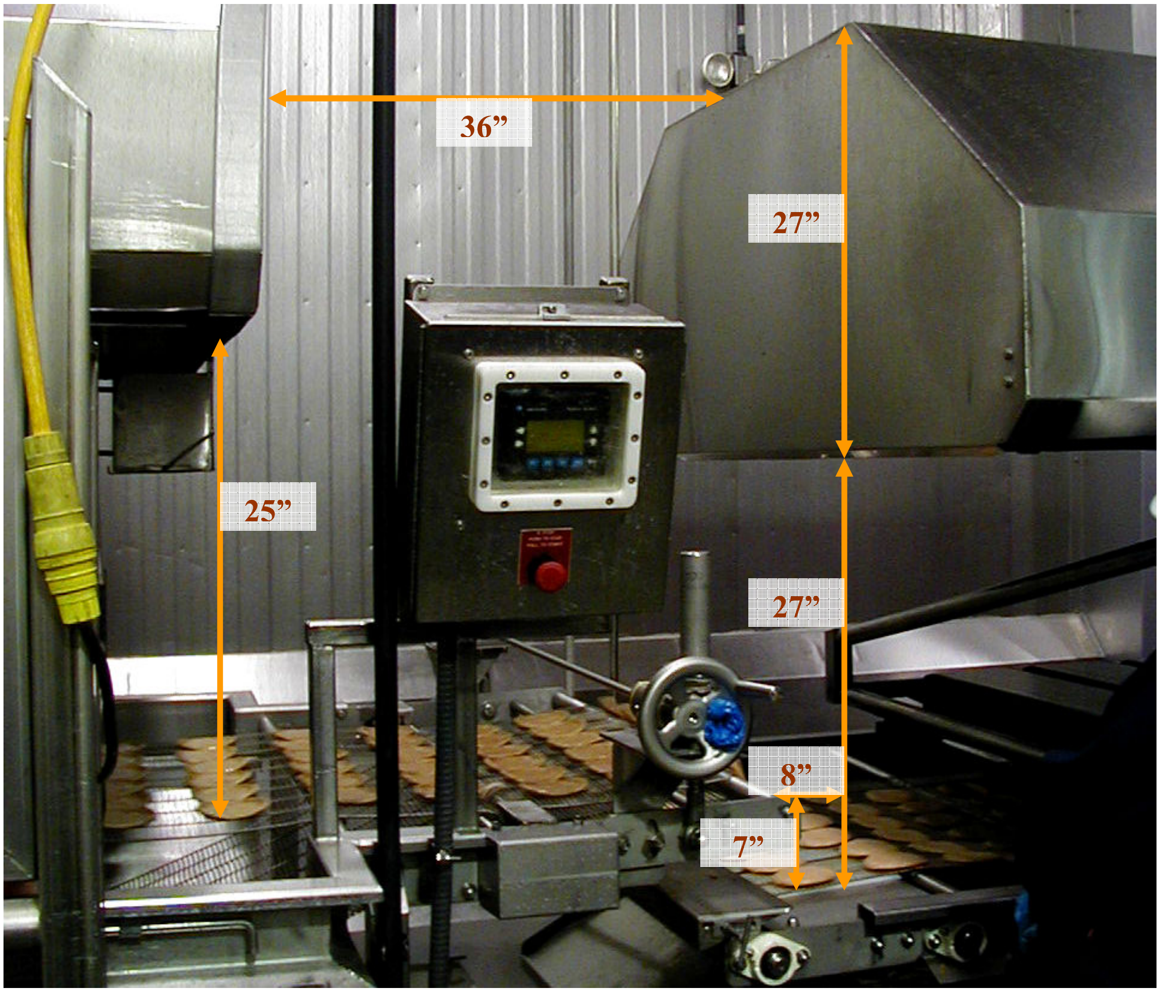


Diagram of section of conveyor where the patties are flipped.

Appendix 3

Task List for Semester

- Modeling
  - Develop a model of oven lines
    - Obtain space in the BAE Lab
    - Have model of the oven lines built
    - Obtain patties from Lopez to use as models
- Research
  - Find a software system that will effectively meet the needs outlined in our mission statement
    - Meet with sales representatives from possible providers
    - Determine the three most likely systems
    - Present findings and our recommendations to Lopez
    - Gain Lopez's consent to purchase software
  - Find hardware that will work in conjunction with software that will meet the needs as defined in our mission statement
    - Determine the software system's compatibility with hardware
    - Check for hardware in the BAE Lab
    - Purchase hardware if needed for simulations
    - Buy hardware for Lopez with their consent
- Simulation
  - "Teach" software
  - Test inspection system on model images
    - Run the vision inspection on model lines to test for accuracy
    - Develop ideas for improving accuracy
    - Obtain samples from Lopez to use in testing
      - Test on actual samples
- Experiments
  - Set up inspection system at Lopez
    - Set up inspection software and hardware
      - Develop any necessary housing for hardware
      - Have housing built (if needed)
  - Test inspection system on running line
  - Develop ideas for improving accuracy
  - Implement new ideas
- Physical Testing/Data Collection
  - Obtain the quality control information from Lopez
- Purchases
  - Vision Inspection Software
  - Hardware (possibly)
  - PLC (possibly)
- Travel:
  - Lopez Foods
  - See Software in a production setting (possibly)
- FAPC/BAE Lab Resources
  - Vision Systems Lab
  - Camera Equipment
  - Space for modeling oven lines
  - Check to see if there is any type of conveyor we can use

Project Schedule

Task Name	Duration	Start	Finish
Visit Lopez	**1 day**	**Fri 2/2/07**	**Fri 2/2/07**
Make presentation	1 day	Fri 2/2/07	Fri 2/2/07
Ask about trigger	1 day	Fri 2/2/07	Fri 2/2/07
Request Patties	1 day	Fri 2/2/07	Fri 2/2/07
Request Conveyor Piece	1 day	Fri 2/2/07	Fri 2/2/07
Research	**6 days**	**Mon 2/5/07**	**Mon 2/12/07**
Camera	**6 days**	**Mon 2/5/07**	**Mon 2/12/07**
Color Vs. Black and White	3 days	Mon 2/5/07	Wed 2/7/07
Decide on Camera to recommend to Lopez	3 days	Thu 2/8/07	Mon 2/12/07
Lighting System-Best Colors	1 day	Mon 2/5/07	Mon 2/5/07
Look and decide on Trigger	5 days	Mon 2/5/07	Fri 2/9/07
Processing Units	5 days	Mon 2/5/07	Fri 2/9/07
Shield Material for protecting camera	5 days	Mon 2/5/07	Fri 2/9/07
Meetings	**5 days**	**Wed 2/7/07**	**Tue 2/13/07**
Safety Meeting	1 day	Wed 2/7/07	Wed 2/7/07
Lopez	**1 day**	**Tue 2/13/07**	**Tue 2/13/07**
Pick up conveyor	1 day	Tue 2/13/07	Tue 2/13/07
Pick up Photo Eye	1 day	Tue 2/13/07	Tue 2/13/07
Pick up scrap patties	1 day	Tue 2/13/07	Tue 2/13/07
Present Final Budget	1 day	Tue 2/13/07	Tue 2/13/07
Present Camera, Trigger,Shield Material	1 day	Tue 2/13/07	Tue 2/13/07
Obtain permission to purchase	1 day	Tue 2/13/07	Tue 2/13/07
Purchasing	**8 days**	**Thu 2/15/07**	**Mon 2/26/07**
order camera	1 day	Thu 2/15/07	Thu 2/15/07
order trigger	1 day	Thu 2/15/07	Thu 2/15/07
order processing unit	1 day	Thu 2/15/07	Thu 2/15/07
order material for shield	1 day	Thu 2/15/07	Thu 2/15/07
wait for materials to arrive	7 days	Fri 2/16/07	Mon 2/26/07
Programming/Fabrication	**16 days**	**Tue 2/27/07**	**Tue 3/20/07**
Put system together	2 days	Tue 2/27/07	Wed 2/28/07
Finish developing program	14 days	Thu 3/1/07	Tue 3/20/07
Develop Camera Housing	3 days	Tue 2/27/07	Thu 3/1/07
Program working completely	**14 days**	**Wed 3/21/07**	**Mon 4/9/07**
trouble shoot program	7 days	Wed 3/21/07	Thu 3/29/07
analyze efficiency	7 days	Wed 3/21/07	Thu 3/29/07
analyze color recognition	7 days	Wed 3/21/07	Thu 3/29/07
miscellaneous problems	14 days	Wed 3/21/07	Mon 4/9/07
Final Presentation	**7 days**	**Tue 4/10/07**	**Wed 4/18/07**
Collect all research data	2 days	Tue 4/10/07	Wed 4/11/07
write report	5 days	Thu 4/12/07	Wed 4/18/07
Create Powerpoint presentation	5 days	Thu 4/12/07	Wed 4/18/07

Appendix 4 – User's Manual

NI Vision Builder AI Program

This program consists of several steps called states. Each step contains tasks performed in that step. Steps are organized into a flow chart with connectors that represent transitions to the next step in the program (see Figure 1). Transitions are either default, meaning the logic follows that path unless told to do otherwise, or activated when a certain condition is met. Default connectors cannot be edited. Other connectors can have names and transition activation conditions edited by double-clicking on them.

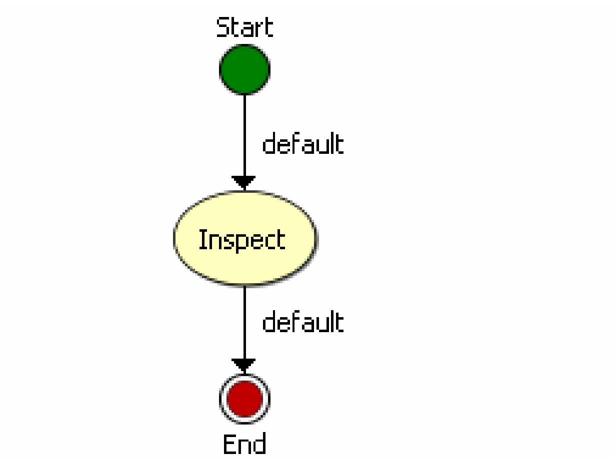


Figure 1 – Basic flow chart with one state, Inspect.

Outputs from tasks can be accessed by other steps in that state, but tasks in other states cannot. Global variables can be created and used in all states.

The startup window for NI Vision Builder (see Figure 2) gives users the opportunity to either configure an inspection process or run an inspection. For editing the program, go to Configure Inspection. In the configuration part of NI Vision Builder, the program may be run through once by clicking the green arrow pointing to 1 or run continuously by clicking the looping green arrows until the stop sign is clicked. The green arrow pointing to the red X will run through the inspection until failure.

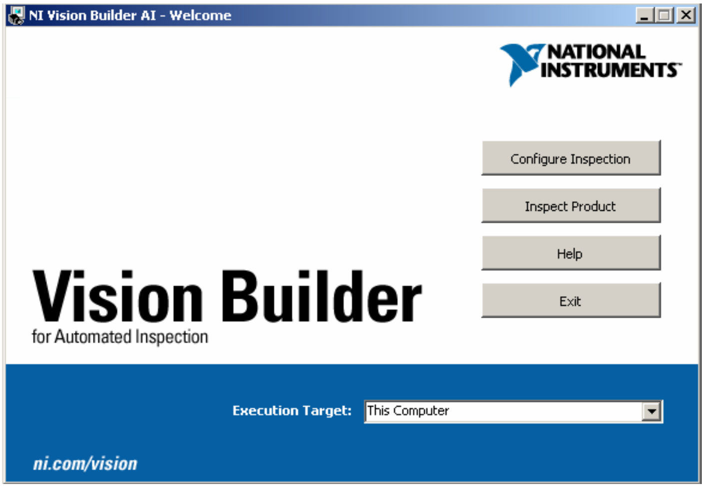


Figure 2 – Start up window.

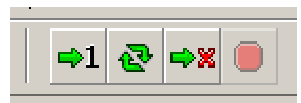


Figure 3 – Buttons for running inspection.

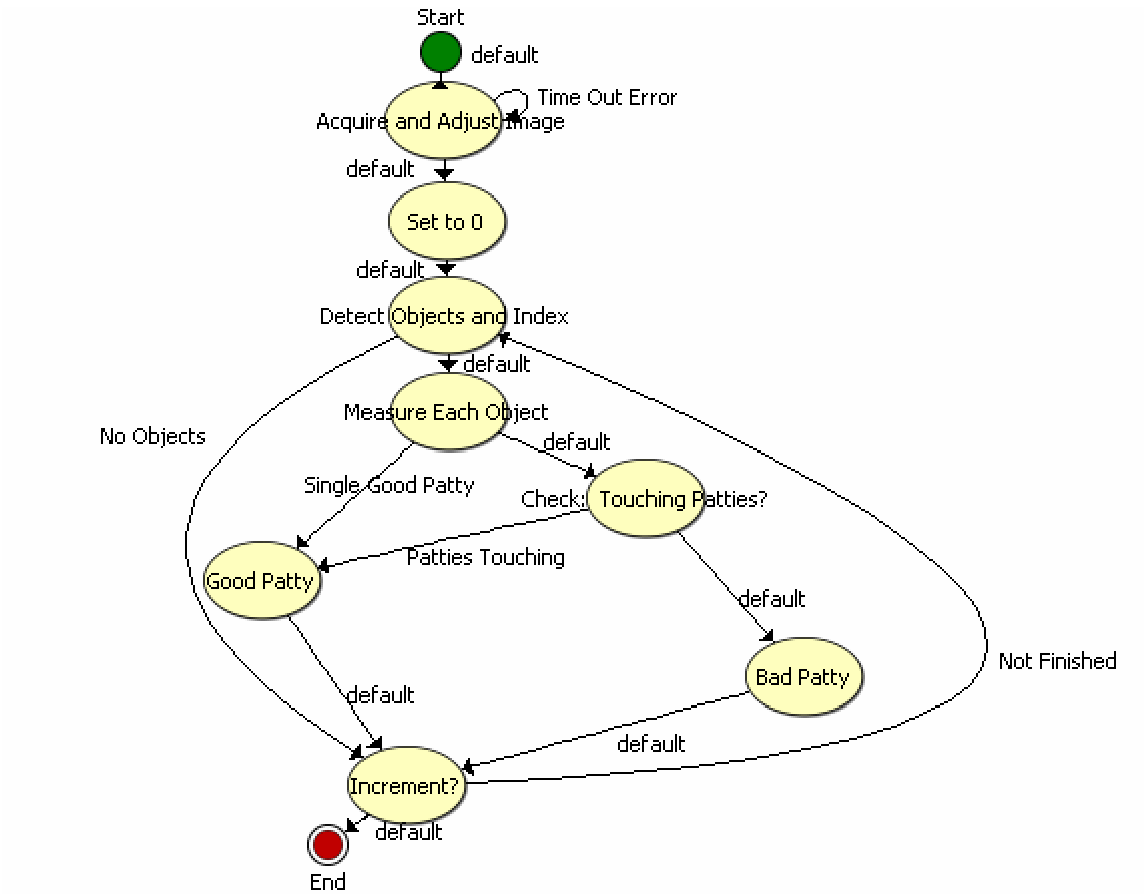


Figure 4 – Flowchart of patty inspection program.

