# KINECT-BASED RGB DETECTION FOR 'SMART' COSTUME INTERACTION

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## Abstract

This paper is an overview of a Kinect-based RGB detection software developed as part of an ongoing 'Smart' (Smart Textiles and Wearable Technology in Pervasive Computing Environments) Costume project. The project involved a multi-disciplinary team in the domains of textile design, engineering and computer science. In this work we aimed to establish initial studies on how the Microsoft Kinect performs in tracking a 'smart' costume that has thermochromic elements under different lighting conditions. We explain the computer application capable of detecting, tracking and measuring colour changes (Red, Blue and Green) created using the Microsoft Kinect API.

**Keywords:** Kinect, Thermochromics, Smart Costume, Performativity, Textile Design, Multidisciplinary,Colour-change Detection

## Introduction

Designing with thermochromic and fluorescent dyes is a carefully planned process where heat and light creates pattern with colour which evolves as the costume changes. The same can be said for designing with the Kinect, using it as a tool to establish another level of design to the overall 'performativity' of the costume and its environment. Thus it is essential to establish precisely how these dyes are perceived by the Kinect under different lighting conditions. This paper describes research undertaken to determine whether or not Microsoft Kinect was appropriate for use as a controller and tracker for a colour changing costume. This research was validated through two distinct experiments in which several thermochromic samples were subjected to four different lighting environmental conditions. The RGB values of each sample were collected under each lighting environment and compared to a benchmark RGB reading taken from a high-resolution digital reading. Our results consolidate existing common knowledge that indicates that lighting conditions significantly affect the Kinect's performance, and that it performs better under higher lighting conditions. This is of particular interest for colour changing costumes that will be subject to a multitude of lighting conditions in the performance space. Our results also showed that lighting conditions significantly affect the colour that is detected through a Kinect device and that green is the colour most affected. This is important as the colour choice of the designer will then be dictated by the performace of the Kinect under different lighting conditions and therefore could be used as a design tool.

A second aim of the project was to create an automated colour detection mechanism through which a change in colour would act as a trigger and work as a catalyst for subsequent colour changes to take place. This would enable a 'Smart' costume to continuously change throughout a performance and create a cyclical process of events. The possibility of combining associate computer vision knowledge and technologies within the performing arts has precedence, and several practitioners [1, 2] have combined dance with the use of pervasive computing and colour changing textiles. There is, however, little prior evidence showing a combination of computer vision knowledge and colour changing textiles in the performing arts. In this project we have looked at the possible integration of the Kinect sensor with an interactive space (dance environment) in which the Kinect device would be used in detecting colour changes in a prototype dance costume (Figure 1). Based on the nature and characteristics of these changes, the system would alter the dance environment (i.e. temperature and lighting conditions). Since the dance environment lighting conditions can rapidly and repeatedly change during a performance, it is essential for this research to investigate:

- The performance capabilities of the Microsoft Kinect under different lighting conditions
- The relationship between lighting conditions and colour detection.

Since previous research related to this particular subject area has mainly been concerned with the reading of skin colour, we decided to concentrate on the core aspect of colour detection and try to understand how, in such a context, lighting can affect the colour detection capabilities of the Kinect.

In this paper we describe the development of a computer application that will be used, among other things, to measure Kinect's Sensor performance under different lighting conditions. We also discuss the building of a colour changing costume and how we use different lighting to produce different colour effects and how the Kinect could be used as a catalyst for change during the course of a performance.

