

**Facial Recognition as a tool to determine if students understand a topic**

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I wish to thank…

Abstract

Abstract …

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**Definitions**

Table - Definitions

|  |  |
| --- | --- |
| Read the room | In the context of this research, read the room refers to the ability of a lecturer or professional to become aware of the attitude and emotions of the students or employees. |

**Abbreviations**

Table - Abbreviations

|  |  |
| --- | --- |
| CFU | Checks for understanding |
| CSV | Comma-separated value |
| DSR | Design science research |
| E.g. | Example |
| FER | Face Expression Recognition |
| FCP | Facial Characteristic Points |
| HOG | Histogram of oriented gradients |
| SIFT | Scale invariant feature transform |
| SDLC | System Development Life Cycle |
| URL | Uniform Resource Locators |

Chapter 1 – Introduction

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## Introduction

This project is about finding a solution to the problem that lecturers, teachers and professionals are unable to keep an eye on every student or employee in large classrooms or online environments, allowing them to gauge attention and understanding based on facial expressions. In this project, the aim will be to determine if facial recognition technology can be used to solve this problem. This chapter will provide the study background, problem statement, possible uses, paradigmatic perspective, aims, objectives, research methodology, validity, data collection and its processing, project plan and approach, ethical and legal implications, provisional chapter division, summary and lastly the references.

## Background to study

There are numerous techniques for lecturers and teachers to determine whether students in a classroom comprehend the current topic (Fisher & Frey, 2014). These techniques are called “Checks for understanding” or in short “CFU” (Quinzio-Zafran & Wilkins, 2020). The CFU is designed for school classrooms; therefore, not all of these checks can be used in big lecture halls, corporate meetings, or online learning environments.

For physical classes, one CFU technique is to use oral language (Quinzio-Zafran & Wilkins, 2020), like asking questions (Finley, 2014). Because of time constraints, lecturers are unable to enquire every student in big classrooms about their understanding of the topic (Kopf *et al.*, 2005). Alternatively, lecturers rely on students’ facial expressions to determine the students’ understanding of the topic (Sathik & Jonathan, 2013). However, checking everyone's facial expression can be challenging in large classrooms or online learning environments (Kopf *et al.*, 2005).

COVID-19 forced education to switch to an online delivery mode, creating new challenges for lecturers and teachers alike (Paudel, 2021). The primary obstacle for students was acquiring the necessary technology to participate in these online classes (Alshamrani, 2019). For lecturers, a proven disadvantage is that the social interaction between students and lecturers, and the opportunity to observe students’ behaviour was significantly decreased (Lamanauskas & Makarskaite-Petkeviciene, 2021). Lecturers must look at the textbook, their notes, or slides on the screen, and is not always able to keep an eye on all the students attending the class, therefore unable to observe the students’ facial expression and determine if the students understand the topic.

Considering the concerns discussed above, it appears that lecturers, teachers, and professionals need to be able to “read the room” without physically having to pay attention to each individual student.

This study will attempt to fill the gap by providing a way for lecturers to determine how many students understand the current topic at hand, without physically paying attention to the individual students.

## Problem statement

Lecturers, teachers, and professionals require a method to use in large lecture halls and online environments for determining whether students or employees comprehend current topics. Previous methods include the CFU techniques, but these options don’t allow the lecturer to read the whole room.

As mentioned previously, conventional CFU techniques are insufficient for large classrooms or online learning environments.

Would a system that enables lecturers to “read the room” without having to physically look at each student, be advantageous for a lecturer?

## Where would such a proposed system be advantageous?

This system can be used in a variety of environments. It is suitable for use in large lecture halls, classrooms, online environments, and corporate meetings. Anywhere a lecturer, teacher, or corporate staff member is required to determine whether students or employees understand the topic at hand.

## Research aims and objectives

A well-defined research objective is critical for establishing the project's purpose. Additionally, there should be a clear list of objectives that must be met for the research objective to be accomplished. Achieving the aim and completing the set objectives will allow the lecturers to read the room and get a better understanding of what the students are feeling during classes.

### Research aim

The aim is to create a system that will be helpful to lecturers, by providing the ability to “read the room” when it comes to teaching, using facial recognition.

### Research objectives

To accomplish the above-mentioned aim, there are certain objectives that the researcher will need to reach

* Research current methods to determine if students understand their work
* Analyse facial expressions and how those emotions are displayed
* Exploring facial detection techniques and how it works
* Survey lecturers and students to get a better understanding of what would be beneficial to them
* Comparison between different types of facial detection and expression programs
* Developing an artefact using the above-mentioned programs
* Evaluating if the proposed artefact will be able to identify common emotions linked to understanding

### Study design

#### Research Paradigm

A paradigm is described as a collection of shared beliefs and consensus among scientists about the proper way to approach and solve problems (Kuhn, 1970). Choosing the appropriate paradigm is critical when conducting research because it defines how the researcher thinks and interprets the data gathered (Kivunja & Kuyini, 2017). It also helps us shape the following fundamental elements: ontology, epistemology, axiology, and methodology (Park *et al.*, 2020).

The research paradigm that will be used during this study is Positivism. Positivism states that the world is independent, meaning that people cannot change nature’s laws. Researchers will gain knowledge through observation and experimentation, without changing the nature of the environment. (Rehman & Alharthi, 2016). The experiments of this study will be done objectively from a distance, not bothering the students while they attend class. Surveys and questionnaires are a collection method for this paradigm and can be used to determine whether the experiments achieved accurate results. This paradigm makes use of quantitative data (Sousa, 2010), therefore a methodology will be used that supports this paradigm. Numerous methodologies can be used, but the one that will be used in this study is “Design Science Research”.

#### Research Methodology

As mentioned above, the research methodology that will be used in this project is “Design Science Research”, hereinafter referred to as DSR. DSRs’ main goal is to create an artefact that will solve a specific problem and then evaluate it afterwards. The reason why this methodology is suitable for this project is that DSR helps us achieve two goals in this project: Researching the problem and creating a solution to the problem (Dresch *et al.*, 2015).

Using DSR, quantitative data will be gathered from the artefact and the participants, and this data will be analysed and compared to determine whether or not the artefact yields positive results, thereby providing an answer to the problem identified.

To achieve the goal of creating an artefact that will solve the problem identified in the problem statement, the DSR steps need to be taken (Peffers *et al.*, 2007):

1. **Identify the problem - Chapter 1**

This section contains the problem identified in the problem statement, as well as the justification for its resolution.

1. **List the objectives that need to be met in order to solve the problem - Chapters 1 and 2**

Eight objectives must be met, as stated in the "Aims and Objectives" section of Chapter 1. To accomplish these goals, research must be conducted. This is part of Chapter 2 - Literature.