The flowchart of the program GRO created for Lopez is shown in Figure 4 with all of the transitions and states. The first step is Acquire and Adjust Image. The first task in this step communicates with the selected camera to capture an image. The trigger can be used to send an image or an image can be captured whenever the task is activated. For online inspection it is best to have the trigger on in Mode 0 with a short timeout and the transition after a timeout error looping back into the Acquire and Adjust Image state.

The Vision Assistant task is next in the same state. First it extracts the red plane. Then the threshold sets red pixels to white and not red pixels to black. Then the erode tool under basic morphology takes away small objects using a 3 x 3 square structuring element and 3 iterations. Next, the fill holes tool under advanced morphology makes the patties solid. Only small holes are filled, but this step may need to be removed when looking for scraps on patties. Then the lookup table automatically sets the pixels to white or black. The Vision Assistant steps should be adjusted each time the system is set up.

The only task in the next step sets the User-Defined Global Variable "Counter Objects" equal to 0. In this inspection the Counter Objects variable will be told to increase as each patty is inspected. This step moves automatically to the Detect Objects and Index step.

The Detect Objects task looks for bright objects in a given region. The definition of bright is not really important because all colors are now either black or white after the Vision Assistant step. Detect Objects is set to Ignore Objects Touching Region of Interest so that it will not capture only a part of a patty. A minimum object size of about 700 pixels will ignore any small bright spots from the background. Detect Objects outputs many variables about the objects it locates. It numbers the objects with the one farthest forward on the conveyor being 1.

Increase Counter and Set Detect increases the Counter Objects by one. Index X, Y, Area, Aspect for Object stores those measurements for the object numbered at the current Counter Object number. These variables will be used in other states. If no objects are detected in the Detect Object task, the transition takes it directly to increment state. The next step increases the counter then the x position, y position, area, and aspect ratio of the object are indexed.

The Measure Each Object state determines if the current object is a single patty with correct dimensions. The first task sets a horizontal line across the center of the object. Then the edges are found along that line. Third, the distance between the edges is calculated. Then the same tasks are performed for a vertical line and two diagonal lines through the center of the object. If any of the measurements are not within specifications, this state will fail and go to the Check: Touching Patties state. If everything is good, it will move on through the Good Patty state to the Increment state. The dimensions the program deems satisfactory should be adjusted to fit a perfect patty each time the system is set up.

Check: Touching Patties state has two tasks. Object Region sets a region of interest which will fit any two touching patties. Classify Two Touching uses NI Vision Builder matching to compare the image to previous images saved as examples of two touching patties. If it is a match with a score above 930, it is proclaimed to be two touching patties, which is acceptable, and sent to Good Patty. If the score is lower, it is classified as Other and it moves to Bad Patty. The classifier should be trained with as many images of two touching patties as possible. This will increase the accuracy of the program dramatically.

Good Patty sets the inspection status to Pass. Bad Patty sets the inspection status to Fail and logs the measurements of the bad patty to an output file. Changes can be made to log many different measurements for each failed patty. Either case proceeds to increment which loops back to Detect Objects if there are more patties in the image.

Lens Calibration

The easiest method for lens calibration is to start in a laboratory. Attach and install the camera into a computer, and set it the required focal distance away from a wall. Place tape or marks on the wall to signify the desired width of the field of view, and adjust the lens until all marks can be seen on the edge of view. Trial and error is the best method to obtain a clear picture of a desired field of view and the required brightness level. Once a satisfactory picture is found, tighten the set screws on the lens so that it will not go out of focus during the move to the inspection site.

Vortex Cooler Calibration

The vortex cooler attaches to the back side of the camera container. It requires a dried, oil-free air supply. The screw on the "hot end" of the vortex cooler is the adjustment for the amount of air going through each end. Loosen the screw and more air goes out the hot end, tighten the screw and more air goes out the cold end. The less air that is flowing out the cold end, the colder it will be. A good place to start with respect to pressure is 30 psi, and adjustments can be made from there to find a setting that will cool the camera but will not be an energy waste.

Cooler Box Construction

The cooling box should be constructed of either Plexiglas or Lucite, with the camera easily removable from the box. Attached is a drawing of the container designed for the camera.

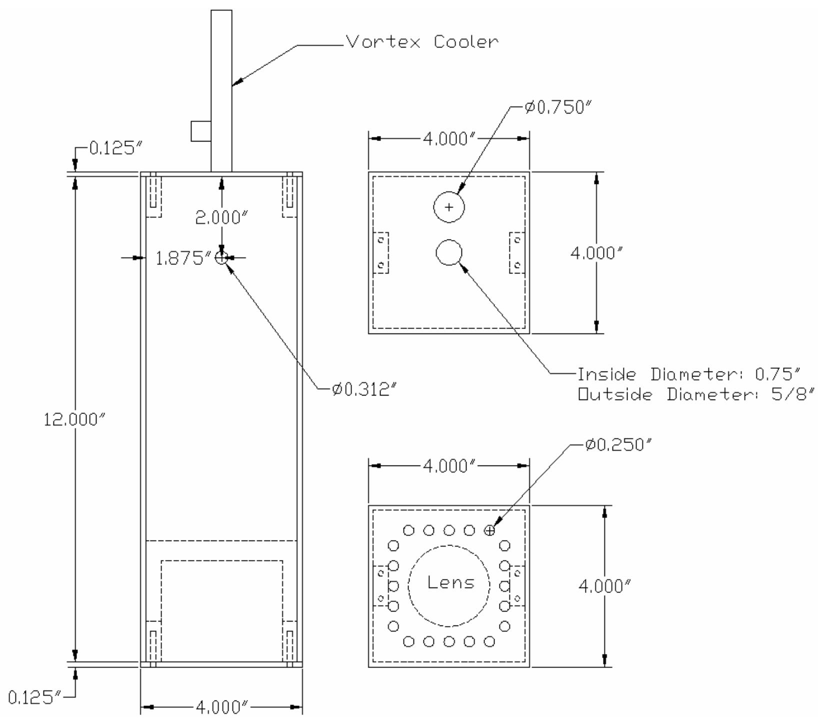


Figure 5 – Drawing of cooling box

Mounting Frame Construction

The mounting frame should be constructed from stainless steel and mounted between the two oven hoods. Variations in the distances are needed to fit between different oven hoods on the lines.

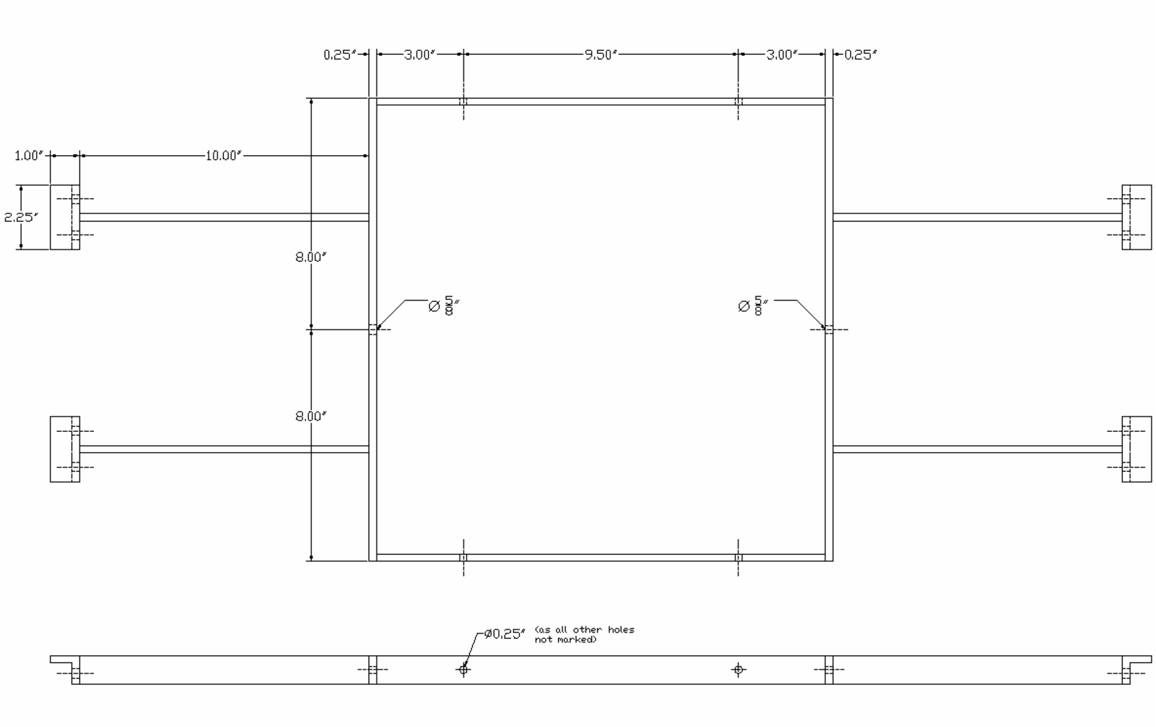


Figure 6 – Mounting frame construction

Appendix 5 – Specification Sheets

Sony XCD-X710CR Camera

Imaging Device	1/3 type progressive scan IT CCD
Resolution	1024 X 768
Digital Interface	IEEE 1394
Trigger	External
Lens Mount	C Mount
Frame Rate	Up to 30 fps
Dimensions	44 X 33 X 116 mm
Mass	250 g
Operating Temperature	-5 to 45° C (23 to 113°F)
Storage Temperature	-30 to 60°C (-22 to 140°F)
Operating Humidity	20 to 80% (non condensing)
Storage Humidity	20 to 95% (non condensing)

Tamron Lens-12VM412ASIR

Imager Size	½ inch
Focal length	4-12mm
Aperature Range	F/1.2-Close
Horizontal Angle of View	31.2°-93.7°
Mount Type	C-Mount
Dimention (from Mount Surface)	54mm

Illumination Control Light- BAF WHT-6

Length	36.9 inches
Height	1.5 inches
Width	2.5 inches
Operating Temperature	160°F*
Current	1,820 mA
Illuminance	2000 Lux

* Light specially manufactured to accommodate temperature requirements

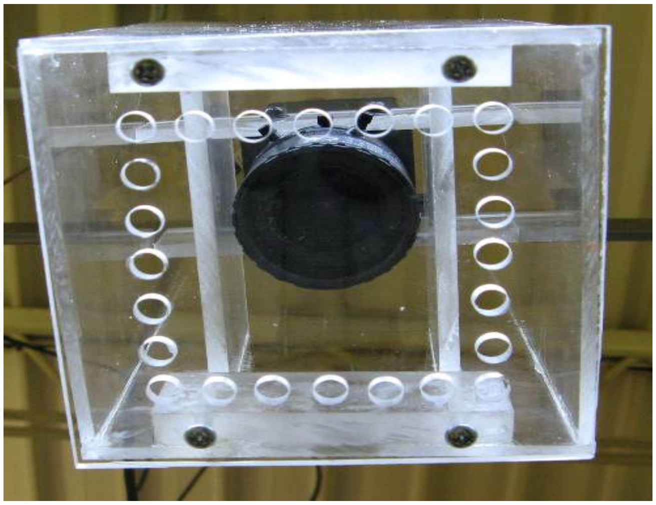
Trigger- Banner World Beam Q12 Series

Supply Voltage and Current	10 to 30 V dc @ less than 20 mA
Supply Protection Circuitry	Protected against reverse polarity and transient voltages
Output Response Time	Opposed: 1.3 ms ON; 900 ms OFF All others: 700µs ON/OFF
Delay at Power up	120 ms
Operating Temperature	-20 to 55°C (-4 to 131°F)

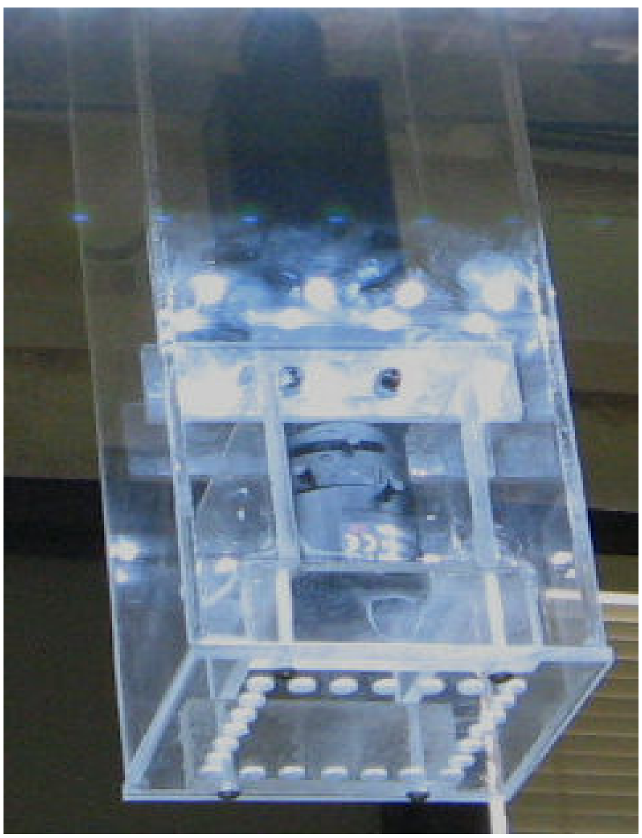
McMaster-Carr Cold Air Vortex Tube

Air Consumption @ 100psi	2 cfm
Cooling Capacity @ 100 psi	135BTU/hr
Overall Lg.	4.13 inches
Air Inlet, NPT Male	1/8 inch
Cold Air Output, NPT Female	¼ inch