**Fig.1. Dance Tutu 1, Origami Structure Screen Printed with Thermochromic and Fluorescent dye on silk with tulle net. (Photo © Lynsey Calder)**

## Context

This 'Kinect' project is part of a larger research project named 'Smart Costumes'. Initially the project concept was to explore how different technologies could be connected with each other in a system. We created a possible scenario describing how the system could operate, and this was conceptualised as follows: a performer, wearing a colour-changing smart costume and performing a choreographed dance, will be tracked using a Kinect sensor. The Kinect sensor will be connected to a computer that will be running an application that will fire a specific event depending on the colour change detected on the smart costume. The computer will be connected to an electronic switch, which in turn will be

**Please reference as: [Author(s)-of-paper] (2013) [Title-of-paper] in Cleland, K., Fisher, L. & Harley, R. (Eds.) *Proceedings of the 19th International Symposium of Electronic Art*, ISEA2013, Sydney. http://ses.library.usyd.edu.au/handle/2123/9475**
**Page numbering begins at 1 at the start of the paper.**

connected to a heat source and a cooling source. Depending on the output generated by the specific application event, the electronic switch will turn the heat source on and the cold source off, or vice versa. This will make the environment or textile temperature change, which consequently will make the colour of the smart costume change. This cycle will be repeated until the end of the performance. During the entire performance, the computer application will also track and record the space position data of the performer.

With regard to this project, being just a small part of a much bigger project, several other requirements were identified. One of the objectives of the 'Smart Costumes' project is to build a complex system integrating smart costumes with emissive and non-emissive colour-changing technology (thermochromic and fluorescent) and interactive spaces. Considering the possible scenario described above, it was required that the application should be able to:

- Track and record the space position data of the performer. (This data will be used later for the creation of beautiful data visualisations or infographics)
- Automatically detect colour changes in the smart costume and, depending on those changes, fire an event that will later be used to turn an electronic switch on or off
- Develop an application that will allow researchers to create new software applications based on the work developed
- Create software documentation

## Evaluation Criteria

The following criteria were used to evaluate the success of the project:

- Is the application able to detect colour change?
- Is the application able to track colour?
- Is the application able to track and record the space position data of the performer?
- How well can Kinect perform under different lighting condition?
- How does light affect the colour that is detected by Kinect?

The developed application allows its users to detect and track a certain colour in a real-time image captured by the Kinect Sensor (Figure 2), and perform several different tests based on that im-

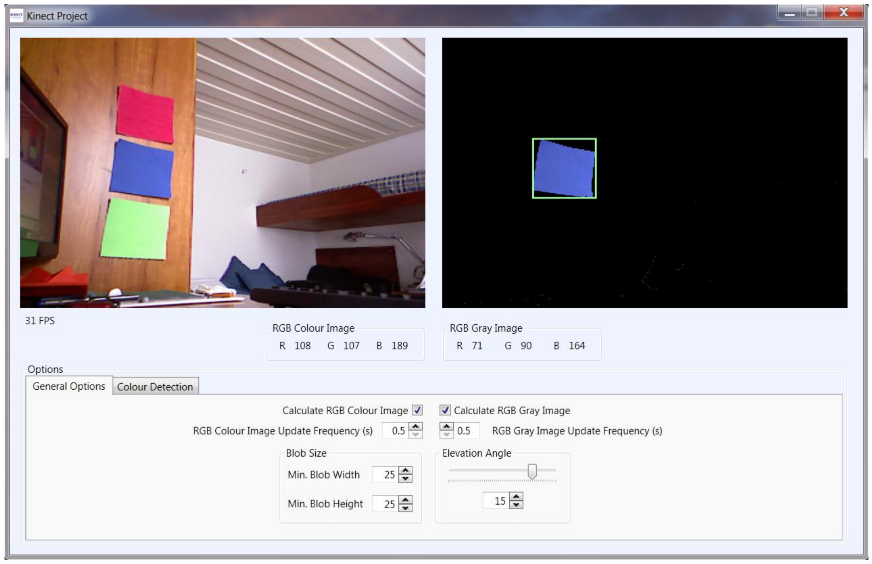



**Fig. 2. Application main window (Photo © Jose** Magalhaes)

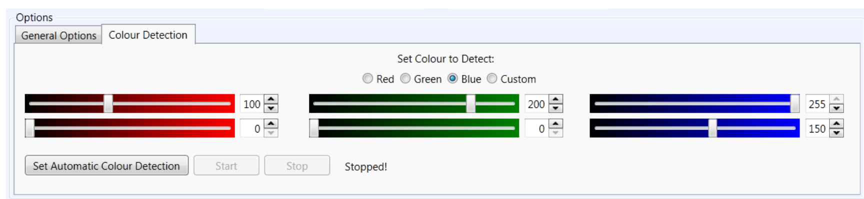



**Fig. 3. Colour detection options (Photo © Jose Magalhaes)**

age. In order for the process to be simple and easy for a new user to access, a simple interface was created that maintained a common look throughout.