1. **Design and develop the artefact - Chapter 3**

Using the research from Chapter 2, an artefact will be designed and developed to address the problem identified, using the Iterative system development life cycle, that will be discussed in section 3.3.

1. **Implement the artefact - Chapter 3**

This step is typically where the artefact is put into practice. However, for this project, the artefact will not be used in classrooms or online environments, but rather will be subjected to tests and experiments with a select group of participants to identify whether this solution will work in practice.

1. **Evaluate the artefact - Chapters 4 and 5**

The artefact will be tested on participants, with the results being noted. The participants will then complete a survey, the results of which will be compared to the artefact’s result.

1. **Conclusion - Chapters 4 and 5**

Following the completion of the tests in step 6, the results will be compared to determine whether or not the artefact successfully resolved the identified problem of assisting lecturers in lecture halls to determine whether students understand the current topic at hand.

Additionally, advice and errors will be listed to ensure that other researchers do not make the same errors.

## Research methodology

As mentioned previously in the section on study design, throughout this project, "Design Science Research" will be used to collect data from the artefact and the participants. These data are critical to the methodology and research project in order to determine if it is a viable solution to the identified problem.

### Process of obtaining informed consent

Consent must be obtained from participants prior to data collection. If the document is in physical form, the participant must read and sign it. If the form is online, the participant must first select a radio button before the survey or questionnaire can be accessed.

### Data collection

During this project, the positivism paradigm and DSR methodology are used. This means that quantitative data will be collected. Quantitative data is numerical values that can be used to answer questions (Apuke, 2017). Numerical values can be used to group and compared, making it easy to analyse the data.

#### Data collection tool

There are numerous data collection tools to collect quantitative data, such as surveys, questionnaires, observations, and experiments. There are numerous quantitative data collection tools available, including surveys, questionnaires, observations, and experiments (Sukamolson, 2007). All of the tools listed above will be used to collect quantitative data for this project. Surveys to elicit responses from participants' emotions. These data will be compared to the artifact's results to determine whether they were accurate. Questionnaires to gather feedback and advice from lecturers. Observations will be used to gather researcher input to compare to the results of the artefacts. Experiments with the artefact will be conducted to gather data and improve the artefact.

## Rigour, validity, and reliability

When doing research, it is important that the research is not lacking rigour, meaning it must be thorough. To ensure this, the researcher must follow the mentors’ advice, not be biased, and be careful when conducting experiments and recordings the findings of the experiment and surveys.

Validity is very important because it determines whether the study is logically and factually sound. Reliability refers to how consistent the results are being measured (Heale & Twycross, 2015). Reliable data does not ensure validity, but usually, validity ensures reliability. Ethical considerations. To ensure reliability, the surveys, questionnaires, and experiments will be done in the same environments, respectively. To ensure validity, the measuring tool must be able to measure what it says it can (Sürücü & Maslakçi, 2020).

To ensure reliability, all surveys and questionnaires are the same and will be answered in the same environment. To ensure validity, results will be compared to studies previously done. The experiments and surveys should also give the specific results that are aimed to achieve.

## Legal and Ethical considerations

When it comes to facial recognition, there are a plethora of ethical considerations. The primary consideration is the storage of facial recognition data. According to the "Protection of Personal Information Act No.4 of 2013," or more commonly known as the POPIA, students must be informed that facial recognition technology will be used (Government, 2019) and that their facial features will be used in an algorithm to determine their current emotion. Additionally, it will be stated that no personal information gathered from the recordings will be stored in a database.

Another consideration is the use of information that will be gathered through questionnaires and surveys. The collected data will not be shared or sold to third parties and will be used solely for research purposes. A data ethics form will be completed, ensuring that all necessary steps are taken with the data. This also contributes to the project's validity and reliability.

### Permission and informed consent

All subjects will be informed in advance of any recording or use of facial recognition technologies, and the aforementioned considerations will be made clear to them.

### Anonymity

Because no personal data such as names, surnames, or student numbers will be collected, subjects will remain anonymous. The facial recognition will occur in real-time, which means that no recordings will be stored in a database. Only generalised data from users’ facial features will be used in the algorithms, further ensuring the subjects' anonymity.

### Confidentiality

Since no personal data about subjects will be stored in a database, all personal information about them will be kept strictly confidential. And non-personal information will be used solely for research purposes and will not be shared or sold to third parties.

## Approach to project management and project plan

When conducting research, it is very important to address the following: Scope, limitations, and risks. The scope is, in essence, the aim of the project. The limitations are the restrictions that can take place, and that must be accounted for. The risks are things that could possibly go wrong during the project.

To make a success of this project, proper planning needs to be done, and all deadlines must be reached within time. A Gantt chart will be used to do the planning, along with the due dates provided.

### Scope

The scope of this project is to determine whether facial recognition can be used to assist lecturers, teachers, and professionals in their daily lives to determine if students or employees understand the topic at hand. The technology that will be used is a 1080p Hikvision web camera. The system will be written in python using Visual Studio Code and Visual Studio 2019.

### Limitations

Limitations are any facts or events that the researcher cannot control. Sometimes these limitations are predictable, and sometimes these limitations are unpredictable (Price & Murnan, 2004). In this research project, there are two known limitations:

* Time

The final documentation, artefact and poster should be finished by the 28th of October.

* Technology

Most facial recognition algorithms are written in Python, and therefore I have to code in Python to make use of facial recognition algorithms and libraries such as “OpenCV”.

### Risks

A big risk that can occur is if students do not consent to be recorded on a camera for research purposes. Another risk could also be that the existing libraries and code for recognising facial expressions do not contain the main expression that will be focused on.

### Project plan

The following dates are important as they are the due dates of the different project parts. It is very important to stick with the planning that will be displayed in the Gantt Chart to ensure the deadlines are met in time. The figure below will provide a timeline that will be followed.

The table below consists of two columns: Date and Description. The dates are the due dates provided to the researcher. The description table describes what should be submitted on the given date. It is very important that the Gantt chart is followed to ensure the due dates are met.

Table - Due Dates

|  |  |
| --- | --- |
| **Date** | **Description** |
| 22 April 2022  *Extended to 2 May 2022* | Project planning and research proposal submission |
| 30 June 2022  *Extended to 7 July 2022*  *Extended to 27 July 2022* | Literature Study |
| 20 October 2022 | Poster and Artifact demonstration |
| 27 October 2022 | Complete documentation submission |

Table - Gantt chart tasks

A picture containing timeline

Description automatically generated

A picture containing timeline

Description automatically generated

Figure - Gantt Chart

## Provisional chapter division

Below is an overview of the chapters that will be present in this research project.