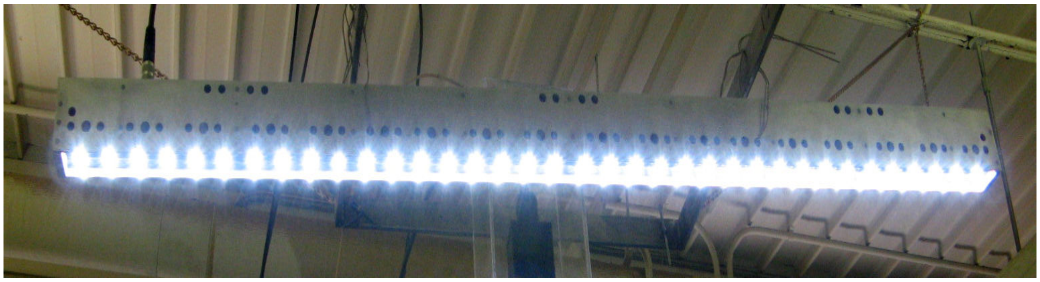
Appendix 6 – Pictures of Components



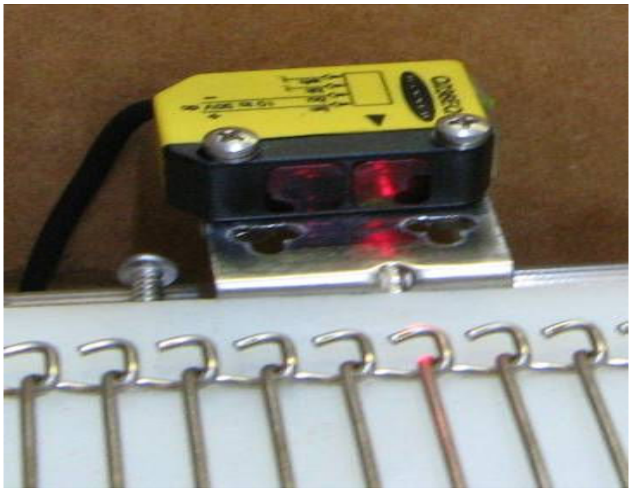
Lens and Camera inside of Lucite Box



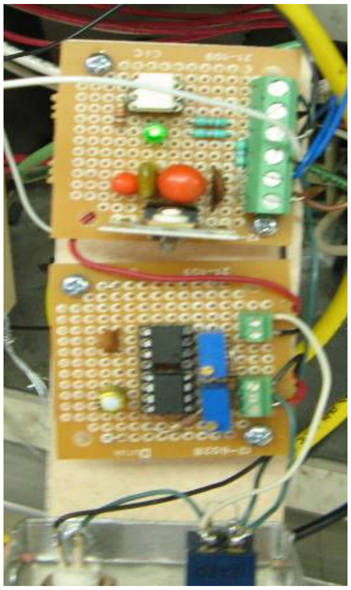
Side view of Camera and Lucite Box



36 Inch LED Light



Banner World Beam Q12 Photoelectric Eye



Trigger for Photoelectric Eye

Appendix 7

Quality Control Management System Safety Analysis - Caleb Bates and Eric Dabbs

Abstract

Oklahoma State University students in the Biosystems and Agriculture Engineering department were selected to design a system at the request of Lopez Foods Inc. The goal of the system to be developed was to improve the current meat cooking and transportation line within the Oklahoma City facility. At the completion and submittal of their engineering design proposal, students Josh Grundmann, Sarah Rowland, and Ashley Oulds of GRO Engineering were paired with students from the Fire Protection and Safety Engineering Technology department. These two students, Caleb Bates and Eric Dabbs, were tasked with performing a Preliminary Hazard Analysis, contributing ideas and thoughts for improved safety of the GRO design, and finally performing a Functional Hazard Analysis. These two groups worked together to further develop and improve the initial design of GRO. This report serves to inform the advisors of each group (BAE and FPST) what analytical approaches were taken to evaluate the general safety of the system as well as safety critical features of the system design of the BAE group. This report contains information which clearly defines the scope of the project from the system safety analysts' point of view, the findings which were documented as a result of the research and effort of the safety team, and finally, the recommendations to be reviewed by the BAE group and Lopez Foods.

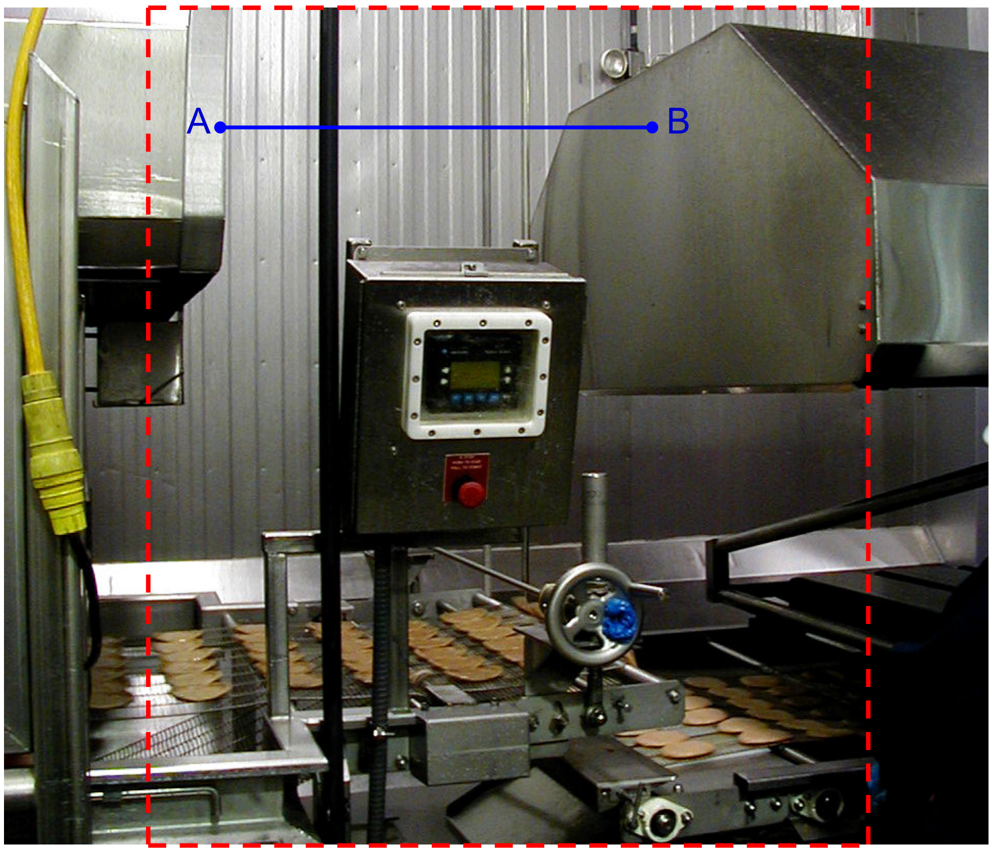
Introduction

In February of 2007, Fire Protection and Safety Technology (FPST) students Caleb Bates and Eric Dabbs were teamed with Biosystems and Agriculture Engineering (BAE) students Josh Grundmann, Sarah Rowland, and Ashley Oulds to work in conjunction with Lopez Foods Inc on the development of a new quality control function. The BAE team was tasked with developing and implementing the quality control monitoring system for a meat cooking line at the Lopez Oklahoma City facility. The FPST team had the task of performing a safety evaluation and analysis of the system designed by the BAE team.

This report details the safety aspect of the project and shows the steps taken in order to make the quality control system safe and efficient for Lopez Foods Inc. The primary purpose of this project was to perform a complete system safety analysis of the quality control monitoring system. The final safety analysis was achieved through meeting with the BAE group to understand the design and intent of the monitoring system, developing a Preliminary Hazard List and Analysis, and finally developing a Functional Hazard Analysis. Through the use of these different analysis techniques all possible safety critical factors were evaluated, and as a result, final recommendations for Lopez Foods were established.

Scope

The first step in performing a safety analysis is the development and definition of the scope of what the safety analysis will actually cover. Initially the scope of the safety function for this project was to "Perform an advanced analytical technique which will observe and document known or suspected hazards associated with the proposed food monitoring system in a defined area." To better understand the mechanical boundaries that were included in the safety analysis, refer to Figure 1.1 below. This figure is an example area of where the proposed GRO design would be placed.



The GRO quality control system is made up of various components which are all attached to a hanging bracket which would be placed between the two cooking ovens (points A and B) and over the conveyor line. To actually limit the scope of the safety project, a hypothetical box was placed around the cooking and transportation line that would be directly affected by the addition of the proposed monitoring system which is indicated by the dashed red line in Figure 1.1 as well. This area is also representative of where the BAE team chose to limit their design to. The creation of this hypothetical "box area" proved to be a key factor in the creation of all safety analyses. Had the box not been drawn, many more external safety factors could have contributed to the success or failure of the proposed monitoring system. Ultimately the approach taken from the safety team was determining how the safety of the proposed BAE design would be affected by sources within the red box area.

Throughout several meetings between groups it was also learned that there would be a Lopez employee exposed to elements directly related to the proposed system. The consideration of this employee, or employees, became a critical safety element as the development of the analyses came together. Although it was an addition from the initial idea of only considering the mechanical aspect within the red box area, the overall idea and scope of the project was not changed. Another factor which presented itself throughout time was the fact that there was also an element of having a large impact on the economics of Lopez Inc. with the addition of this proposed system. After the scope of the project had been re-defined, the actual system safety analysis began with the intent to "Perform an advanced analytical technique (Functional Hazard Analysis) which will observe and document known or suspected hazards associated with the proposed food monitoring system with the intent to prove how the overall quality control aspect of food production at the Lopez Inc. could be affected as a result of the installation of this monitoring system." This process is further explained in detail in the following sections.

Analysis

The Lopez Inc. system was a unique process to perform an analysis on, but the techniques used were basic in nature. The analysis process included the creation of a

Preliminary Hazard List, a Preliminary Hazard Analysis, and finally a Functional Hazard Analysis. Through the use of each of these processes, the quality control system was analyzed from a variety of angles which provides a thorough evaluation and offers a wide range of information.

The first step in evaluating the proposed design was the creation of a Preliminary Hazard List. This list included all relevant, and even questionable, items that might have an impact or create a hazard to the system or as a result of the system. This list can be considered a starting point for all other methods of analysis. This list is found in the Appendix of this report, and details each of the items initially considered to pose a threat. Although this list served as a guideline for the rest of the process, the list was rearranged multiple times as priorities shifted and the scope developed further. With these developments and shifting priorities there is an initial list and a final list.

The second step in the safety process was the creation of the Preliminary Hazard Analysis. This is simply the analysis of all elements contained on the (final) Preliminary Hazard List. For this method each of the elements are reviewed and broken down into sections. These sections classify each of the hazardous elements into functional elements of the entire system. As this is done, each of the hazardous elements is further identified by an initiating mechanism and a target/threat. These ultimately provide to allow for the consideration of the possible outcomes or effects should the hazard be realized. The PHA is available for reference in the Appendix.

The final step in performing the system analysis was the creation of a Functional Hazard Analysis. This analysis is available for reference in the Appendix. This technique serves to break down and analyze a mechanical system which contains elements of software, hardware, and humans. Although only one of many available techniques, this type proved to be the best fit for the Lopez project. To form the FHA the PHA was simply expanded upon. All relevant hazards were taken into account and analyzed. For this method however, the goal was not to simply list the hazard and break them down into elements, but it was to assess these cause/effect relationships and assign a "Risk Value" to each of them. This risk value is based upon a designated Probability and Severity table which assigns an alphanumerical value. The matrix is represented in Table 1.1 below.

Severity	**Probability**
1. Catastrophic	**A.** Frequent
2. Critical	**B.** Probable
3. Marginal	**C.** Occasional
4. Negligible	**D.** Remote
	E. Improbable

Table 1.1 Functional Hazard Analysis Risk Matrix –
Ericson, Clifton. *Hazard Analysis Techniques for System Safety*. Wiley. 276.

The combination of the probability of an event occurring and the severity of the situation should that event occurs equals an Initial Mishap Risk Index. By assigning an IMRI, the safety analysts were able to show where the system currently had deficiencies and documented the findings related to such deficiencies, as well as offering corrective actions to alleviate those situations. It is important to remember that throughout this analysis the only area of consideration is that of the red box and things directly affected by it.

Findings and Recommendations

Although most clearly seen by referring to each of the analyses mentioned previously, a summary of findings and recommendations will serve to further inform Lopez Foods Inc. The areas of focus for analysis which were deemed **findings** of are:

- Personnel
  - Heat Stress
  - Slip, Trip, Fall Hazards
  - Ergonomic Issues
  - Training
- System
  - Integration with current system
  - Mounting and power supply
  - Training
  - Maintenance and upkeep

After reviewing each of these elements in their states of analysis, several key recommendations are worthy of immediate attention. These **recommendations** are:

- Personnel
  - Elimination of employee exposures by removing from cooking line
  - Reviews of safe work practices in all areas of work
  - Rotation of workers and variation to work shift
  - Implementation of management/employee led training program which covers all hazards of current cooking line as well as special area of focus to new quality control system

- System
  - Addition of automatic removal system for unacceptable meat
  - Employee training on how to control and monitor proposed system (software)
  - Use of proper hardware for harsh environment
  - Training of maintenance and other employees of how to monitor system for proper working condition (hardware)

Conclusion

Through the duration of approximately nine weeks, students from various engineering disciplines worked together on the design, installation, and safety analysis of a quality control monitoring system for a major food processor, Lopez Foods Inc. The students worked together to provide Lopez with a design which had been tested from a function standpoint (BAE) as well as from a safety standpoint (FPST). By working together the students successfully provided Lopez with a quality design which has been analyzed and modified to offer the highest quality available to both Lopez as a company and to its consumers. By installing the recommended quality control system Lopez should see an immediate improvement in worker health and safety as well as increased production.

System: Meat Cooking Line

Subsystem: Lopez Inc.

Lopez Foods Inc.

Analysts: C. Bates, E. Dabbs

Date: April 19, 2007

Function	Hazard No.	Hazard	Effect	Causal Factors	IMRI	Corrective Actions	FMRI	Comments	Status
Computerized Camera/Light Control System: Monitoring of meat transportation, monitors for unacceptable meat continuation along cooking line, notifies monitoring operator (out of cooking area) of unacceptable meat location for removal	LF1	Computer monitoring system fails, creating monetary loss and lost production time	Batch of food is contaminated with "bad" meat and requires removal of large quantity of food	Power outage caused by nature	1D	Install protected electrical equipment or have option of emergency power generation for computer system separately from other functions		Not likely to be needed as in a natural power loss the rest of production is likely to go down as well	Open
	LF2	Computer monitoring system fails, creating monetary loss and lost production time	Batch of food is contaminated with "bad" meat and requires removal of large quantity of food	Computer system hardware/software crash or glitch	1C	Continue to have one "roaming" maintenance employee in production area monitoring for bad meat production		Employee should not work near ovens on a continual basis, but work at the end of the line near the storage area looking at the final products	Open
	LF3	Computer finds too many "bad" meat products	Monetary loss, product waste	Software malfunction reads too many "bad" meat products on transportation line	2C	Continuous human monitoring of computer system from remote area			Open
	LF4	Computer monitoring system failure	Computer monitoring system out of service, transportation line must be watched by humans	Incompatible wiring used for the harsh environment	2D	Critical that weather resistant (heat/moisture) fixtures and wiring be used for all components of the system to be used in meat transportation area		Many options available, Lopez must research what products they want	Open

	LF5	Computer monitoring system failure	Computer monitoring system out of service, transportation line must be watched by humans	Monitoring system incorrectly re-installed after maintenance	3B	Training of maintenance employees of correct connect/disconnect procedures. Also consider creating a color coded connection system		Easily avoided by creating a 'wiring harness' that contains a color coded connection system	Open

www.lopezfoods.com — ***Functional Hazard Analysis Performed by Professional Safety 101 LLC*** — *www.prosafety101.com*

System: Meat Cooking Line
Subsystem: Lopez Inc.

Lopez Foods Inc.