## Implementation of Colour Detection Mechanism

The application starts by receiving the colour image being captured by the Kinect Sensor – the image displayed on the left hand side window ("Colour Image"). The colour image then goes through image processing routines and the result is displayed on the right hand side window ("Gray Image") where we can see if the colour is being detected or not (see Figure 2).

To treat the received images we had two options:

1. Create a Bitmap every frame, or
2. Create a Writeable Bitmap during the first frame and then use it on the other frames.

Initially it was thought that using the second option of creating a Writable Bitmap during the first frame, and then using it on the other frames would be more efficient than creating a Bitmap every frame. This decision was made during the initial stages of the development and proved to be unsuccessful. At a later stage of the development, when we started to implement the image processing routines, we found that the image saved in the Writeable Bitmap would need to be converted to a Bitmap, so that those and the blob detection routines would work. This led to the creation of a method that converts a Writeable Bitmap into a Bitmap, creating a new Bitmap each time the application fires (which is in each frame).

To perform the colour detection we used an image processing technique called blob detection. Blob detection is a technique that detects points and/or regions in an image that differ in properties, for example brightness and colour, compared to its surroundings [3].

Before the blob detection routine can be applied, the colour image needs to be filtered by colour – the filter removes the background leaving it completely black with only stand-alone objects with a certain colour being visible – and then transforms this into a grayscale image. To perform these operations, some other AForge.NET routines are used. The AForge.NET colour filter filters pixels inside and outside of a specified RGB colour range, keeping the pixels with colour inside the specified range and filling the rest with a specified colour (in this case, black). The "Gray Image", in the Main Window, shows an image after the filter has been applied. In that image we can see that the filter keeps the pixels that are inside the defined range and fills the rest of the pixels with black. If no filter was applied, or if the RGB colour ranges were all 0 (lower value of red, green and blue range) and 255 (higher value of red, green and blue range), the image displayed would be exactly the same as the one displayed by the "Colour Image".

After this process, the image is converted to a grayscale image using an AForge.NET image grayscaling routine. It is also important to mention that we can see if a certain colour is being detected if, in the "Gray Image", in the Main Window, a green box is drawn around the colour/object.

When a colour is being detected, the average RGB values of that colour are calculated. Those calculations are based only on the pixels inside the green box.

## Evaluation Method

Twelve different samples (twelve pieces of fabric, three of which were printed with one colour pigment dye and nine were printed with a combination of a one colour pigment dye and a thermochromic dye) were submitted to two different detection procedures.

In the first procedure, the RGB values for each sample were calculated based on high resolution pictures taken under a specific lighting condition (Light 0), using a digital camera. The aim of this exercise was to measure the RGB values of each sample under a controlled lighting environment and determine a baseline for kinect-based RGB detection.

In the second procedure, we submitted the same samples to three other different lighting conditions (Light 1, Light 2 and Light 3) and measured the RGB values for each sample using a Kinect sensor and the application we developed for this project.

This study used a within-subjects design. There was one independent variable with four conditions: lighting condition (with four levels: Light 0, Light 1, Light 2 or Light 3). Each sample was tested under the four different lighting conditions and for each, the Red, Green and Blue colour values were measured. Both procedures were based on twelve samples (i.e. pieces of fabric printed with one colour pigment dye, or, a combination of a one colour pigment dye with a thermochromic dye) created for this project.