**Chapter 1 – Introduction:**

This section will focus on everything before the literature study. It covers the background of the project and what is the problem identified. There will also be looked at the aim of the project and the objectives that need to be reached, along with a project plan. The paradigm and methods will also be discussed.

**Chapter 2 – Literature review:**

The literature review will include research that has been conducted to aid in the completion of the objectives stated under "Aims and Objectives." Three topics will be discussed: current research methods for determining whether students understand a topic, facial expressions and their connected emotions, and finally, facial detection and recognition.

**Chapter 3 – Artifact planning and development:**

This chapter will outline the steps necessary to complete and test the artefact on time. The research used in the literature review will determine what technology and algorithms will be used to develop this artefact. Additionally, documentation will be completed during the planning and development of the artefact, which will contribute to the Chapter 5 reflection. Subjects will also be tested, and a questionnaire will be completed to determine whether the artefact correctly predicted the emotion the subject was experiencing at the time.

**Chapter 4 – Results**

The results of this project will be discussed in this chapter, where the research question will be answered. There will also be an overview of Chapter 3 to determine whether the artefact was successful in detecting the subjects’ emotions.

**Chapter 5 – Reflection**

This chapter will focus on the researchers’ experience throughout the project, the lessons learned and, what could have been done differently. The reflection is critical because it could inform other researchers of potential mistakes and how to avoid them.

## Summary

In summary, this chapter concluded the following: The current methods teachers, lecturers and professionals use to check student or employee understanding are insufficient for large- and online environments. In the problem statement, there is concluded that there is a need for lecturers and professionals to be able to keep an eye on everyone, without physically looking at them. The proposed system is applicable in numerous environments, but the main focus will be on large lecturer halls and online environments.

The project aims to equip lecturers with the ability to read the room. To achieve this aim, seven objectives have been identified that must be addressed and accomplished. To ensure that these objectives are met, a Gantt chart will be used, and the scope of the project will be revisited to ensure that the researcher remains focused on the problem. Throughout this project, the positivism paradigm will be followed, and the methodology that will is used is Design science research. By adhering to this paradigm and methodology, rigour, validity, and reliability are ensured. Seeing facial features will be captured and data extracted from it, legal- and ethical considerations, risks and limitations should be kept in mind. Consent will be obtained, and participants will be kept anonymous and their data confidential. Lastly, the five provisional chapters were laid out, which will be discussed in further detail in the subsequent chapters.

Chapter 2 – Literature Review

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## Introduction

This Chapter will include research that will be addressing the aim of creating a system that will aid lecturers in classrooms. It will explore the existing methods for determining comprehension, as well as their advantages and disadvantages. Following this, facial expressions seen in lecture rooms will be analysed and discussed. Lastly, facial detection techniques will be investigated, and its applications will be discussed.

Discussing the topics above, will give the necessary information to develop an artefact in Chapter 3, and aid the researcher in answering the research question.

## Methods to determine if students understand their work

### Introduction

There are numerous techniques for lecturers and teachers to determine whether students in a classroom comprehend the current topic (Fisher & Frey, 2014). It can be done via assessments, CFU techniques and student feedback. Each of these methods has its benefits and drawbacks that will be discussed. It is crucial to determine whether students comprehend the work being covered in class because the lecturer needs this information to determine which areas to spend more time on, and which parts of the subject the students have more difficulty understanding. The following three methods for measuring student comprehension will be discussed and compared: assessments, CFU techniques, and student feedback.

#### Assessments

Assessments are very important in any type of education (Taras, 2008). It enables instructors to determine how effectively students comprehend the subject and its topics. The lecturers can then structure their teaching methods and determine where further focus is required (Tosuncuoglu, 2018). There are two types of assessments that are most commonly used by lecturers to assess students (Dixson & Worrell, 2016):

* **Formative assessments**
* **Summative assessments**

**Formative assessment** is a way teachers and lecturers receive feedback, and check for understanding during the learning process (Andersson, 2008). In-class discussions, weekly quizzes and homework assignments can be considered as formative assessments. Formative assessment takes place during the semester and the lecturer should be able to use this assessment to identify, analyse and respond to the problems of students (Hunt & Pellegrino, 2002).

The following advantages and disadvantages of formative assessments are described by Ahmad- and Jeelani Bhat (2019).

**Advantages of Formative Assessments**

1. Provides information to lecturers

Formative assessment provides valuable information to lecturers during classes and assessment periods to determine if students understand topics.

1. Provides feedback to students

Using these assessment methods, students can also become aware of the topics they do not understand before they write summative assessments.

1. Adjusting teaching methods

Lecturers can use this assessment method to help them adjust their teaching methods that enable them to help students understand certain topics.

**Disadvantages of Formative Assessments**

* 1. Time

Lecturers have a lot of material to cover in class and don't always have enough time to conduct formative assessments like class discussions and quizzes.

* 1. Lack of participation

Students are very shy in larger classrooms and may not participate in classes. During quizzes that may not count towards their grade, students may not care about the assessments, and not take them seriously.

* 1. Lack of training or experience

Without proper training or experience, lecturers may not know how to analyse these types of assessments to determine where a gap is in students’ understanding.

**Summative assessments** are usually formal assessments taken at a specific point in time (Garrison & Ehringhaus, 2007), like semester tests and exams during or at the end of a semester. The purpose of summative assessments is to see how good students understand the subject after a certain time, or amount of work handled, and assign a grade to the student (Angelo & Cross, 1993). There are certain advantages described by Ahmad- and Jeelani Bhat (2019) that will be discussed below:

**Advantages of Summative Assessments**

1. Test student knowledge after a time period

Tests and exams can be used by lecturers to assess their students. This will provide quantitative data on how well students comprehend the subject and its many topics. Because these assessments take place periodically throughout the semester, lecturers can utilize the data to identify if students are improving.

1. Marks and Grades

These assessments are typically used to grade students and determine whether they have adequate knowledge to pass a module. In order to pass, this assessment method motivates students to study the subject and its topics.

1. Identify weak areas

Lecturers utilize this data to determine where additional attention is needed, and which topics students are struggling with.

**Disadvantages of Summative Assessments:**

1. Guessing multiple choice questions (Qu & Zhang, 2013)

During summative assessments, multiple choice questions can be asked, and students can guess the correct answer, without understanding the work. This may give inaccurate information to the lecturer, leading them to believe that most students understand the work.

1. Cannot improve understanding after an examination (Ishaq *et al.*, 2020)

Exams are at the end of a semester. The marks determine whether students pass. The drawback with this type of assessment is that if you see students struggling with certain topics, it is too late to help them because it is the end of the semester or year.