Analysts: C. Bates, E. Dabbs
Date: April 19, 2007

Function	Hazard No.	Hazard	Effect	Causal Factors	IMRI	Corrective Actions	FMRI	Comments	Status
Light System: Illuminate area of computer monitoring to allow software to properly read conditions of meat being transported	LF6	Unacceptable meat passing through computer monitoring system incorrectly	Improper lighting allows unacceptable meat to pass through undetected	Light source expiration or failure	2D	Use of weather resistant (heat/humidity) light fixture with long-life light source		High temperature resistant LED lighting in sealed fixture will work	Open
	LF7	Unacceptable meat passing through computer monitoring system incorrectly	Improper lighting allows unacceptable meat to pass through undetected	Light source incorrectly installed after maintenance	2B	Training of maintenance employees of correct connect/disconnect procedures.			Open

	LF8	Unacceptable meat passing through computer monitoring system incorrectly	Improper lighting allows unacceptable meat to pass through undetected	Light may either be too bright or not bright enough, and will "trick" software into mis-reading meat	2C	Human monitoring of software system and periodic tests to ensure proper light levels			Open
	LF9	Contaminated food on transportation line	Pieces of light source falling from mounting system onto food transportation line	Light source breakage	1D	Use of sealed fixture and lighting enclosure along with routine inspection of light source			Open

Function	Hazard No.	Hazard	Effect	Causal Factors	IMRI	Corrective Actions	FMRI	Comments	Status
Camera/Light Mounting System: Responsible for holding camera and light system. Mounting system must be easily removed on a daily basis	LF10	Contaminated food on transportation line	Hardware falling onto meat transportation line	Faulty hardware connections (nuts, bolts, screws, chains)	2D	Industrial/Food Grade connector material sturdy enough to hold load			Open
	LF11	Contaminated food on transportation line	Hardware falling onto meat transportation line	Mounting system incorrectly re-installed after maintenance	2C	Properly train all maintenance workers on proper system connections			Open
	LF12	Employee injury	Hardware falling onto employee	Faulty hardware connections (nuts, bolts, screws, chains)	3E			This scenario is not likely to occur if proper hardware is installed and the system is properly re-installed after maintenance	Open

Vision Inspection System

Josh Grundmann, Sarah Rowland, Ashley Oulds
Advisor: Dr. Paul Weckler

Prepared for Lopez Foods

Course BAE 4022

April 26, 2007

Sponsor: Lopez Foods, Inc.

- Provides frozen, pre-cooked sausage patties to major food corporations
- Several different recipes being produced on six oven lines

Sponsor: Lopez Foods, Inc.

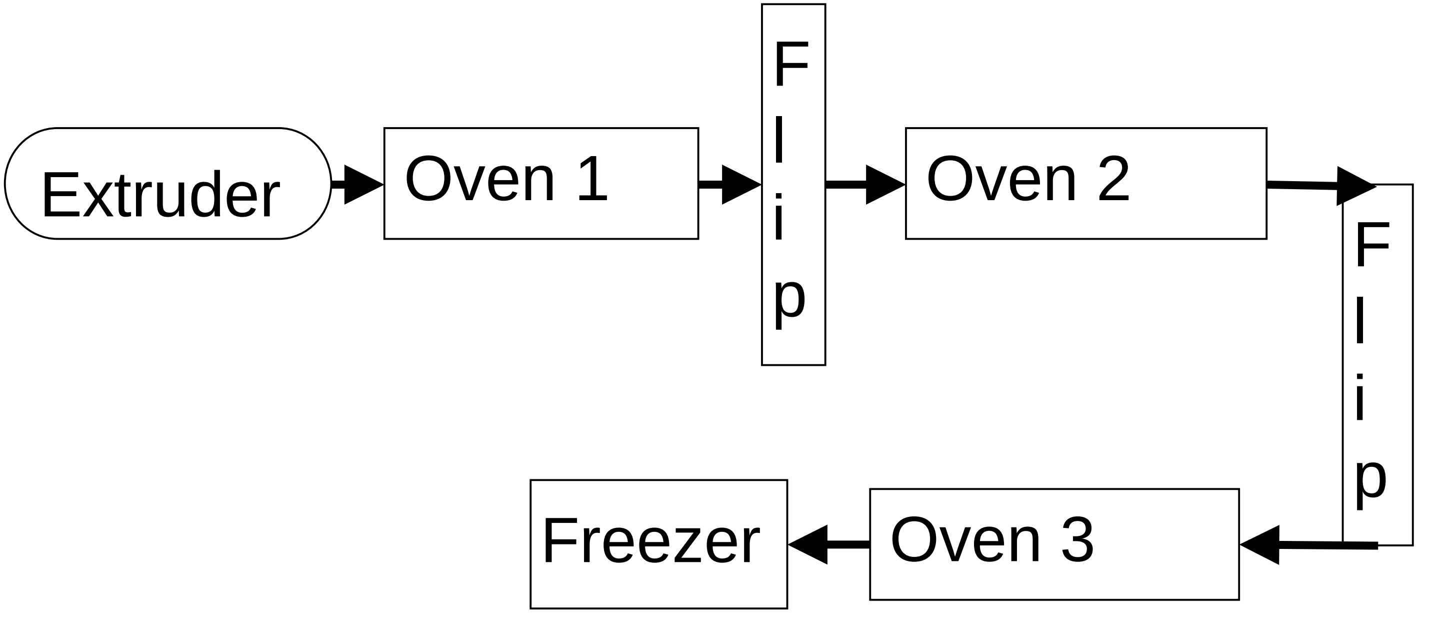
- Considering automation of patty inspection
  - Avoid uncomfortable working conditions for employees
  - Programmable quality tolerances
  - Statistics for unsatisfactory patties
- GRO to provide automated vision inspection system
  - Rejection system for unsatisfactory patties to be designed at a later date

Automated Vision Inspection System

- Requirements:
  - Identify unsatisfactory patties
  - Log statistics
  - Be able to withstand environment
  - Easily cleaned
  - Be user-friendly
  - In future, communicate unsatisfactory patty location to rejection mechanism

Introduction to Problem

- Each patty is subjected to two flips in order to ensure even cooking on both sides

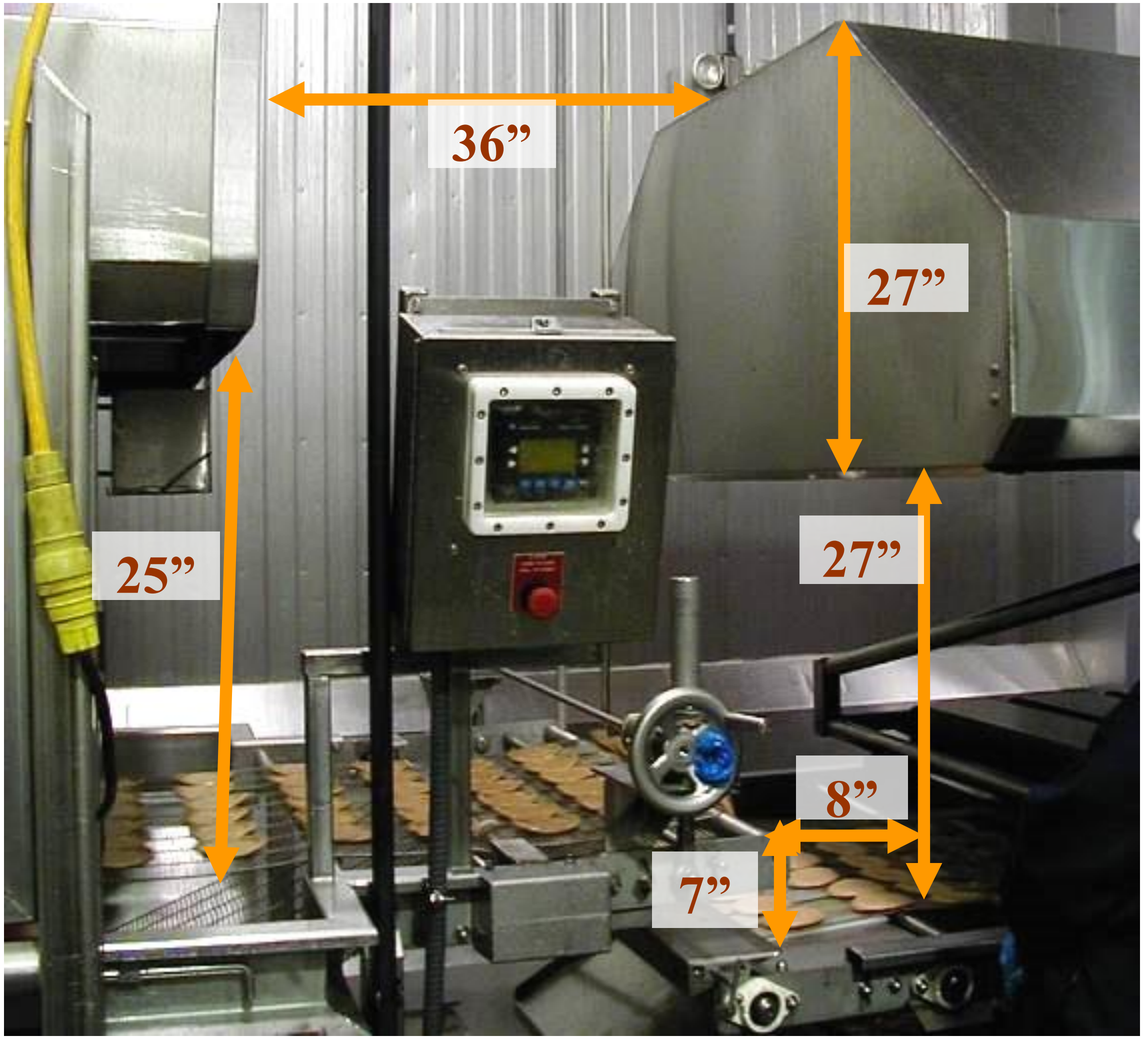


- Flipping can cause patties to fold over or overlap and not cook properly

Introduction to Problem

- Currently, patties that are "unacceptable" are removed by a quality assurance worker

System Placement



System Components

- Hardware
  - Camera
  - Cooling system
  - Lens
  - Lighting
  - Background
  - Trigger
- Software
  - Package
  - Program

Camera Specifications

- Firewire connectivity
- High frames per second
- Moderately high resolution
- Color capability
- External trigger
- Operational in high humidity and temperatures up to 150°F

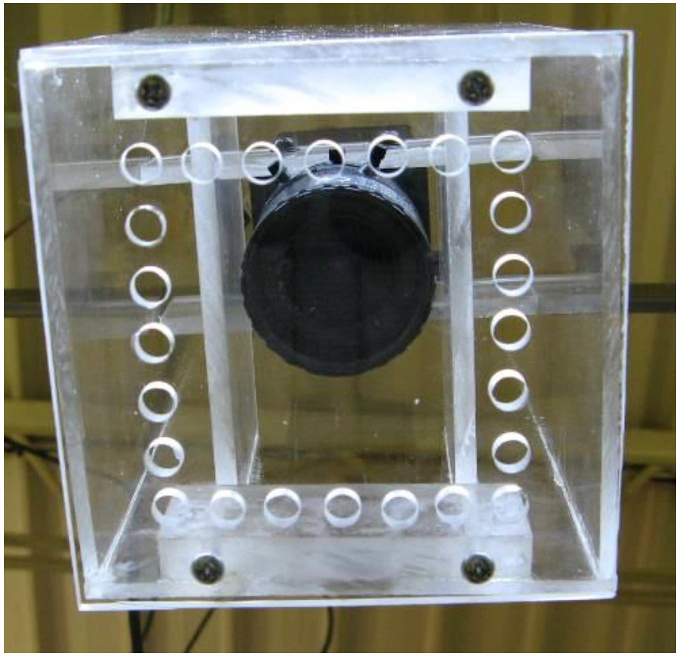
Camera for Design

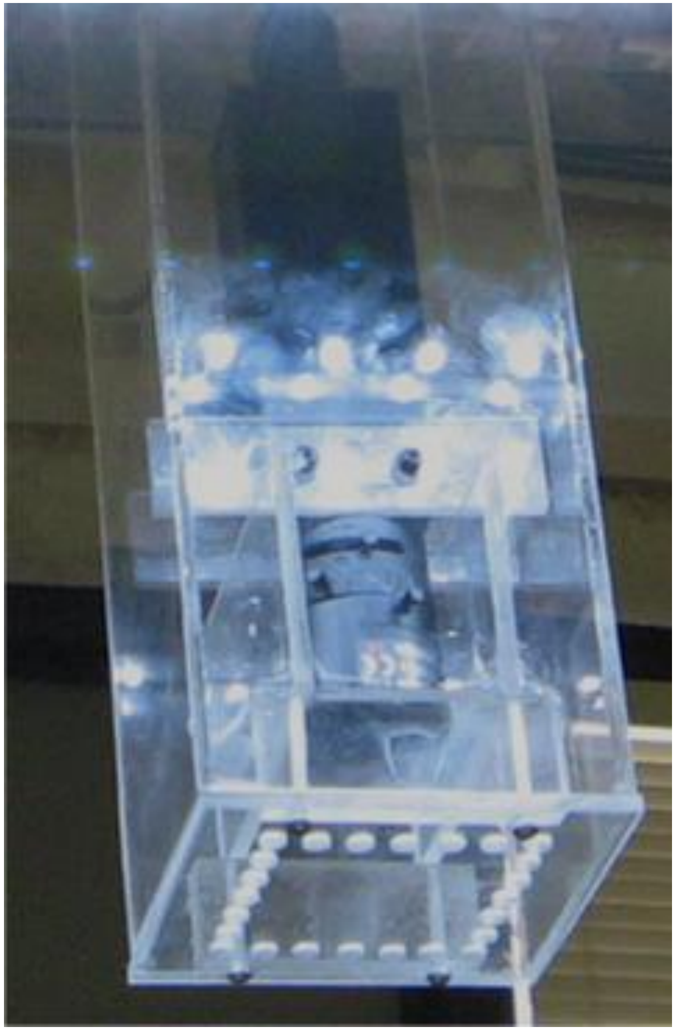
- Sony IEEE 1394 Progressive Scan Color Camera
  - 30 frames per second
  - 1024 x 768 resolution
  - Durable, easily mounted casing
  - Maximum operating temperature: 113°F

Camera Cooling System

- Considered possibilities
  - Refrigeration system
  - Circulating chilled water
  - Thermoelectric cooler
- Cooler for Design
  - Expanding compressed air through vortex cooler
  - Forces air flow through container and out around lens
  - Easily cleaned

Camera Cooling System





Lens

- Wide picture – 30” field of view
- 1 meter working distance
- Angle of View: 42°
- Varifocal from Tamron

Lighting Specifications

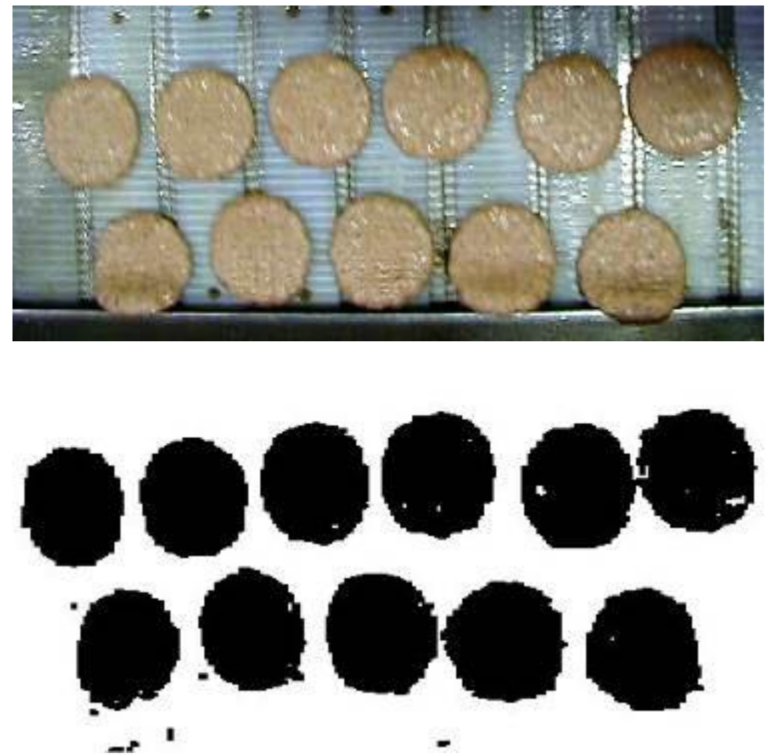
- Remove shadows
- Withstand oven room conditions
- Long life
- Differences with and without light