**Procedure 1:**

To collect the data under a controlled lighting environment, we set up the first experiment which allowed us to take a high resolution picture of each sample. In a dark room two Elinchrom D-Lite 400 lights and a Canon EOS 5D MK II digital camera were set up facing a white marker. After calibrating and configuring all necessary parameters of the machines, we placed our first sample in front of the camera, turned off the lights, and took a picture. For each sample with thermochromic dyes, first a picture was taken before heat had been applied to the sample. After taking that picture, we applied heat to the same sample using an iron. After heating up the sample, we placed it in front of the camera, turned off the lights and took another picture of the same sample, which had now a different colour. This process was repeated for all the other samples. The RGB values for each sample were calculated using the Histogram function (i.e. Mean values) in Photoshop CS5.

**Procedure 2:**

Once we had collected data for each sample under controlled lighting conditions (procedure 1), we set up an experiment in which we collected data under three other different non-controlled lighting conditions, using our application.

Three different measurements were performed at three different times during a day. At the beginning of each of the three different measurements, we used a light meter to measure the amount of light that the sample would be exposed to at the moment of the experiment. The first measurements were performed in the middle of the day, with high natural lighting (Light 1), meaning the samples were exposed to ≈2490 lux of light. The second measurements were performed at the end of the day, with low natural lighting (Light 2), meaning the samples were exposed to ≈28 lux of light. The third and final measurements were performed at night, with no natural lighting, and recurring to artificial lighting (Light 3), meaning the samples were exposed to ≈71 lux of light.

In a room with plenty of natural lighting, a Kinect sensor, which was connected to a laptop running the developed application, was placed facing a wall. To test the first sample, we attached it to the wall directly in front of Kinect and configured the application to detect the sample colour. When the colour was detected, the RGB values were automatically calculated and that data recorded. For each sample with thermochromic dyes, a first measurement was made before heat had been applied to the sample. After recording the necessary data, we applied heat to the same sample using an iron. After heating up the sample, we repeated the same process as described above. This process was repeated for all the other samples.

## Results and discussion

The main result of this study was that Kinect performs better under high lighting conditions rather than low lighting conditions. This result also shows that lighting conditions significantly affect the colours that are detected by the Kinect sensor. This is especially true for low lighting conditions, where the colours detected by Kinect are significantly affected. It is also possible to conclude from these results that, between the 3 different RGB colours, the green colour values are the ones that are most affected by the lighting conditions.

Figure 4 shows the mean values of the Red, Green and Blue colours for each lighting condition. The errors bars represent the 95% confidence interval for the mean. When comparing the measured RGB values under Light 0 with the values measured under Light 1, 2 and 3, it is clear that, as expected, the RGB colour values detected by Kinect are highly affected by light. It also suggests that the RGB values detected by the Kinect are more sensitive under the lower lighting conditions, Light 2 and Light 3, thus providing helpful information as to the