1. Not a true representation of understanding (Ishaq *et al.*, 2020)

Tests and exams are very stressful, causing students to hit a ‘blank’, meaning they stress so much that they forget the work studied. But this can be a sign of the last disadvantage explained next.

1. Summative assessments test memory more than knowledge (Sporer, 2022)

During the exam and test periods, students are more likely to memorise the work, rather than understand it. Thus, summative assessment marks don’t always reflect students’ understanding, but rather their memory.

#### CFU techniques

CFU is an abbreviation for “Checks for understanding”. The CFU techniques are designed for school classrooms; therefore, not all these checks can be used in big lecture halls, corporate meetings, or online learning environments. CFU techniques are useful in smaller classes, but in big classrooms, time constraints make it much more difficult (Kopf *et al.*, 2005). According to Fisher and Frey (2014), there are numerous ways of checking understanding among students, a few of them are oral language, facial expressions, hand gestures and tests. A short description of these examples will follow:

**Oral Language**

Oral language encompasses all verbal communication in the classroom. The most typical type involves lecturers asking students to demonstrate their comprehension of a topic (Dufour, 2021).

**Facial Expressions**

Teachers and lecturers rely heavily on facial expressions to determine whether or not students comprehend the subjects (Butt & Iqbal, 2011). Emotions are one of the hardest things to conceal among students. It is a technique for lecturers and teachers to determine whether or not students grasp the material without directly communicating with students or poor performance in tests, as explained in the section on assessments (Fisher & Frey, 2014).

**Hand gestures**

Lecturers may request that students raise their hands if they comprehend or do not comprehend the material covered in class. The lecturers will then use this information to evaluate if they need to revisit the topics (McTighe, 2021).

**Tests**

This may consist of a combination of formative and summative assessments, as described in the previous section. The downsides have been mentioned previously.

Each of the aforementioned CFU techniques has its own advantages and disadvantages, specifically when it comes to large classrooms, but the most notable downsides are summarised in Table 5 to see how they might, later on, be improved and even used to help lecturers.

Table - CFU Disadvantages

|  |  |
| --- | --- |
| **Disadvantages of certain CFU techniques** | |
| **Oral language** | Students are shy, and do not want to ask questions in large classrooms or see lecturers alone in their offices. |
| **Facial Expressions** | Lecturers cannot attentively look at more than 100 students to determine whether they understand a topic. |
| **Hand gestures** | In large classrooms, lecturers may not be able to observe all the hands up in the air, or it may take a while to count. |
| **Tests** | As discussed in the Assessments section, there are numerous disadvantages to this technique. |

#### Student Feedback

Student feedback is important to lecturers because it gives lecturers the chance to address problems and topics head-on. The student feedback technique relies on the cooperation of students. In order to establish whether the proposed system would be feasible, a voluntary survey was conducted among university students. The survey received 31 responses from various students, and the detailed results of this survey can be found in Appendix A.

According to the survey results, 58% of students are shy and would not want to be personally addressed and 58.8% of students would not raise their hands in class. There are several ways students engage with lecturers, but the two most common are raising their hands in class and seeing the professors in their offices. These two techniques will be discussed below:

**Hand Raising**

Hand-raising is a common behaviour by students in classes. It allows them to participate and draw the lecturer’s attention to ask for explanations (Böheim, 2020). Unfortunately, one drawback is that most students are shy about raising their hands in large classes (Kettner, 2015), and therefore a new way should be determined to gather student feedback.

**Visiting lecturers in office**

Visiting a lecturer can be daunting for students, and most students would prefer not to see lecturers in their offices during office hours. Lecturers are unable to help and assist students that do not seek any help.

### Summary

Lecturers wish to be able to assist students in thoroughly understanding and comprehending the work prior to exams and assessments, not only to increase students' grades but also to enhance their comprehension and prepare them for the workforce.

Assessments can be an effective method for gauging pupils' understanding; however, they are typically administered too late. As Ishaq *et al.* (2020) noted, students tend to become anxious and forget their work, which can lead to poor performance. This may be due in part to the fact that students memorize rather than comprehend their work.

Because the majority of students do not feel comfortable engaging in-class activities or visiting lecturers during office hours, student feedback is unreliable and difficult to use as an indicator of student understanding.

Checks for understanding are an excellent approach for determining if students comprehend the material prior to tests and exams. The issue with CFU techniques is that they are extremely time-consuming and challenging to apply. The oral language and hand gesture CFU techniques are not reliable, seeing it requires student participation to be successful, and most of them are too shy to participate. Tests are too late, and lecturers are unable to see everyone’s facial expression during a class. As indicated in the CFU techniques section, reading facial expressions is an effective CFU technique, however, it is very time-consuming and just not feasible in large classrooms. Assisting professors and aiding students will be revolutionized by the development of a system that will read and understand facial expressions, without lecturers spending time individually looking at students.

This chapter brings us closer to the question of whether there is a way to improve the CFU techniques, allowing lecturers to get a better understanding of whether their students understand a topic. The next section will discuss the role of facial expressions in classrooms and their connected emotions.

## Facial expressions and connected emotions

### Introduction

In the previous section, it was established that the CFU techniques of utilising facial expressions in a classroom to properly identify whether pupils grasp the content, is a good approach to address the issues in large lecture halls. Now there has to be identified which facial expressions are encountered in classrooms, and what are their associated emotions actually mean.

Different facial movements and muscle positions result in a specific expression (Butt & Iqbal, 2011). Facial expressions are a universal way to express emotion. Different things may infuriate various individuals, yet the face muscles and movements are nearly identical among them (Ekman & Keltner, 1997). People struggle to conceal their emotions since emotions are spontaneous (Dimberg *et al.*, 2000).

This chapter will explore facial expressions in classrooms, their associated emotions, their importance, and technologies used to detect them.

### Classroom facial expressions and it’s connected emotion

There are six types of emotions most commonly noticed on people: disgust, sadness, happiness, fear, anger, and surprise (Yang & Hirschberg, 2018). All these emotions can be encountered in classrooms. A smile may be an indication of happiness, and crossed eyebrows and a frown may be seen as anger or disgust. An open mouth and big eyes may be an indication of surprise. But one expression that is encountered a lot in classes is the “confused” facial expression. But what is considered as confused?

