Design Document Part 1: Introduction

1.1. Problem Statement

Machine learning offers a versatile toolkit for a wide range of applications. In the context of our project, our client, JR Spidell, wants to develop a system capable of monitoring the focal point of an individual's gaze. The current primary objective of this endeavor is to analyze the movement of a user's pupils. This initial foundation opens the door to other applications such as monitoring emotions, visual aid assistance, and within different health fields and further general development of computer vision applications.

To achieve this, three algorithms have to be ran: image preprocessing, blink detection, and eye tracking simultaneously. All algorithms must run simultaneously as each algorithm depends on one another to monitor the users current state of their eyes from frame to frame of input. This project has benefitted from the contributions of many teams, previous teams successfully executed some of the algorithms independently on the Kria board providing some results and proof of concept for implementation. Our challenge, however, is to design a comprehensive program capable of concurrently operating all three algorithms.

This task is complicated by the hardware constraints of the Kria board, which, at the moment, is equipped with a single Deep Learning Processing Unit (DPU). Both the blink detection and eye tracking algorithms rely on the DPU. On top of that, by running multiple resource heavy algorithms at the same time, other resources, such as memory and processor cores, have to be delicately managed.

With prior teams building a foundational code base and implementing the ability for some of the algorithms to perform inferences while individually running on the Kria board. Our objective is to design a system that optimizes the distribution of the resources on the board across the different algorithms to achieve a target throughput of 200 frames per second (FPS) while all algorithms are running. Our design will perform multiple inferences on different frames simultaneously while also passing the frames across the different algorithms. This implementation will handle all necessary inferences required to determine the state of the users' eyes in one pass, utilizing different techniques such as multi-threading, memory management, and proper resource allocation to achieve the target throughput. 200 FPS is deemed the minimal requisite for the system to fulfill its intended function effectively.

1.2. Intended Users

The product we are developing finds its significance across multiple user demographics, each with distinct characteristics and expectations. These include our primary client, with a vision for advancing research and educational opportunities, Dr. Mark Johnson, focusing on enhancing patient treatment through eye tracking, and a hypothetical third client, a software development company specializing in educational tools.

Primary Client: The Researcher and Benefactor

- **Persona:** Our primary client, JR Spidel, is an academic researcher and alumni of our university, dedicated to the innovative field of emotion detection via eye tracking. He is motivated by the dual objectives of contributing to groundbreaking research and offering practical learning experiences to students.

- **Needs:** The client aims to harness eye tracking technology to decipher emotional states, thereby advancing the understanding and application of this technology in various fields.
- **Benefits:** By achieving this, the client not only furthers research in an emerging area but also enriches the academic community by providing students with a hands-on project that bridges theoretical knowledge and real-world application. This alignment with the project's goal of fostering an educational ecosystem while pushing the boundaries of machine learning applications.

Client 2: Dr. Mark Johnson, The Medical Researcher

- **Persona:** Dr. Mark Johnson is a forward-thinking doctor engaged in pioneering research that integrates eye tracking with patient care. He is deeply invested in exploring the correlation between eye movements and emotional states to improve both physical and mental treatment strategies.
- **Needs:** Dr. Johnson seeks innovative tools that can provide new insights into patient emotions, potentially unlocking more holistic treatment approaches.
- **Benefits:** The product promises to enhance Dr. Johnson's research by offering precise, real-time data on eye movement patterns, facilitating a deeper understanding of patient emotions. This could revolutionize the way mental and physical ailments are approached, directly linking our project to the broader aim of improving healthcare outcomes.

Client 3: EdTech Innovations, The Educational Software Company

- **Persona:** EdTech Innovations is a company at the forefront of developing educational software that incorporates cutting-edge technologies to create more engaging and effective learning experiences. Their team is composed of educators, developers, and researchers who are passionate about harnessing technology to enhance education.
- **Needs:** They are interested in exploring how eye tracking can be used to assess student engagement and comprehension in real-time, tailoring educational content to individual needs for optimized learning outcomes.
- **Benefits:** Integrating our eye-tracking technology could enable EdTech Innovations to develop applications that adapt to students' emotional and cognitive states, making learning more personalized and effective. This potential to revolutionize educational methodologies and tools reflects our overarching objective of leveraging machine learning to address complex, real-world problems in innovative ways.

Each of these user groups stands to gain substantially from our project. The researcher and benefactor, by achieving a groundbreaking stride in emotion detection; Dr. Mark Johnson, by opening new avenues in patient care; and EdTech Innovations, by pioneering personalized learning experiences. Together, they encapsulate the multifaceted impact of our work, highlighting its relevance to academic research, healthcare, and education.