Lighting for Design

- Ultra-bright, broad area flood, high-power LED array from Illumination Control, Inc.
  - 36 inch linear array
  - White LEDs
  - Operates at temperatures up to 160°F
  - Light output: 2000 Lux

Importance of Background

No background

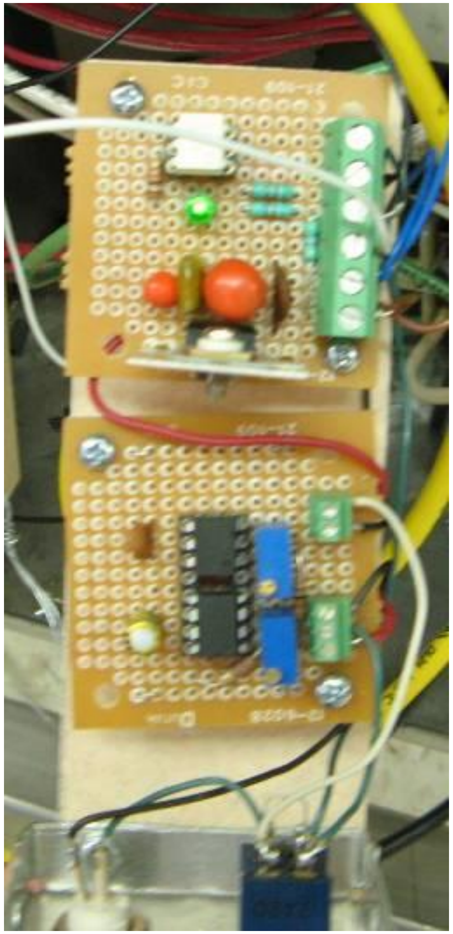


White background

Trigger

- Photoelectric eye from Banner Engineering

- Single/multiple impulse signal generator



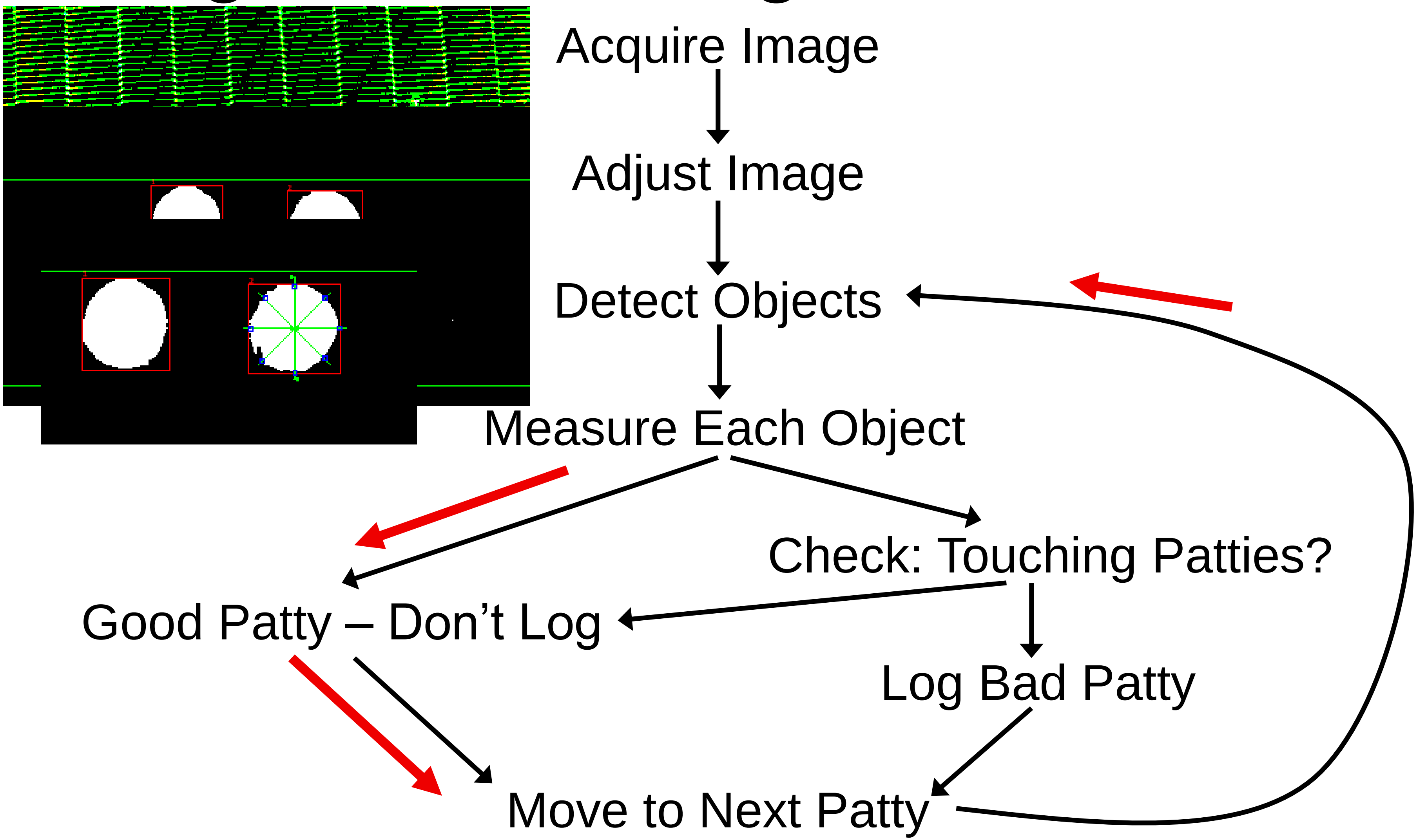
Software Requirements

- Locate several objects in image
- Pre-programmed to make necessary measurements
- Communicate with trigger
- Output data to rejecter
- Color processing
- Simple interface for user

Software for Design

- National Instruments Vision Builder AI 3.0
  - Good company
  - Robust system of built-in tools
    - Analyze color and hue
    - Find objects, measure distances, classify, etc.
  - Fast image processing
  - Easy-to-use, window-based format

Program for Design



Statistical Analysis

Category	Correct
Single Acceptable Patty	100.00%
Two Touching Patties	95.41%
Overlapping Patties	98.96%
Single Unsatisfactory Patty	97.80%
Two Touching Unsatisfactory Patties	81.82%

Touching

Overlapping

Unsatisfactory

Statistical Analysis - Issues

- Two touching patties
  - Rejected conforming patties – Type I error
- Overlapping patties
  - Did not reject – Type II error
- Two touching unsatisfactory patties
  - Did not reject – Type II error
- Three errors can be remedied by further ‘training’ of classifier

Statistical Analysis – Issues (cont'd)

- Single unsatisfactory patty error
  - Did not reject – Type I error
  - Edge misshapen
  - Patties causing errors on verge of satisfactory

Budget

Component	**Estimated Cost**
Processing Unit	Variable
White Background	Provided by Lopez
Camera	$1624
Software Package	$1500
Lens	$153
Laser Trigger	$70
Lighting	$1388
Vortex Cooler	$149
Filter	$49
Bracket & Camera Housing	$200
Total	**$5133 + Processor and Background**

Thank you!

- Lopez Foods, Inc.
- Dr. Paul Weckler
- Dr. Tim Bowser
- Bill Quimby
- Dr. Kevin Nanke
- Craig Trible
- Wayne Kiner
- Mike Veldman

Vision Inspection System

Josh Grundmann, Sarah Rowland, Ashley Oulds

Advisor: Dr. Paul Weckler

Prepared for Lopez Foods

Course BAE 4012

December 8, 2006

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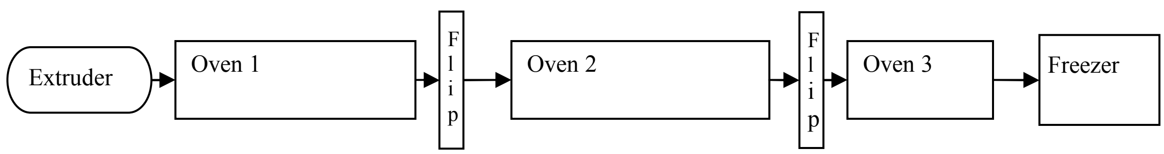
Mission Statement

GRO Engineering is a consulting group dedicated to assisting clients in solving food design and control problems. The solutions developed will increase overall production efficiency to further the client in customer satisfaction and profit.

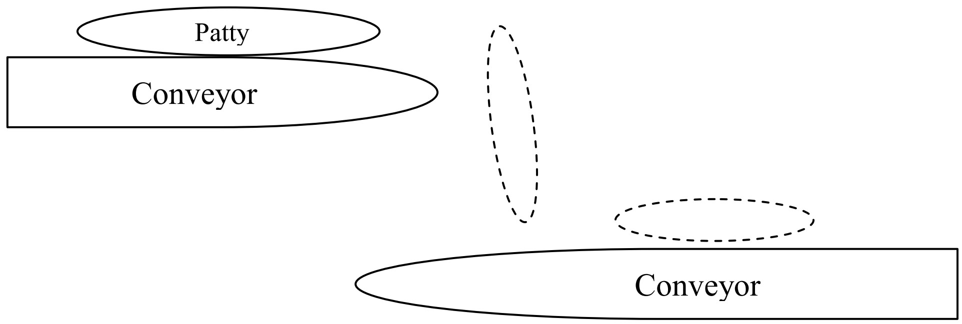
Introduction to the Problem

Lopez Foods, Incorporated provides frozen, cooked sausage patties to many large food corporations. Cooking lines for the sausage patties consist of a conveyor belt beginning at an extruder and running through three ovens to a blast freezer (see Figure 1). The patties are extruded onto a conveyor belt and proceed down the conveyor belt to be cooked then stored in the freezer until shipping.



- Figure 1 – Flowchart of sausage patty production line.

During Lopez Foods' cooking process, patties are flipped twice to allow them to be cooked evenly by the ovens which only radiate heat towards the top of the patty. Flipping is achieved by running the patties off the end of one conveyor onto another conveyor (see Figure 2).



- Figure 2 – Diagram of patty flip procedure. For a picture of flip, see Appendix 2.

The flipping method intermittently causes the delicate patties to overlap, break, or fold over themselves (for pictures of non-satisfactory patties, see Appendix 1). If these patties are folded or overlapped, their effective thickness is twice that of the design thickness for which the oven was programmed to cook. This means the patties have not been cooked adequately for the center temperature to be raised high enough for the meat to be considered safe for consumption. These patties must be located and removed from the cooking line. Removal must occur before the patties are transferred into the freezer so that any bacterium which may remain in the undercooked meat is not allowed into the sterile freezer.

The current method of ensuring only quality patties enter the freezer consists of three Lopez employees stationed on each oven line to remove any defective patties from the conveyors. Two employees are inside the oven room inspecting patties before each flip and one is in the transition room to the blast freezer to inspect the patties a final time. The working conditions for these employees can be very harsh. Work done last year by Thermal Solutions showed the oven room can reach temperatures of 120 Degrees Fahrenheit and it is much warmer next to the ovens, while the transition room is about 40 Degrees Fahrenheit while it is much cooler next to the openings to the blast freezer. One of the main objectives of installing a computer-operated vision inspection system is to make it unnecessary to have employees working in such conditions.

Statement of Work

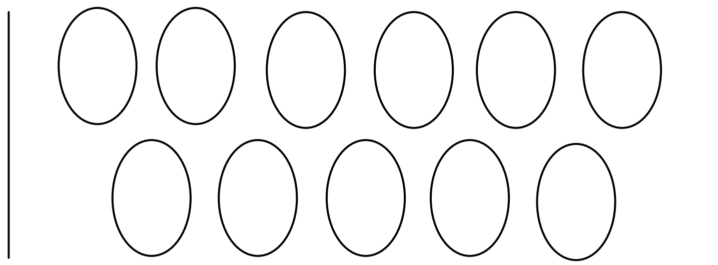
Project Definition:

GRO Engineering should provide to Lopez Foods, Inc. a sensing system which will identify all products which are defective in perimeter, thickness, and, possibly, color. This system should be easily cleaned, withstand environment of oven and freezer transition rooms, work in the space given, and adapt to various situations and products. If time allows, GRO Engineering will also provide a design for a defective patty rejection system and controller to operate the rejection system. A vision system will increase safety to consumers, accuracy of removal, and working conditions for employees.

Software:

For this project, we must obtain a software package capable of identifying patties of different shapes and sizes and locating the position of the patties on the conveyor (see Figure 3). This software should be provided by a company with a reputation of good quality assurance and technical support to assure that Lopez will be able to run the program effectively in the future. In choosing the software, we must consider the compatibility to the image capturing hardware. To implement this system, we will program all of the steps needed to capture and analyze a photo of each row of patties including quality tolerances for each patty. We also will determine a way to trigger the camera to take an image of the randomly placed patties.

The software we choose must be able to connect images from as many cameras as necessary to "see" the whole width of the conveyor. The program must be able to discern the location of as many patties as may appear in that section of the belt at any one time and their shape. Software will also have the capability to pinpoint location of patties on the moving conveyor and communicate with a controller to remove defective patties.



- Figure 3 – Approximate patty placement on the conveyor

Hardware:

The camera(s) we choose for the system must be compatible with the purchased software package. Because of the necessary washing of the production area and the harsh conditions, it will probably be necessary to design a shield for the camera.

Implementation of the camera system includes determining the amount of space available to implement our system and constructing a bracket to hold the camera with an acceptable view of the conveyor. We will discern the material type for the conveyor which provides the clearest image while maintaining oven safety standards, as well as finding a way to adequately illuminate the area where the image will be taken. This system should also include a controller for a rejection system to remove the non-satisfactory patties from the line based on the information given from the software.

Because there are several oven lines in the Lopez Foods plant, these vision inspection systems should be easily reproduced and fitted for each cooking line in the factory.

Market Research Review

GRO Engineering reviewed many types of software and hardware while researching prospective suppliers. In this list were software providers, hardware manuals, an overview of the BAE vision lab, Vision Systems Design Magazine, and presentations by sales representatives from Banner Engineering Corporation, Texonics, and Omron. These methods are the most effective in obtaining information about the ever-changing vision inspection industry. Patents and research papers were consulted and searched at length, but because of the specific nature of vision systems, there were no resources found in these sources which will be of use to us on this project.