Confusion is an emotion connected to knowledge, meaning it is an epistemic emotion. It causes cognitive disequilibrium, meaning learners face situations such as obstacles to goals, contradictions, incongruities, anomalies, and conflicts (D’Mello & Graesser, 2012). These obstacles can be anything from not understanding certain work or struggling to achieve good grades. Confusion can be picked up by looking at the facial expressions of students. A study was done and found that lowered eyebrows, frowns and tightened lids were associated with confused expressions (D’Mello & Graesser, 2014). Silvia (2013) stated that confusion makes people frustrated, which makes people scrunch, lower their eyebrows and furrow that is caused by frowning. When looking at these expressions and actions, it can also be associated with other emotions, such as anger, sadness and disgust. People that are angry will frown, and their brows will furrow (Reed *et al.*, 2012), people that are sad will also have their brows furrowed and have lowered eyebrows (Kohler *et al.*, 2004) and finally disgusted people will scrunch and their lids tighten (Pochedly *et al.*, 2012). All these expressions can also convey that students may experience confusion.

### Importance of these expressions

As mentioned previously, confusion causes cognitive disequilibrium, and students need to overcome this disequilibrium in order to move on (Arguel *et al.*, 2019) and get a better understanding of the work. For a lecturer to improve classes or the way they present certain topics, they accurately need to understand the expressions of the students. Whether it is confusion, boredom, anger, happiness, or any expression the lecturer can identify within a classroom. Lecturers will use this information to make the necessary changes during a lecture.

Even though it can be an accurate way to determine the understanding of students, it is very difficult for lecturers to read all the faces of the students during a class, because there are too many students to keep an eye on at all times.

Another big problem that can be encountered is alexithymia. Alexithymia is a disability, making it very difficult or even impossible for students to identify their own, or others’ emotions (Taylor, 2000). Alexithymia is not a rare disability. One in every ten people has Alexithymia (Cherney, 2021). Even in the rare case, a lecturer doesn’t find it difficult to observe an entire classroom, the lecturer may have Alexithymia making it impossible to determine which facial expressions and emotions the students are currently expressing.

These problems may be solved by using technologies with certain algorithms, allowing lecturers to get feedback on the facial expressions of students.

### Technologies and algorithms for recognizing facial expressions

To create a system that allows lecturers to read the room, another pair of “eyes” needs to be available. There also needs to be a way for the system to communicate to the lecturer and let him/her know what it is currently perceiving. For the system to know what it is perceiving, an algorithm needs to be determined and implemented into the system.

This means the system can be divided into 2 sections, technology, and workings, also known as the algorithms and coding.

Technologies and algorithms are very important throughout this project because the technologies, such as cameras, will be used as an extra pair of eyes that the lecturers can use to their advantage. It will be used to perceive the students’ facial expressions. The algorithms are the brain of the system and will take the percepts/observations from the camera, analyse the facial expression, and determine whether the student comprehends the work being discussed.

This system can be seen as an agent. An agent can be seen as anything that perceives the environment through sensors and acts upon that environment through actuators (Russel & Norvig, 2021).

The following Figure 2 demonstrates the working of an agent. The Agent is the system, and the environment is the classroom. The Sensor is the camera that perceives the environment. The actuator is the display that shows the result to the lecturer. The question mark is “brain” or the intelligence of the agent. In this case, it’s the algorithms and code making it possible for the agent to detect whether the student understands the topic being discussed.

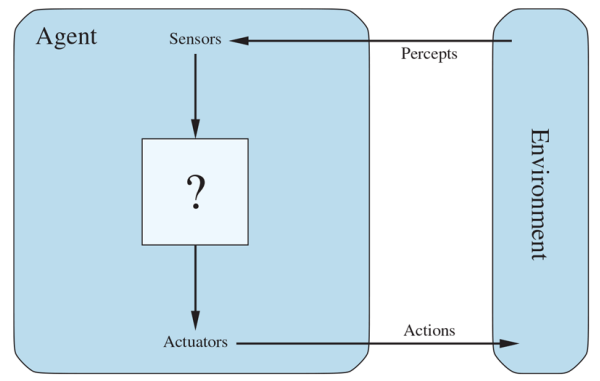


Figure - Basic Agent Working (Russel & Norvig, 2021)

The **technologies** that can be used to develop the proposed system should therefore have appropriate sensors and actuators:

Sensors

* Cameras
  + These cameras will be used as the “eyes” as mentioned above. It will be used to observe the large classrooms and give its input to the system.

Actuators

* Computer
  + In order for the program to run, a computer needs to be used. It needs to be a mid-range computer. Preferably with a Intel i5 CPU or higher. It also needs a USB port to connect a camera.
* Computer Screen
  + This is where the output will be displayed to the lecturer of how many students do not understand the topics being discussed.

**Agent’s Intelligence** refers to the “brain” of the system. This “brain” needs to be able to receive information from the technologies such as the sensors and analyse it with the use of algorithms and programs.

* Algorithms and Programs
  + There are numerous algorithms and code that can be used in order to assess facial expressions. The workings of these algorithms are discussed at “How facial detection work”. Numerous algorithms can be used and implemented, and a few algorithms will be researched and tested in Chapter 3 of this search project.

### Summary

Facial expressions are something everyone has. It is a trustworthy and valid method to determine whether a student understands a topic and work that is being discussed. There are six common expressions, but the expression that is the most relevant to this study is confusion. This facial expression can be seen as lowered eyebrows and tightened eyelids.

These emotions are very important to lecturers because it allows them to get a better understanding of whether or not the students are taking in the work, and how much they understand the topics being discussed. It was noted that it is difficult for lecturers to keep an eye on every student, or in some cases, it is impossible for them to determine which emotion is displayed by students and therefore need some help with another pair of “eyes”.

Technologies and programs or algorithms, also known as an agent, can be used to assist the lecturer. The programs and algorithms will use the input received from cameras and determine whether students understand their work. These results will be displayed on a screen assessable by the lecturer. This study will provide some background on how facial detection and recognition work.

## Facial detection and recognition

### Introduction

Facial recognition is used to identify and verify an individual’s identity and can be used in various scenarios such as security and entertainment (Mohammad, 2020). Facial recognition can be largely attributed to Woodrow Wilson Bledsoe. In the 1960s, Bledsoe created a database of thousands of images, in his efforts to create a face-identifying system (Libby & Ehrenfeld, 2021).

Facial detection is a part of facial recognition which is a popular subject when it comes to biometrics (Khan *et al.*, 2019). The difference between facial detection and facial recognition is that facial detection involves the detection of an image or video. This means the system will detect whether there is a face on the image or video provided (Kumar *et al.*, 2019). The system can be programmed to draw a square around the detected faces. The proposed system will use facial detection, and not facial recognition, seeing the aim of this project is not to determine who the person perceived is, but rather to analyse the facial features using facial detection algorithms. This algorithm will determine which emotion the student is experiencing and use that information to get an understanding of whether the student comprehends the topics being discussed.

During this section, it will be discussed how facial detection and recognition works, along with current facial detection and recognition applications, and the advantages and disadvantages thereof.