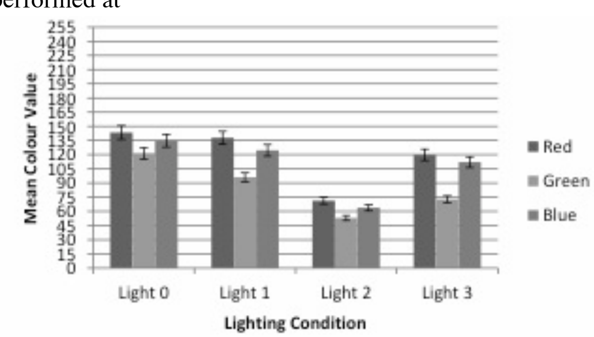



**Fig.4. Effect of lighting on RGB detection**

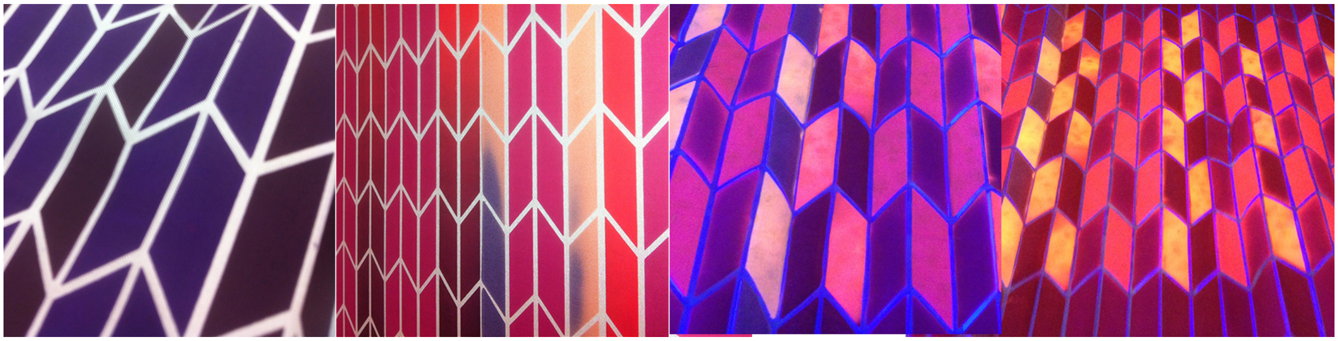


**Fig. 5. Thermochromic printed textile under three different heat and light conditions (Photo © Lynsey Calder)**

potential use of such technology in live performances.

Potential problems could arise in a scenario where the application was developed and Kinect would be used to automatically detect several different colours under very low lighting conditions. One main problem would be the difficulty in distinguishing between different colours. In a scenario where good lighting conditions are used, results suggest that Kinect and the developed application would have good performance, being able to detect a specific colour from a wide range of different colours with a considerable level of accuracy.

It is also important to mention that, although the results showed that there is a significant difference on the colour detected under Light 0 when compared to Light 3, lighting conditions similar to Light 3 would still be possible to use in a real scenario. The performance would be worse, but the developed application and Kinect would still be able to detect different colours with a certain level of accuracy.

## Colour changing technologies in performance and performativity

As part of the larger theme of 'Smart Costumes', Silk twill fabric samples were screen-printed with a combination of thermochromic and fluorescent dye systems (Figure 5). The combination of thermochromic dyes (non-emissive) and fluorescent dyes (emissive) provides a transition from dark blue/purple to fluorescent red, orange and pink which glows under UV light. As the thermochromic dyes (which resembles purple in this combination) go through a transition to colourless (on temperature change) the red, orange and pink fluorescent pigments are revealed (see Figures 5, 6 & 7). This combination is designed to create, firstly, a colour change and secondly an emissive fluorescent effect. It is

hoped that the development of the Kinect application will be used in combination with the costume seen in Figures 6 and 7 in an interactive dance space. The desire is to use the Kinect to discern a change in the costume appearance (see Figure 8) which can then trigger or fire another event which will in turn create a second change in the appearance of the costume.

**Fig. 6. Thermochromic screen printed tutu in unchanged non emissive state (Photo © Lynsey Calder)**

## Conclusion

As part of the 'Smart Costumes' project, the concept of using the Kinect to detect and promote a colour change through a cyclical chain of events was explored, discussed and evaluated. The initial idea and experiments raised questions about Kinect's performance with respect to detecting colour changes under different lighting conditions.

Through the creation of a new software application that is capable of detecting, tracking and measuring colour, as well as automatically detecting colour changes in real time images captured by the Kinect sensor, we were able to conduct an initial study about the Kinect's performance under different lighting conditions. The evaluation results showed that lighting conditions significantly affect Kinect's performance, and that Kinect performs better under high lighting conditions than under low lighting conditions.

Taking into account the results of this study, we suggest that should the 'Smart Costumes' project make use of the developed application and Kinect in a real dance environment, and that an environment with low lighting conditions should be avoided. Other than that, the developed application and Kinect should display good performance and be able to automatically detect and track changing colours in a smart costume.

This new software represents a tool which can be used by the 'Smart Costumes' project in their research. Its user-friendly interface will allow current and future researchers to readily operate it in a short period of time. The code was developed and recorded in such a way that will also allow current and future researchers, with technical knowledge, to add new features to the application very easily.