Banner Engineering Corporation Presentation:

On October 23, 2006, we were able to have a workshop in the BAE computer lab pertaining to all the software and hardware from Banner for vision inspection. We were presented with software and hardware possibilities and were interested to see a vision system programmed to run. A Banner representative, Mr. Glenn Haueter, presented the workshop where he constructed a system to analyze several aspects of a target that was much like a piece of cooked sausage.

The P4 Omni hardware system is made by Banner Engineering and is capable of working in the conditions in our problem statement because it will only have to work at about 1.5 Hz, according to our measurements of the speed of the conveyor. At this rate the system will have enough time to make a full analysis of each patty to obtain a pass or a fail signal from the machine. Mr. Haueter brought to our attention that a huge issue with any vision analysis is the lighting system. He said the lighting accounts for about 70% of the success of any vision system, and colors of emitted light are also important to the success of the machine. Mr. Haueter mentioned that a triggering mechanism would be required so that the computer would know when to grab an image and not continuously take pictures. We are still considering the options of a laser trigger system or an input trigger system to let the camera know when to receive an image.

Banner’s software seems very easy to program and to use, and it would not be necessary to write code with this program. Specific image analysis tools in the software will be most important to analyze a sausage patty for roundness and size. The first is a “locate tool”, which finds the target in the field of view of the camera. In our case it might look for the left edge of the patty, and when found, it will find the bottom edge relative to the left edge. Everything in the analysis will be relative to the edge it is programmed to find first rather then to a specific place in the picture so that the patty can be found no matter where it appears in the image. The locate tool finds an object in the picture, but the object still needs to be analyzed.

The “edge tool” is the fastest way to analyze an object. This tool finds where the lighter background stops and where the darker patty begins. It can also be used to find where the patty stops on the other side, and, using this information, calculates the diameter of the patty. While this is not useful in one dimension, when several edge tools are used to find multiple diameters at various angles, it gives an idea of the roundness of the object.

A second tool for analyzing the patty object is the "BLOB tool", short for Binary Large Object. It essentially finds the object, changes each pixel into a black or a white one, based on programmed tolerances of lightness and darkness, then counts the black pixels within the space. This count can be compared to programmed tolerances to determine if the patty is large enough to be a whole patty (not torn or folded over) and if the patty is small enough to not be two overlapping or touching patties.

The third useful analysis tool for this system is the "geo tool", which will actually recognize the shape of a circle and then analyze both the diameter and area along with other constraints. The geo tool takes longer to run than the edge or BLOB tools, but the speed of the conveyor belt will probably allow us to use it. In this application it is probably feasible to use the BLOB and edge tools together to analyze the patty.

The total Banner package is about $2500 per camera system, and we may need two or three of them at each inspection point due to the width of the conveyor belt and the flow rate of the patties. Our main concern with the Banner package is the system's apparent lack of ability to conjoin pictures from multiple cameras.

Texonics Presentation:

On November 9, 2006, Mr. Chaital Shah, a graduate of Oklahoma State met with us to discuss hardware and software available through Texonics, Inc. We received many pamphlets with products including hardware and software packages. The pertinent software from Texonics is NetSight, a basic program with similar tools to the Banner software. We have received trial versions of these programs, but in testing them have discovered that they are not very user friendly, something that is important to our final decision. Texonics also is a supplier of hardware such as laser triggers.

Omron – F-series Vision Sensors:

There are several packages in this line of vision automation products. The F150-2 Vision Sensor looks like a program that could fit our software needs. It uses drop-down menus to set up functions including filtering; adjusting the shutter speed; background suppression; X, Y, and Theta position compensation; and image calibration. Measurement tools include area, edge position, edge pitch, degree of defect, and more. With this program, there are options for 16 setup scenes and up to 16 measurements per scene. The F160 is one step above the F150 and allows for two cameras.

Omron Presentation:

On November 14, 2006, our group met with Mr. Louis Watts of Omron Electronics. During this meeting, we were able to explain our problem and our goals for our project to Mr. Watts. He explained the vision inspection tools available through Omron including their F-series packages. From previous research, we determined the F150-2 Vision Sensor may supply a solution to this problem. This sensor uses drop-down menus to set up functions including filtering, adjusting shutter speed, background suppression, and image calibration. During our discussion with Mr. Watts, we were informed there may be a more appropriate system available through Omron. Our group provided Mr. Watts with information he could take to his engineers so they could determine whether or not Omron had a software package capable meeting our requirements.

National Instruments – Vision Builder for Automated Inspection:

This software works with analog, digital, or FireWire cameras which means we are free to connect it to a camera which meets all of our specifications. There is no programming required. Vision Builder can be tested offline with a downloadable trial version of the software. The menu-based program can be used for color or black/white inspection. It is capable of locating and analyzing multiple objects. National Instruments is a well-known company and seems to be very user friendly. The price for this software is $1499.

FSI Automation – XCaliper:

This system can be connected to outside image capture devices. Teach tools allow users to program calipers, various edge locators and blob analyzers, all of which sound very compatible to the Banner software. It can locate several blobs on an image. XCaliper can analyze patches of color on an image.

Vision Systems Design Magazine:

Vision Systems Design Magazine is a publication that showcases up-to-date hardware and software of vision systems, and also shows practical applications of these systems. Illustrations and name-brand advertisements gleaned from this resource are very useful. The pictures give us a view of what others have done with respect to design of vision systems, and the advertisements have allowed us to know the major hardware and software systems on the market with an idea of price ranges. The screenshots of the software are helpful in finding a suitable program with an easy interface that is robust enough to meet our needs. For the purposes of general knowledge and for gaining names of possible software and hardware distributors, Vision Systems Design Magazine is very useful. Reading the articles allows us to know that there is a solution to our problem, simply because others have applied this to very similar engineering problems.

Hardware Manuals:

With a vision inspection system, it is necessary to have both a software package and compatible hardware. Edmund Optics publishes an optics and optical instruments catalog. This catalog includes various pieces of hardware that may be needed for a vision inspection system such as illumination systems and color or monochrome analog cameras. Not only does the catalog have pictures and descriptions of each piece of hardware, it also includes pricing information for most of the inventory displayed in the catalog.

BAE Vision Lab:

In addition to presentations and magazine reviews, GRO Engineering has the facilities and equipment available in the Biosystems and Agricultural Engineering (BAE) Vision Inspection Laboratory at Oklahoma State University available to us. On October 5, 2006, our group was able to schedule a time with Dr. Weckler to tour the BAE Vision Lab. During this tour, we were introduced to the hardware that the department has already purchased for research in the field of vision inspection. The BAE Vision Lab has many different cameras available for use in our preliminary testing of vision inspection software. The cameras available use both analog and digital output allowing our group to be able to customize our system to the specifications deemed necessary. Our tour concluded with a discussion on how digital images are transferred into binary numbers which in turn are outputted into the image that we see. From this tour, GRO Engineering decided to test our inspection system using the hardware found in the BAE Vision Lab and a software package purchased through a commercial vendor.

Customer Requirements

The vision system provided to Lopez Foods by GRO Engineering will need to meet many requirements as specified by Lopez Foods. These requirements include the following:

1. Ability to determine the quality sausage patties from defective patties based on patty thickness, diameter, and eccentricity.
2. Ability to locate multiple randomly placed patties on moving conveyor.
3. Ability to track defective patties on moving conveyor.
4. Communication with defective patty rejection mechanism.
5. Easily cleaned with water.
6. Resistant to large temperature and humidity ranges.
7. Have a very high success rate.
8. Be easily reprogrammed.
9. Fit into space available on oven lines.
10. Possibly recognize color patterns of the patties.

11. Should inspect patties at least at Oven 1 and Oven 2 positioning.

<u>Engineering Specifications</u>

Target diameter for Lopez's most frequently produced patty is 3.75 inches with a tolerated variance of +/- 0.25 inches. Target thickness for this patty is 0.400 inches with a tolerated variance of +/- 0.05 inches.

The conveyor is moving at a rate of one row of patties per second. The conveyor belt is 30 inches wide with a 7 inch dead space on either side.

The lenses must have at least a one-meter working distance with a wide field of view—around 42 degrees of view. It should also have a field of view that is at least 750mm so that the entire belt may be seen by the camera.

The camera used should communicate with the processor via Firewire for fastest processing time.

It is imperative that the camera lens stay clean. During our second trip to Lopez's facilities, the conveyor system, including grease splatter, was measured and photographed (see Appendix 2), the patties' positions on the lines were measured and photographed, and the environment inside the oven room was reassessed. Measurements show that grease splatters only a few inches above the conveyor belt height. For information on the space available for the camera and bracket, please see Appendix 2.

A second discussion with the quality control personnel at Lopez revealed that the most important inspection points are before the first flip to ensure all patties were cooked correctly in Oven 1 and after the first flip to ensure the patties cook correctly in Oven 2.

Oven 3 does not do imperative cooking, so the patties do not necessarily have to be checked after the second flip.

Preliminary Design Concepts

The past several decades have made vision inspection a fast-paced and quickly evolving science. Now with a camera, a compact processing system, and guidelines for the processor, vision inspection can be made possible in almost any environment. With these three components and a suitable surface for inspection, a vision system comes to life. These four components, the camera, processing system, algorithm, and surface, are the subjects for selection in this design project.

The camera is essential because it captures the image. The camera should be positioned to achieve the best possible angle of the product and should also show all of the important parts of the product. A good image requires a good light source to illuminate the product's features and allow the picture that the camera receives to be bright and clear and without glare. An ideal camera will be able to look at the entire width of the conveyor line with a high enough resolution so that good product can be easily distinguished from bad. The lens should allow the camera to be a reasonable distance away from the product—far enough away to see the whole width but close enough that no photo distortion effects occur.

The processing system is a computer that receives the signal from the camera. It can be a personal computer with a monitor or it can be a control box that only contains the algorithm for pass/fail. This processing system, once it has determined quality, must then have outputs that convey the verdict to a rejection device further down the line. This system must be fast enough to process all patties before the next row passes the camera.

The guidelines or algorithm for the processor are custom to the job, but basically all include product location, some kind of measurement, and a pass/fail statistic. The location part depends on the processor finding the product's edges on the image and creating a reference point from there. A measurement then takes place, where the computer either calculates the area, the diameter, or the aspect ratio of the product to make sure that it is within the specified bounds. Lastly, it will give each product a pass or fail rating based on the measurements and location and will deliver the coordinates of the product to the rejection system. Our processor unit will likely be positioned outside the oven room, so heat and humidity tolerance need only be assessed for the connecting cables.

The inspection surface is also very important. It must be kept clean because debris will confuse the algorithm which cannot distinguish debris from patties. In the Lopez situation, a clean surface is also necessary for health inspections. The surface should also be an appropriate color so that the product can be easily distinguished from the background.

Evaluation of Designs

Several options exist while designing the vision inspection system, one of the most important being to select a software package. Through the internet, magazines, and advice from professors and industry experts, we narrowed the vast and varied field of vision inspection software to a few products which seemed suitable for our application.

Please see the information in the Market Research Review section of this paper for information about the products we considered in depth including packages from Banner, Texonics, Omron, FSI, and National Instruments.

The possibilities are endless with regard to cameras for this system. For a system on one conveyor line, we will need at least two cameras.

The first question in the design was whether or not to add a new conveyor to the system. This would be expensive and require a rearrangement of the ovens, but would also allow for a consistent background color and speed for the patties. With a proper cleaning mechanism, it would ensure an environment that is in the best interests of successful product inspection. The alternative to this would be to film the patties on the wire rack belt without adding a new conveyor. The wire rack is a difficult hurdle for a vision system, and the darker background underneath makes it even more difficult for the patties to be found against the shadows.

We considered several methods for triggering the camera. A trigger allows the camera to take a picture only when the patties are passing in the field of view, making sure the patties are always in the same place for the camera. Laser triggers could be incorporated so that the camera snaps an image a certain time delay after a laser beam is broken. An alternative to this is a mechanical trigger, with plastic or metal "fingers" touching the conveyor surface and being deflected by a patty moving down the line. A third alternative is to set the trigger on a time lag with the extruder's signal. Every time the extruder makes patties, a time delay occurs and the camera takes a picture after a time depending on the speed of the conveyor. A final alternative is to set the camera rate at a high speed, and allow it to find the patties on its own. This will require much more processing power.

The next decision is the positioning of the controller. Since the oven room is very hot when in operation, the controller's vulnerability to heat was in question. One alternative is to place the controller in a climate-controlled box or to have plenty of cooling around it. The other option is to extend the wires to the controller and to place it outside the oven room in a moderate temperature and humidity environment. This may slow the speed of the data through the lines, but would ensure the correct operation of the controller over long periods of time.

Finally the question of where to place the cameras looms. There will be more than one camera so the patties can be inspected on both sides. There may also be a camera in the transition room en route to the freezer to check the second flip. The guiding factors in the placement decision are the placement of a future rejection device and available space.

Determination of Design

With the alternatives for each design decision in mind, the issues were addressed. After using trial versions of several software packages, meeting with representatives from several companies, and not receiving replies from several companies, we decided that NI Vision Builder AI 3.0 will be the best fit for our system. The company has a good reputation for being competitive and customer service. The system can do everything we have specified above and be connected to a variety of cameras. It is robust enough to handle the job and carries a good price tag (see Proposed Budget).

Currently, we have not determined a specific camera to recommend to Lopez. For our research in the lab, we are using Dr. Weckler's Sony Firewire camera.

We used NI Vision Builder to do preprocessing work on the images including converting the color image to grayscale and doing threshold work to reassign each pixel in the image to black or white. In some photographs, the patties were difficult to distinguish because the background had such similar shades of colors. Patties were easily located by this software package in pictures taken after Flip 1 where a white plastic shield had been placed under the conveyor belt (see Figure 4). The color was arbitrary; however it was very good for a background. Adding white plastic background under each camera, as an alternative to adding conveyors, was agreed upon as the best alternative. Not only is it cheaper to incorporate, but will not require more conveyor space in the already filled room.

No Background White Plastic Background

- Figure 4 – Comparison of Background Interference

Each option for the triggering mechanism has pros and cons. Lasers are accurate and an accepted practice in vision inspection. Using "fingers" to detect patties runs the risk of changing the patties' positions on the conveyor so that the processor does not get an accurate idea of the patties' positioning in the oven. Setting the trigger with the extruder would work only if the belts ran at a constant speed all of the time, which cannot be depended on. Having the camera continuously snap pictures is a waste of processing. Of the four options, the best would be to use a laser trigger. This would mean that the camera would only take pictures only when it absolutely needed, reducing the data to be processed to only one image per row of patties.

In considering placement of the processing unit, we determined the best place is outside the room. Research showed that time lag in the wires will not be an issue for this distance of only a few meters. Another positive outcome of placing the controller out of the room is it will be next to all other controllers for the rest of the facility.

The placement and number of the cameras depends purely on necessity as determined by Lopez managers. Since cameras are expensive and will each require processing time, it is imperative to have as few as possible, while ensuring product quality. Our plan for now is to design a system with two cameras: one inspects the patties before the initial flip and one shortly afterward before the patties go into the second oven. This will allow space for a rejection mechanism on the other end of or in the middle of the second oven. Also, the system designed to work between the two large ovens can be reproduced and placed anywhere else deemed necessary.