### How facial detection and recognition work

Facial detection is the method of determining whether a human face is detected within an image (Nagpal *et al.*, 2018). There are different methods that can be used to detect faces, such as template-matching methods, feature invariant method, and appearances-based methods. (Dilawar & Siddiqui, 2016)

Template-matching methods involves finding the correlation between the source image and a testing image of a face (Ping *et al.*, 2003). If there is a high correlation, it means that a face was detected in the source image.

Scale invariant feature transform, also known as SIFT, can be seen as a feature invariant method, because it is a technique for detecting and extracting visual features (Gupta *et al.*, 2021). It identifies key points called descriptors (Lindeberg, 2012) and provides them with quantitative information that may be utilized for object recognition. SIFT is not recommended for facial detection, because SIFT is good with general object detection, which are rigid with sharp edges, where faces are non-rigid and smooth (Geng & Jiang, 2009).

Appearance-based methods like Eigenface. The Eigenfaces approach consists of extracting the distinctive facial features and portraying the face as a linear combination of the so-called 'eigenfaces' derived from the feature extraction procedure. (üge Çarıkçı & Özen, 2012)

Another prominent facial detection method is Histogram of oriented gradients, also known as HOG. HOG may be viewed as a more dense variant of SIFT (Pang *et al.*, 2011). Gradient direction density statistics can characterize the shape and color of a local image object, such as a human face. Since an image's gradient lies at the edge of a local object, its oriented gradient histogram indicates the edge direction density of detection targets (Li *et al.*, 2016).

Face expression recognition, also known as “FER”, is the method of using either descriptors or Facial Characteristic Points to determine which facial expression is expressed. The efficiency of FER depends on how accurate the facial features can be extracted for the descriptor (Anil & Suresh, 2016). Appearance features and geometric features are the two methods used to extract facial features (Revina & Emmanuel, 2021).

**Appearance features**

Generally, appearance-based methods extract the textural variations of face images using a variety of descriptors (Yu & Liu, 2015). The descriptors of different facial features will show a high variance, while descriptors of the same facial features will show little to no variance (Anil & Suresh, 2016).

**Geometric features**

During this method, a facial image is segmented into three parts regions, the mouth, nose and eyes and eyebrows. Facial Characteristic Points, also known as “FCP”, are located for each of these segments (Youssif & Asker, 2011). Using these FCPs the algorithm can then determine the distances and movement between the facial features and then determine which facial expression is most likely expressed.

In conclusion, two methods can be used to achieve FER, but for these methods to work, technologies and algorithms are needed as discussed in Section xxx: Technologies and algorithms for recognizing facial expressions.

### Applications of facial detection and recognition

As mentioned in the introduction, facial detection is used within facial recognition. Facial detection and recognition can be used in various fields such as security, biometrics and law enforcement (Bernstein, 2020). These general applications will be discussed below:

**Security**

Humans can only remember a certain number of faces, while computers with large memories, can store thousands, if not millions of faces. This is a breakthrough in the field of security. Facial detection and recognition can be used in crowd surveillance, such as in airports and private security (Balla & Jadhao, 2018).

**Biometrics**

Biometric recognition is the automatic recognition of people, using their physical features (Delac & Grgic, 2004) such as fingers, voice and face (Woodward Jr *et al.*, 2003). Biometrics can be used at your home or business. Your face can be used to unlock a device such as your cell phone and your fingerprint can be used to clock into work.

**Law Enforcement**

Facial detection and recognition are used by law enforcement, by using surveillance cameras to detect people’s faces and compare them to their database of criminals and people with arrest warrants (Garvie & Frankle, 2016). Some may see this as unethical, as discussed in the *Advantages and Disadvantages of facial detection and recognition* section, but according to a study done by Smith (2019), 59% of the people that participated in the survey said they find it acceptable that law enforcement can use facial recognition in public spaces.

**Other**

Although facial detection and recognition are mostly used in the areas mentioned above, it is not limited to those areas. This proposed system is aimed to be implemented in classrooms to assist lecturers. It has nothing to do with security, biometrics, or law enforcement, but rather for educational purposes.

### Advantages and Disadvantages of facial detection and recognition

There are numerous advantages and disadvantages in various fields of the application when it comes to facial detection and recognition. Some advantages can also be disadvantages, which will be discussed below.

**Advantages**

* Security
  + Facial detection and recognition can be used for security purposes, in either airports or public spaces. Facial detection and recognition make it possible for a computer to detect humans by their facial characteristics (Owayjan *et al.*, 2015). It can be used to detect any criminals or people with arrest warrants (Garvie & Frankle, 2016).
* Biometrics
  + Biometrics is an authentication method, that automates the identification of a person, based on their facial features (Omoyiola, 2018). Facial detection and recognition can be used as a password or two-factor authentication in protecting or accessing important information or devices. It is much more secure and convenient than the traditional password system (Vazquez-Fernandez & Gonzalez-Jimenez, 2016).
* Medical
  + By evaluating subtle face features, facial detection and recognition can, sometimes in instances, pinpoint how specific genetic mutations caused a particular syndrome. The method may be faster and less expensive than standard genetic testing (Gargaro, 2022).
* Attendance
  + Facial detection and recognition can be used in schools or businesses to determine who attended the class or clocked into work on a specific morning. Facial detection and recognition are one of the main methods of recording attendance because it requires virtually zero effort from the students (Kar *et al.*, 2012). Businesses use it because it is much less time-consuming for the management to do it manually (Arsenovic *et al.*, 2017).

**Disadvantages**

* Privacy
  + Facial recognition is a form of surveillance technology that can be used to identify and track individuals. This allows a company or government to gather information about the habits, lifestyles, and interests of individuals (Wright, 2018). According to a study done by Institute (2019), 77% of people surveyed, do not feel comfortable with companies using facial recognition technologies. Section 14 of the South African Constitution, states that everyone has the right to privacy (Government, 1996), which facial detection and recognition can infringe.
* Racial Discrimination
  + Facial detection and recognition have a hard time identifying people of colour, and in some cases even be biased against people of colour (Garvie & Frankle, 2016). This problem originates from machine learning on a particular database of faces (Libby & Ehrenfeld, 2021). This means that when Facial Recognition algorithms are trained using a database predominantly Caucasians, the facial recognition of Caucasians would be much more accurate than that of dark-skinned individuals.
* Fraud
  + Facial detection and recognition can be used to collect personal information, video, and images and that can be used in fraudulent activities (Gargaro, 2022). Programs and applications like “DeepFakes” can be used to imitate certain people, and that can cause a lot of trouble including theft, fraud and even wars (Korshunov & Marcel, 2018).