We cannot say, however, that "everything is done", and in that case there is some future work that can be developed. One of the non-mandatory requirements of the developed application was to use Kinect's depth sensor to track and record a performer's space position data, a feature which, due to the lack of time, was not possible to develop. Kinect's depth sensor can be easily integrated into the developed application in the future, which will allow additional features to be added to the application.

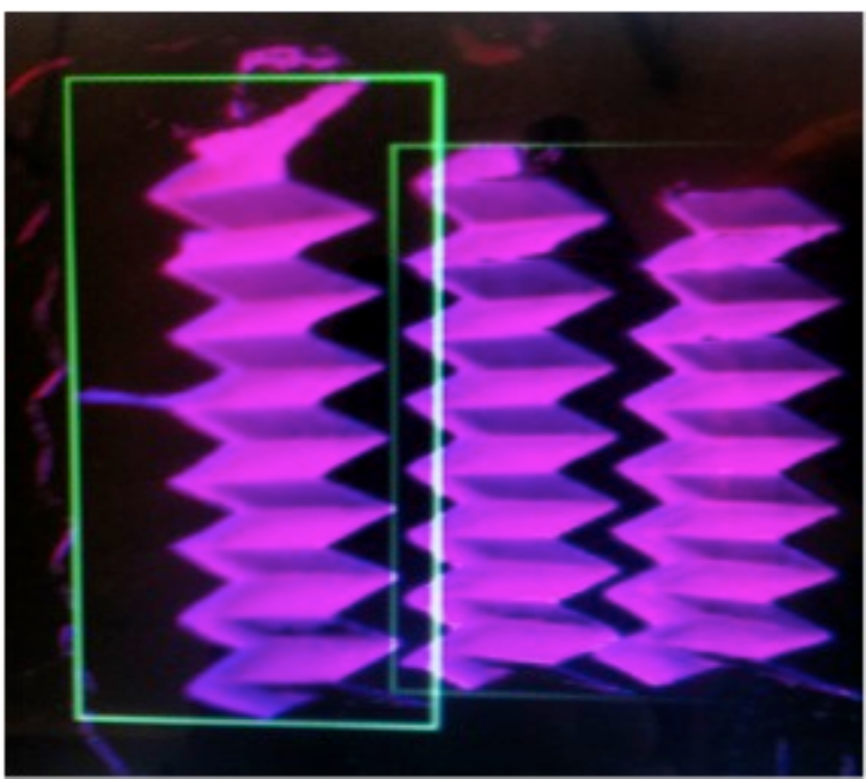
**Fig. 7. Thermochromic and fluorescent screen printed tutu in mid change (Photo © Lynsey Calder)**

The next step in this research will be the integration of the developed application into a pervasive computing environment or dance space as previously discussed. This is something that is currently being explored and the costume, which is close to completion, will be tested with the Kinect and other embedded electronic components. After successful integration, many more studies can be performed based on this project and on the developed application.

It is believed that some technical improvements can also be performed on the application, mainly in the code. However, in terms of technical work, we would like to adapt (port) the application so that it can run on operating systems other than Windows.

In future research, we hope to perform the same experiments under several different and more varied lighting conditions, especially brighter lighting conditions and UV (Ultra Violet). This would enable the collection of further data which could be used to extend this study further. The fact that the initial experiments were conducted under a non-controlled lighting environment made the possibility of controlling all variables impossible; data collected would almost certainly vary slightly if collected again under the same lighting conditions. Therefore, it would be advisable to perform those experiments under controlled lighting environments. The use of a controlled environment to test the lighting conditions would increase the validity of the results.

**Fig. 8. Kinect software picking up an origami magenta thermochromic sample (Photo © Lynsey Calder)**



In conclusion, different techniques to check how accurate the values read by the application developed could also be used. This would allow researchers to compare the values and analyse the application's accuracy in relation to the 'Smart Costume'.

A discussion of the performativity of the costume itself will form the focus of future publications as the project evolves.

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