Though the patties are flipped again on their way into the third oven, this oven is only for reheating uses to obtain a certain color and to guard against the problem that we will solve with the vision system. With the system in place and functioning, all failed patties that were overlapped or defective will have been removed by the time the product reaches the third oven.

Task List and Project Schedule

Please see Appendix 3.

Proposed Budget

Component	Estimated Cost
Processing Unit (for now we can use a desktop)	$2000
White Background	$100
2 Cameras	$2000
Software Package	$1500
Cables	$200
2 Lens	$400
Holding Bracket	$100
Laser Trigger	$200
Lucite Shielding Box	$100
Total	$6400

Acknowledgements

GRO Engineering would like to thank several people:

- Dr. Paul Weckler – Senior Design Advisor
- Dr. Tim Bowser – OSU BAE Food Engineer
- Bill Quimby – Lopez Project Contact
- Dr. Kevin Nanke – Lopez Engineer
- Craig Trible – BAE Information Technology

Appendix 1

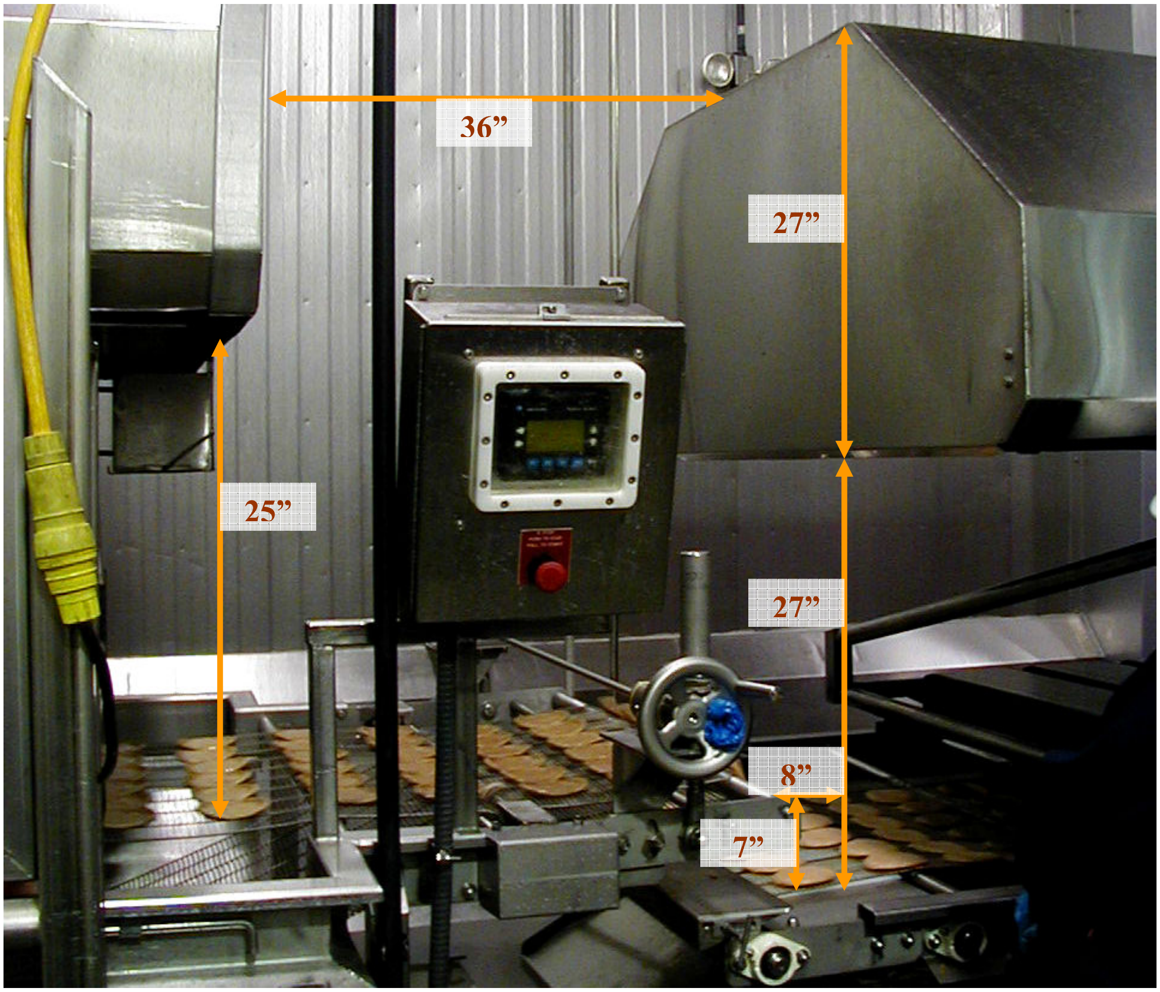
Non-satisfactory patties:

Overlapped patties causing undercooked crescent-shaped piece.

Meat scraps on patty. Scraps burn from being too close to oven and cause undercooked place on patty.

Patty folded over. When unfolded, reveals undercooked meat.

Appendix 2



Appendix 3

Task List:

- Modeling
  - Develop a model of oven lines
    - Obtain space in the BAE Lab
    - Have model of the oven lines built
    - Obtain patties from Lopez to use as models
- Research
  - Find a software system that will effectively meet the needs outlined in our mission statement
    - Meet with sales representatives from possible providers
    - Determine the three most likely systems
    - Present findings and our recommendations to Lopez
    - Gain Lopez's consent to purchase software
  - Find hardware that will work in conjunction with software that will meet the needs as defined in our mission statement
    - Determine the software system's compatibility with hardware
    - Check for hardware in the BAE Lab
    - Purchase hardware if needed for simulations
    - Buy hardware for Lopez with their consent

- Simulation
  - "Teach" software
  - Test inspection system on model images
    - Run the vision inspection on model lines to test for accuracy
    - Develop ideas for improving accuracy
    - Obtain samples from Lopez to use in testing
      - Test on actual samples

- Experiments
  - Set up inspection system at Lopez
    - Set up inspection software and hardware
      - Develop any necessary housing for hardware
      - Have housing built (if needed)
  - Test inspection system on running line
  - Develop ideas for improving accuracy
  - Implement new ideas

- Physical Testing/Data Collection
  - Obtain the quality control information from Lopez

- Purchases
  - Vision Inspection Software
  - Hardware (possibly)
  - PLC (possibly)

- Travel:
  - Lopez Foods
  - See Software in a production setting (possibly)

- FAPC/BAE Lab Resources
  - Vision Systems Lab
  - Camera Equipment
  - Space for modeling oven lines
  - Check to see if there is any type of conveyor we can use

Project Schedule

ID		Task Name	Duration	Start	Finish
1		**Senior Design Project**	**75 days**	**Mon 8/28/06**	**Fri 12/8/06**
2		Select Projects	10 days	Mon 8/28/06	Fri 9/8/06
3		Select Team Leader	1 day	Mon 9/11/06	Mon 9/11/06
4		Select Group Name	1 day	Tue 9/12/06	Tue 9/12/06
5		Set up Group Meeting Times	1 day	Mon 9/11/06	Mon 9/11/06
6		Set Team Goals	1 day	Wed 9/13/06	Wed 9/13/06
7		Schedule Sponsor Visit	5 days	Mon 9/11/06	Fri 9/15/06
8		**Begin Research**	**60 days**	**Mon 9/18/06**	**Fri 12/8/06**
9		Literature Review	35 days	Mon 9/18/06	Fri 11/3/06
10		Patent Searches	31 days	Mon 9/18/06	Mon 10/30/06
11		Magazine Review	31 days	Mon 9/18/06	Mon 10/30/06
12		Software Review	31 days	Mon 9/18/06	Mon 10/30/06
13		Visit Sponsor	1 day	Mon 9/18/06	Mon 9/18/06
14		**Define Problem**	**25 days**	**Mon 11/6/06**	**Fri 12/8/06**
15		Develop Mission Statement	1 day	Mon 11/6/06	Mon 11/6/06
16		Develop Ideas and Concepts	1 day	Mon 11/6/06	Mon 11/6/06
17		**Focus Research**	**24 days**	**Tue 11/7/06**	**Fri 12/8/06**
18		Literature Review	21 days	Tue 11/7/06	Tue 12/5/06
19		Software Review	21 days	Tue 11/7/06	Tue 12/5/06

20		Request Trial Softw are	1 day	Wed 12/6/06	Wed 12/6/06
21		**Set Up Visits and Meet with**	**24 days**	**Tue 11/7/06**	**Fri 12/8/06**
22		Banner Representative	1 day	Tue 11/7/06	Tue 11/7/06
23		Omron Representative	4 days	Thu 11/9/06	Tue 11/14/06
24		Texonics Representative	2 days	Wed 11/8/06	Thu 11/9/06
25		**Determine Work Area**	**24 days**	**Tue 11/7/06**	**Fri 12/8/06**
26		Set up Lab	1 day	Tue 11/7/06	Tue 11/7/06
27		Set up Computer	1 day	Tue 11/7/06	Tue 11/7/06
28		Set up Camera	1 day	Thu 11/9/06	Thu 11/9/06
29		Test Trial Softw are	18 days	Tue 11/7/06	Thu 11/30/06
30		**Visit Sponsor**	**21 days**	**Fri 11/10/06**	**Fri 12/8/06**
31		Record Measurem	1 day	Tue 11/21/06	Tue 11/21/06
32		Take Photograp	1 day	Tue 11/21/06	Tue 11/21/06
33		Take Photograp	1 day	Tue 11/21/06	Tue 11/21/06
34		Determine Engineerir	1 day	Tue 11/21/06	Tue 11/21/06
35		Determine Sponsor	1 day	Fri 11/10/06	Fri 11/10/06
36		**Begin Work on**	**13 days**	**Wed 11/22/06**	**Fri 12/8/06**
37		Develc Recom	7 days	Wed 11/22/06	Thu 11/30/06
38		Invite Spons	1 day	Wed 11/22/06	Wed 11/22/06
39		Develc Pow er	1 day	Wed 12/6/06	Wed 12/6/06
40		Oral Preser	1 day	Fri 12/8/06	Fri 12/8/06

Vision Inspection System

Josh Grundmann, Sarah Rowland, Ashley Oulds
Advisor: Dr. Paul Weckler
Prepared for Lopez Foods
Course BAE 4012
December 8, 2006

Mission Statement

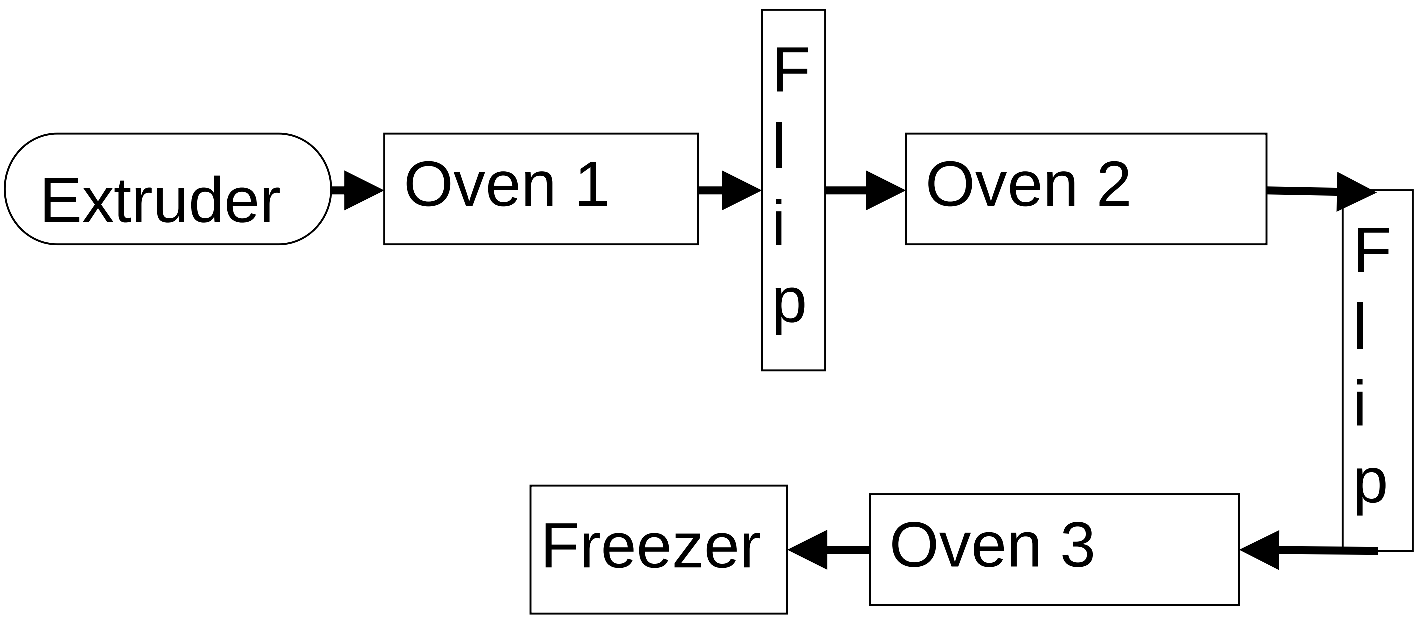
- GRO Engineering is a consulting group dedicated to assisting clients in solving food design and control problems. The solutions developed will increase overall production efficiency to further the client in customer satisfaction and profit.