### Summary

There are mainly two ways that a system can determine facial expressions and their connected emotions. Either through descriptors, using the appearance feature method, or facial characteristics points, or by using geometric features. Numerous algorithms can be used with either of these methods that will be further discussed and researched in Chapter 3.

It was determined that facial detection and recognition technologies and applications are widely used in numerous environments such as biometrics, law enforcement and security. Facial detection and recognition are not limited to any field and can be found nearly everywhere in today’s world and are still being developed and improved upon every day.

Although facial detection and recognition can improve and make our lives easier every day, there are several advantages and disadvantages that need to be considered when using these technologies and algorithms. Taking all the disadvantages into account, one can determine that the main concern of facial detection and recognition for this research is privacy. This issue can easily be addressed by informing participants of their rights and to stay within the law and Constitution.

One key takeaway of all the advantages mentioned is that it is essential for the algorithm to detect a human face, before it can recognise who it is, or in the case of this study, what expression they are expressing.

It was established why this proposed system is applicable and useful, and how technologies and algorithms are used in the two FER methods. In the next Chapter, the technologies and algorithms will be researched more in detail, tested, and integrated into a system that will allow lecturers to use this proposed system to determine whether students understand the work being discussed.

cHAPTER 3 – aRTIFACT plANNING AND DEVELOPMENT

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## Introduction

The purpose of developing this artefact is to determine if the proposed artefact can resolve the problem identified in Chapter 1. This implies that the proposed artefact should strive to accomplish the following:

1. Detect all the faces in the frame
2. Determine each facial expression of the individual faces
3. Determine whether the emotion may be classified as confusion
4. Show the general sentiment for that frame
5. Keep tract of the general sentiment for a determined time
6. Show and save the general sentiment in a comma-separated values file.

This Chapter will provide a description of the artefact, the life cycle followed to finish the artefact, and a development description.

## Description of artefact

During the study, it was determined that lecturers and other professionals needs a tool in classrooms that can help them get a better understanding of whether the students understand the topic being discussed. A way to solve this problem is to use technology, such as a camera, and a program, otherwise known as the artefact. The artefact will display the classroom of students, with their faces blurred out, and a text telling the lecturer how many students are confused at that current moment. The lecturer will also specify a time that the program should keep track of the general sentiment, and the results will be displayed in the python console, as well as written to an excel file for later viewing. After the program has been terminated, a graph will be displayed with the emotions and the timestamps, giving a graphical representation of the results during class.

## The life cycle followed and its different phases

Throughout this project, the design science research method was followed as discussed in section 1.5.3.2. It was determined that 6 steps needed to be followed to achieve the goal of developing an artefact that will solve the problem identified. Step three is about designing and developing the artefact. For the development to be a success a system development life cycle, also known as SDLC, needs to be followed. The term SDLC can be described as the phases an artefact or product passes through, from the original idea to the final product (Jirava, 2004).

The SDLC has 6 main phases, as illustrated in Figure 3, is planning, define requirements, Designing, develop, testing and deployment (Shylesh, 2017).

Table - SDLC Phases

|  |  |
| --- | --- |
| **Phase** | **Description** |
| Planning | During this phase the terms of the project is determined. This is where the goals and due dates of the artefact is determined. |
| Defining Requirements | During this phase, the requirements of the artefact is determined. This is where it is decided what the artefact should do in order to solve the problem identified. |
| Designing | When the requirements are determined, the artefact should be planned out. This is where it is decided which programming languages, code editors, libraries etc. should be used in developing the artefact. |
| Development | During this phase the artefact will be developed according to the requirements and designing criteria. |
| Testing | Testing of the artefact to determine whether it doing what it is set to do. |
| Deployment | This is the last phase of the SDLC, where the artefact is deployed and implemented. |

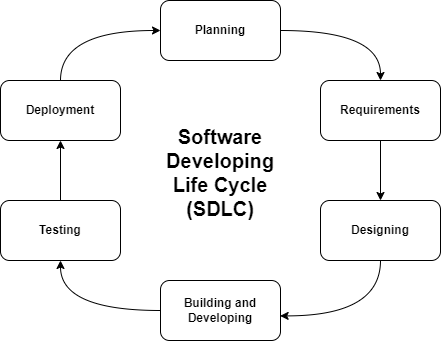


Figure -Software Development Life Cycle

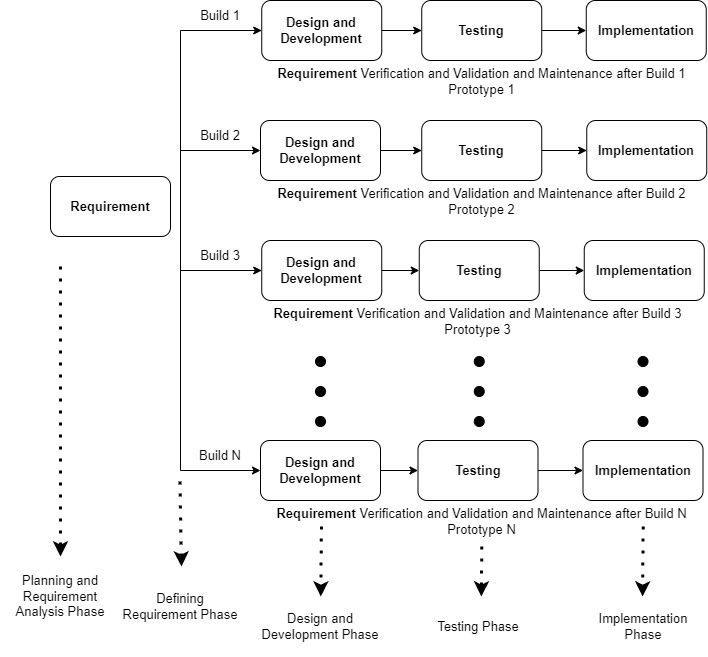
There are different types of types of life cycles that can be used from different methodologies, and these life cycles are variations of the SDLC, such as Waterfall life cycle, agile life cycle and iterative life cycle. The life cycle followed for developing this projects artefact is the iterative life cycle.

Figure - Iterative Life Cycle

The iterative life cycle uses iterations called builds to develop the artefact. Each build is a series of repeated cycles used to add a functionality to the artefact. Figure 4 is used to show how the iterative life cycle works Okesola *et al.* (2020). Clear requirements is needed before the Building cycles can start. Each build is a functionality that is added to the artefact, and needs to be completed, testes and implemented before the next build can begin. Iterative life cycle is very easy to implement when using it with the Design Science Research methodology, and allows the following advantages (Shylesh, 2017):

* Easy to measure development progress
* Small iterations allow easy testing and debugging
* After every iteration/build, a functional product is delivered
* Can easily decide to add new functionalities and requirements

## Description of the development of the artefact

During the **planning phase**, it was determined that the goal of the artefact is to determine whether students understand their work with the use of facial recognition. It was also determined that the due date for the project / artefact to be finished is the 20th of October.