Lopez Foods

- Provides frozen, pre-cooked sausage patties to major food corporations
- Recognized as an industry benchmark in:
  - Food and plant safety
  - Quality production
  - Environmental protection
  - Customer service

Introduction to Problem

- Each patty is subjected to two flips in order to ensure proper cooking



Introduction to Problem

- Patties that are “unacceptable” are removed by a quality assurance worker

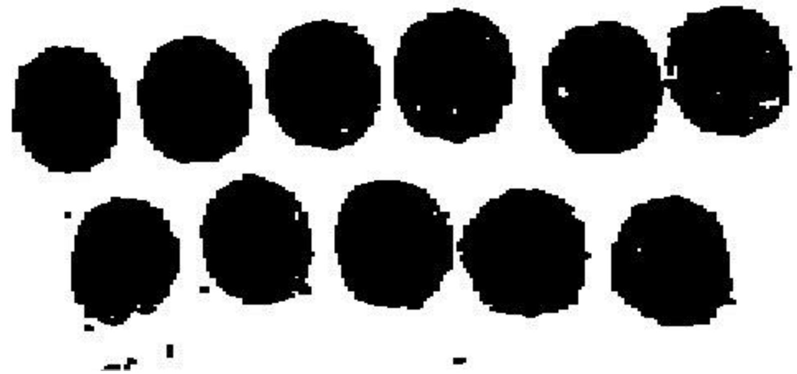
Project Requirements

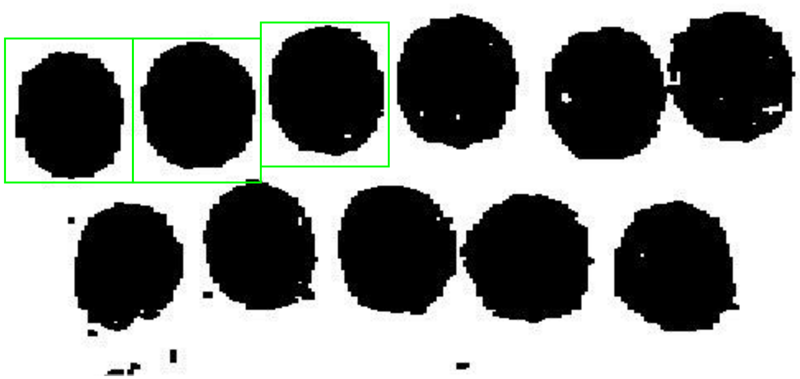
- Identify defective patties
- Communicate location to rejection mechanism
- Be easily cleaned
- Be user-friendly

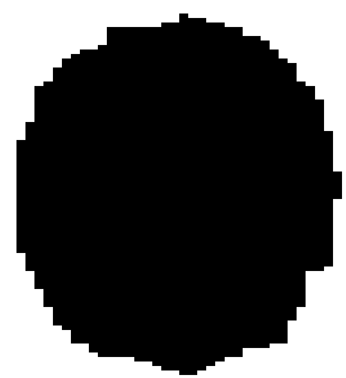
Software Requirements

- Locate several objects in image
- Use as many cameras as needed
- Be consistently accurate
- Color if possible
- Simple interface for user

Software Process







Software Options

- Banner
- Texonics - NetSight
- Omron – F-series
- FSI Automation – XCaliper
- National Instruments – Vision Builder

Hardware Requirements

- Wide picture – 30” field of view
- Background – Can processor see patties?
- Be rugged and easily shielded
- Be user-friendly

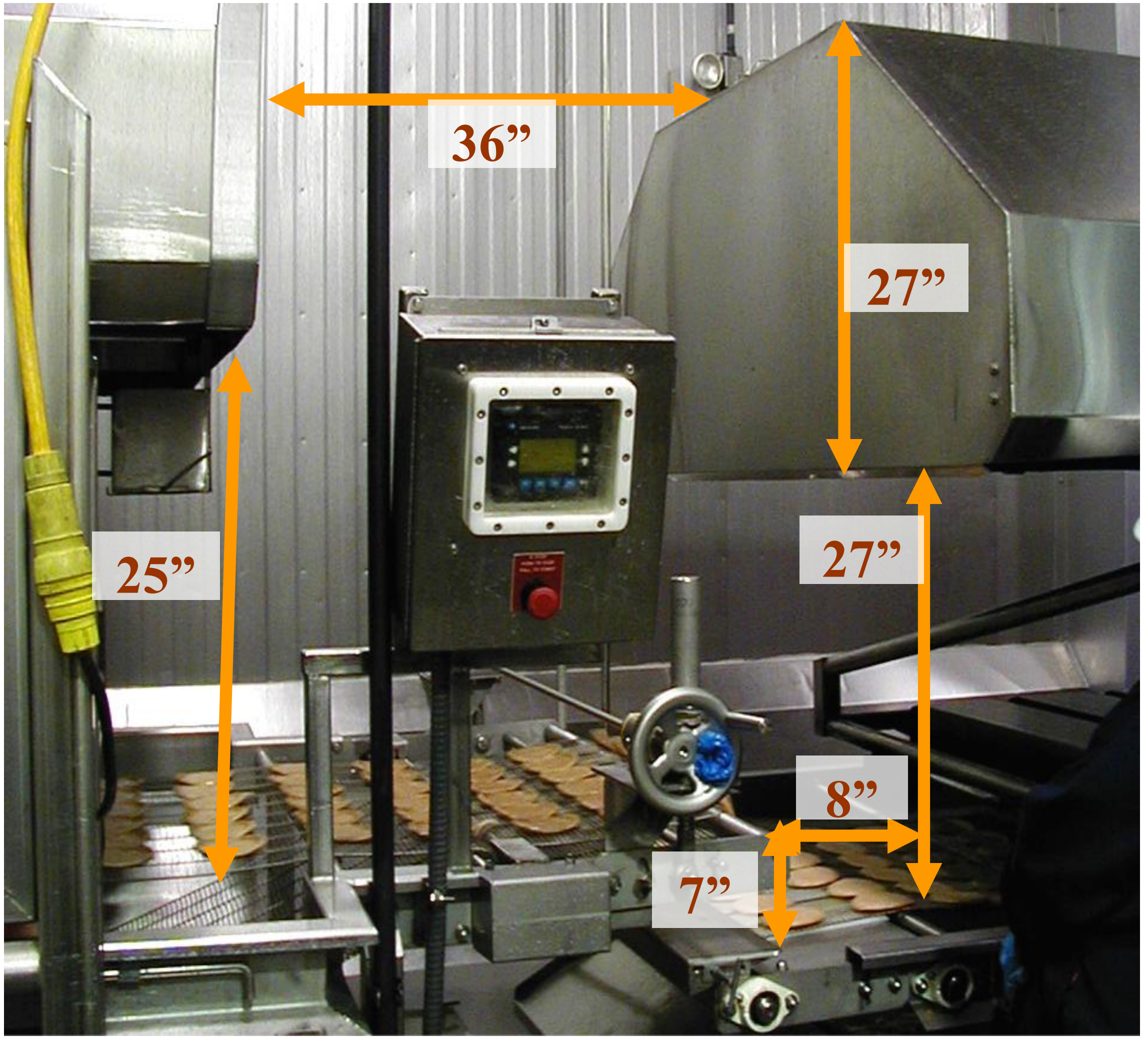
Hardware Options

- Type of camera
- Lens Options
- Communication with processor
- Shield
- Lighting

More Specifications

- Patty size – 3.75” +/- 0.25”
- Conveyor – one row per second
- Camera Positions
  - Before first flip
  - After first flip

Space Between Ovens



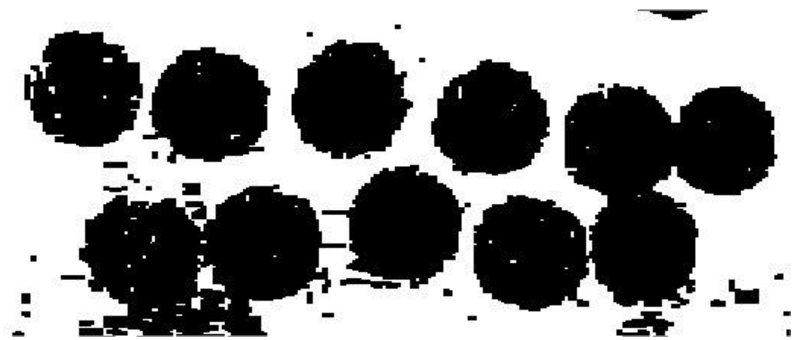
NI Vision Builder AI 3.0

- Good company
- Robust
- Economical Price
- Easy-to-use

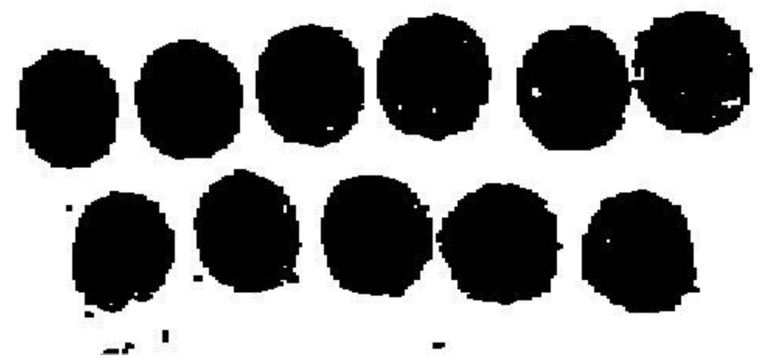
Camera Specifications

- Firewire connectivity
- Lens must have working distance of one meter and must see entire width of belt
- Currently researching with Sony V-50 grayscale camera

Importance of Background



No background

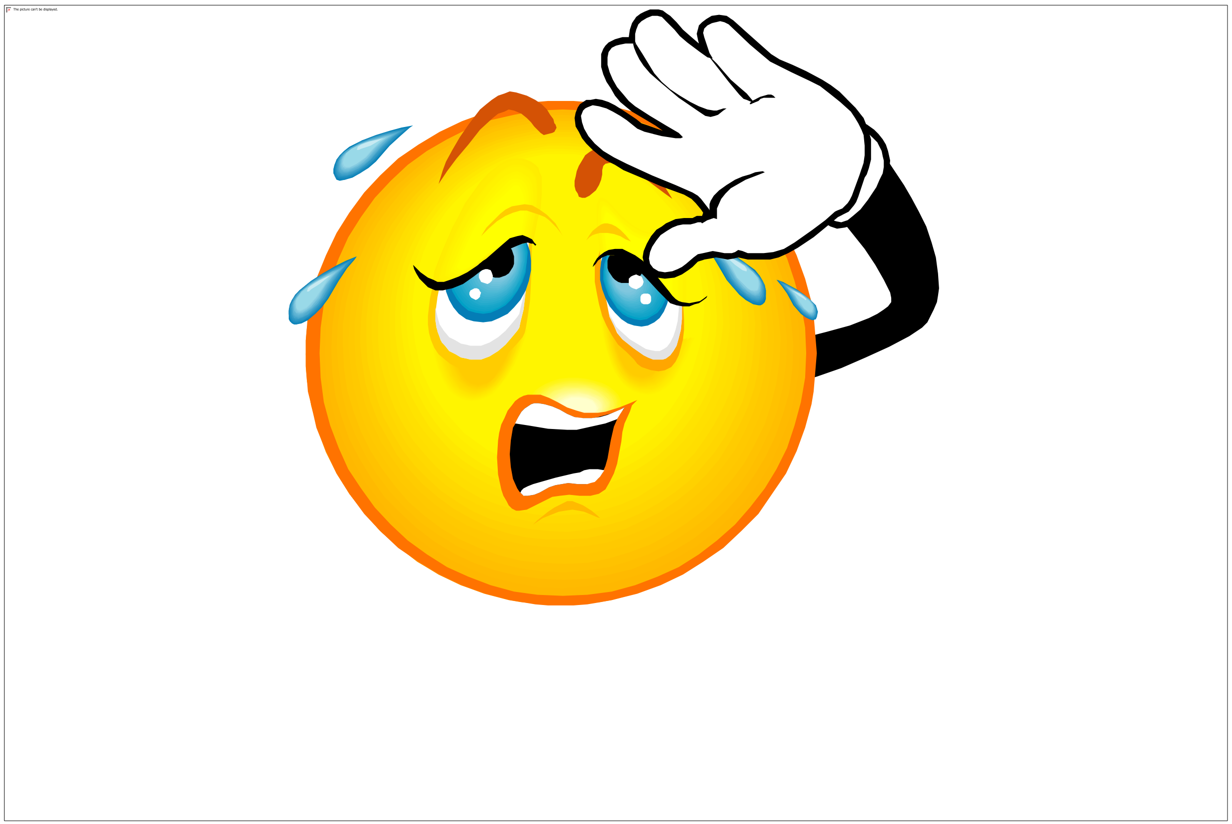


White Background

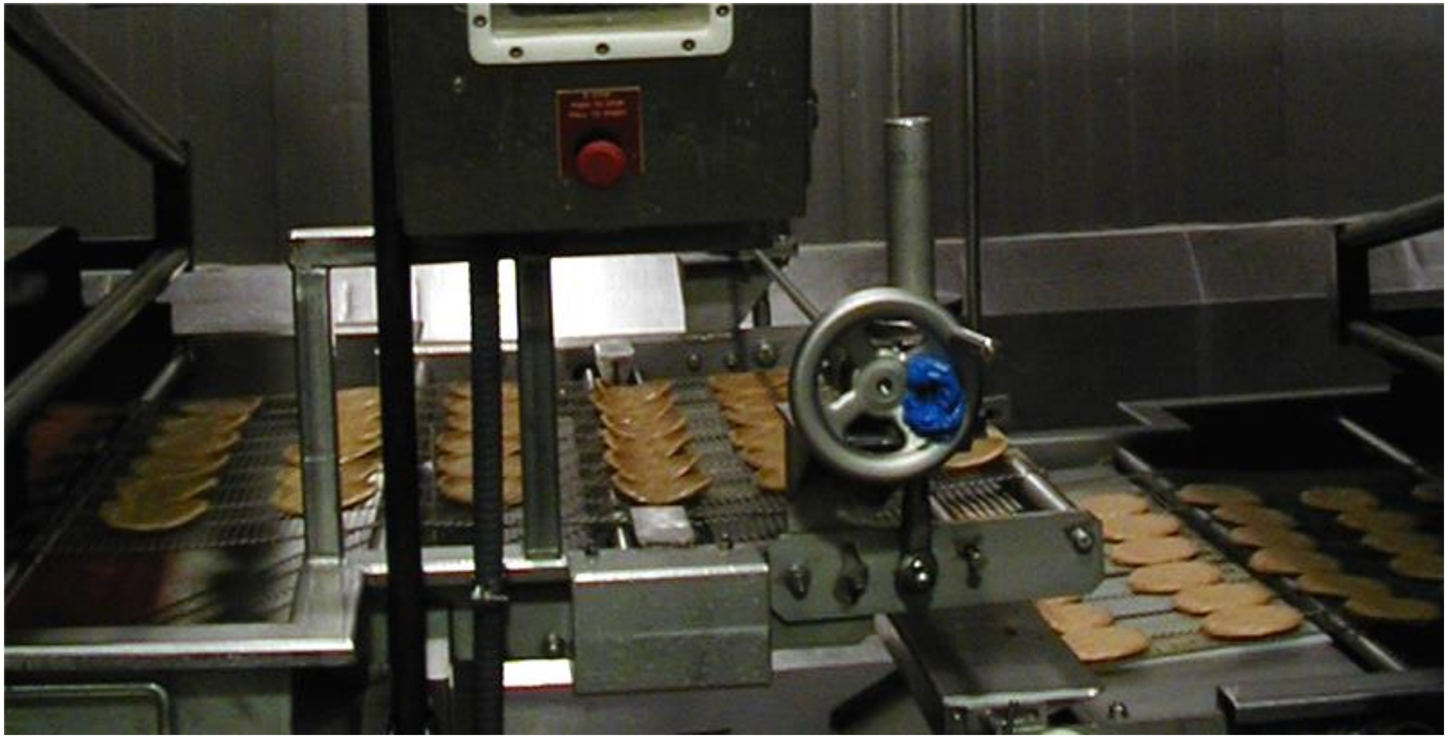
Trigger

- Laser
- Mechanical
- Extruder
- None

Put the unit outside oven room



Number of Cameras



Plans for Next Semester

- Purchase
- Program
- Implement

Budget

Component	Estimated Cost
Processing Unit (for now we can use a desktop)	$2000
White Background	$100
2 Cameras	$2000
Software Package	$1500
Cables	$200
2 Lens	$400
Holding Bracket	$100
Laser Trigger	$200
Lucite Shielding Box	$100
Total	$6400

Thank you!

- Dr. Paul Weckler
- Dr. Tim Bowser
- Bill Quimby
- Dr. Kevin Nanke
- Craig Trible

Questions and Comments?

¿ ?