A goal and due date was determined, but before the development could begin, the requirements needed to be defined during the **requirements** **phase**. The following is the initial requirements of the artefact:

1. Detect a human face
2. Determine the expression the person is displaying and display the expression
3. Determine whether the expression is considered confused, happy or neutral
4. Display the amount of students that are confused

One of the advantages of the iterative life cycle is that the requirements can change and new functionalities can easily be added, and throughout the build, new requirements were also added to the initial requirements list:

1. Blur out the students face
2. Remove the emotion and only display text saying ‘student’
3. Keep track of general sentiment for a time the lecturer provides
4. Write the general sentiment for the time period in a comma separated value file, also known as a ‘.csv’ file.
5. Display the CSV result in a graph for visual representation.

After finalizing the goals, due dates and requirements, some design decisions needed to be made. The programming language, code editor and resource manager and technologies needed to be decided. Python was chosen as the programming language seeing a lot of libraries can be used in aiding the development of the artefact. It is also a simple and easy language to understand with a lot of advantages. The code editor that was used is Visual Studio Code. It is easy to use and has a familiar feel to it. Different extensions such as co-pilot and GitHub aided in the development of the artefact. The resource manager that was used is GitHub. GitHub makes version control easy, and complements one of iterative life cycle advantages of keeping track of progression and builds. Seeing as the goal is to use facial recognition is was obvious that a computer and some sort of camera was needed. A Hikvision 1080p webcam and a North-West University computer was used.

It is important to note that not every build would satisfy a requirement, but could be part of the completion of a specific requirement. After making these decisions, the first build, known as ‘Build 1’ could begin.

**Build 1: Face Detection**

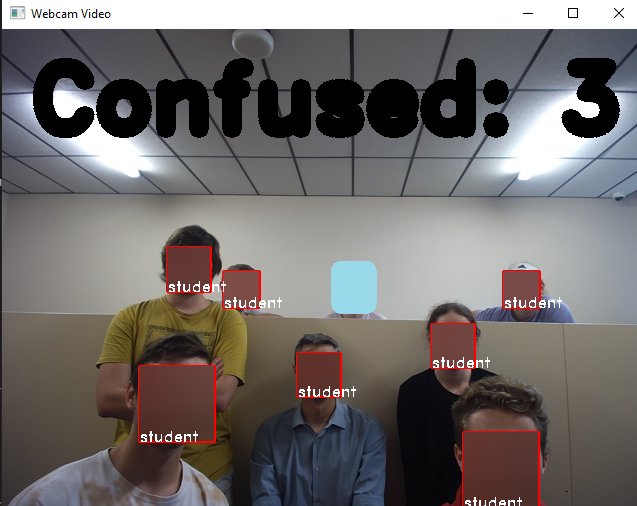
The first build’s goal was to develop a function that could detect human faces. A lot of research was done and the ‘face\_recognition’ and ‘openCV’ was used to create a function that will detect human faces.

Using a camera, the artefact will open a window showing what the camera sees. The video is divided into frames, and each frame is processed. First an algorithm will detect whether faces is present in the frame. The HOG facial detection algorithm will be used, seeing as it looked like one of the better algorithms discussed in Section 2.4.2. When a face is detected, it will draw a square around the face. These functions will be performed using the help of OpenCV, which is a free, open-source library used for computer vision and machine learning and the face\_recognition library. It was continuously tested and once the program detected a person and draw a square around each face, Build 1 was done, and a commit was done to GitHub.

**Build 2: Expression Recognition**

**Build 3: Confusion Counter and UI**

**Build 4: Blur out faces**



**Build 5: Keeping track of General sentiment**

**Build 6: Write general sentiment to CSV file**

**Build 6: Read CSV and show results visually**

Another algorithm will be used to determine the facial expression of the student or students within the square. This will be done using a model and weighs that was obtained on Kaggle, which is a community of data scientists and machine learning practitioners. The model and weights used during this project is provided by Jonathan Oheix, a data scientist from France.

Unfortunately, the datasets only classify the images according to Ekman’s seven basic emotions, seeing there is a lack of datasets for “confusion”. But as explained in Section 2.3.2, anger, disgust and sadness carry the same facial features as confusion, and therefor if it is determined a student is expressing either of these emotions, it can be seen as possible confusion.

There will be 3 counters that will count 3 types of ‘emotions’, namely confused, happy and neural. The counter with the highest value will be referred to as the general sentiment. If a student is detected as sad, angry or disgusted the confusion counter will be incremented, if a student is happy, the happy counter will be incremented and if a student is neutral, the neutral counter will be incremented. Each frame of the video, the general sentiment will be displayed in console and the confusion count will be displayed on screen.

As mentioned in the artefact description, the artefact will also keep tract of the general sentiment for a time period set by the lecturer and will be displayed in console every set time period and will also be written to an excel file that will be saved locally.

After the program has been terminated, a graph will read the

APPENDIX A

A survey was done among third-year Bachelor of Science in Information Technology students from the North-West University in order to get a better understanding of whether the proposed system would be useful. The survey link was uploaded to Efundi which is a portal and website students, and the university uses. The survey was non-compulsory, and the students were also informed thereof.

Survey URL: <https://forms.gle/K97FSaHBnQSVDFef9>

The following Table 6 shows the close-ended questions asked and the survey results.

Table - Close-ended Survey Questions

|  |  |  |
| --- | --- | --- |
| **Question** | **Yes** | **No** |
| Are you aware this Survey is optional and not compulsory? | 31 | 0 |
| Do you give consent for me, Hano Strydom, to use the information gathered as part of my research? | 31 | 0 |
| Are you a shy person? | 18 | 13 |
| Will you raise your hand to ask a question in a classroom with more than sixty people? | 14 | 17 |
| Would it be convenient if a lecturer would know whether you do not understand a topic? (Without direct communication) | 30 | 1 |
| Would you give consent to be recorded in real-time to collect facial features and expressions, without storing any video files? | 22 | 9 |

There was also one that gave an option to provide their own answers shown in Table 7. The first four answers were given, and the final three answers were entered by the students.

Table - Survey Question

|  |  |
| --- | --- |
| Which of these methods do you prefer when you do not understand a topic? | |
| **Answers** | **Results** |
| Put up your hand in class | 4 |
| Review work alone after class | 24 |
| Consult with your peers/students | 24 |
| See the lecturer in his/her office time | 17 |
| Additional resources on Efundi / Internet | 1 |
| Google | 1 |
| YouTube | 1 |

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