INSTITUTE OF SPACE TECHNOLOGY
KICSIT, Kahuta Campus

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I take full responsibility of the research work conducted during the thesis titled "**Panoramic 3D Image Generation**".

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DEDICATION

This research work is dedicated to our beloved Parents, Teachers and Friends who supported and motivated us in tough times and made us into what we are today.

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Regards:

Kashif Ali Javaid

Muhammad Touseef

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ABSTRACT

Panoramic imaging provides a wide field of view that helps users to engage themselves personally in the scene or environment. In the early stages of panoramic image generation, panoramas were created by stitching multiple static images together. This was a time consuming process that firstly required all images to be captured before they can be stitched to generate the panorama. Recently the advancement in the field of computer vision have made it possible to generate panoramas at real time using a single camera feed. This allows panoramas to be created without any preprocessing.

Generating panorama at real-time is accomplished by tracking camera motion between frames and predicting the homography, or transformation, required to connect neighboring frames. New frames are aligned and merged to the existing panorama as the camera travels. This technique is repeated with each successive frame, gradually constructing the panorama over time. Handling parallax effects and distortions that cause misalignment between frames is a significant task. To address these difficulties, powerful image alignment and blending algorithms are necessary.

The goal of this project is to improve the user's experience of immersion and involvement inside a dynamic panoramic environment by proposing an innovative technique to real-time panorama production. In our project we have designed a Panorama generation system that will stitch the images at real time. The approach we have used overcomes the limitations of the offline image stitching process in which we stitch the static images. The large processing time that the static image stitching takes is reduced due to real time processing by using the concept of concurrent programming.

To perform this functionality, the project combines the modules to work together. The system is decomposed in three functional modules each implemented on a separate thread. Firstly, a single camera mount on the rotating structure captures the frames. Secondly, by using the advanced computer vision algorithms, features are extracted from the input frames using the ORB algorithm, then these features are matched and homography is performed using RANSAC, and finally these images are blended.

Real time panorama generation have a number of applications in different fields that includes virtual reality experiences, video gaming, and interactive simulations. It also have possible advantages in the fields of architectural visualization, training simulations, and entertainment.

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Acronyms and Abbreviations

SIFT (Scale-Invariant Feature Transform)

SURF (Speeded-Up Robust Features)

RANSAC (RANdom SAmple Consensus)

CNN (Convolutional Neural Network)

2D (2-dimensional)

3D (3-dimaensional)

ORB (Oriented FAST and Rotated BRIEF)

RGB-D (Red Green Blue Depth)

3DMM (3D Morphable Model)

FOV (Field of View)

SfM (Structure of Motion)

SDK (Software Development Kit)

ICE (Image Composite Editor)

API (Application Program Interface)

IDE (Integrated Development Environment)

BMP (Bitmap)

JPG (Joint Photographic Experts Group)

PNG (Portable Network Graphics)

GPU (Graphics Processing Unit)

HDR (High Dynamic Range)

AR (Augmented Reality)

VR (Virtual Reality)

SDG (Sustainable Development Goal)

CHAPTER 1

INTRODUCTION

Panoramic imaging have evolved as an emerging field and engaging medium to give viewers with a full perspective of a location in the age of immersive technology and visual experiences [1]. Panoramas provide a wide-angle picture of a scene, allowing users to explore and travel around it as if they were physically present [2]. Real-time panorama generation, in particular, has received a lot of interest since it allows users to generate and interact with panoramic views in real time, opening up new possibilities in fields like virtual reality, gaming, tourism, and architectural visualization [3].

The purpose of this project is to create a real-time panorama creation system capable of smoothly capturing and stitching many images to provide an immersive, high-quality panoramic view. The system will use powerful computer vision techniques and algorithms to find overlapping regions in the input photographs and properly align them to generate a smooth, aesthetically attractive panorama. The generated panorama will provide viewers a full 360-degree field of view, allowing them to examine the captured surroundings from any angle.

The research will concentrate on tackling important issues in real-time panorama production, such as dealing with parallax effects, distortions, and misalignments across frames. Advanced algorithms will be developed to properly monitor camera motion and predict the transformations required to align and blend frames together. Furthermore, the system will be tuned to function in real time on a variety of devices, providing seamless and rapid panorama production.

Real-time panorama generation has a wide range of potential applications. This technology brings up new possibilities for interactive and immersive visual experiences, from immersive video conferencing and virtual tours to robotic navigation and cinematic special effects [4]. This project seeks to promote panoramic imaging and its applications in diverse sectors by establishing a stable and efficient real-time panorama creation system.

In the following sections, we will delve into the theoretical details of the project, discussing the background, objectives, and scope of the project.

1.1 Project Background

Panoramic imaging has long been a source of fascination, dating back to the nineteenth century when artists and photographers strove to capture wide-angle views of landscapes and cityscapes [5]. The generation of panoramic images have advanced dramatically with the introduction of digital photography and computer vision technology. Traditional approaches entail photographing a scene from many perspectives and then stitching them together using image processing tools. This procedure, however, is frequently time-consuming and necessitates considerable post-processing, limiting its real-time uses.

As a remedy to these restrictions, the notion of real-time panorama generation evolved. The goal is to generate panoramic images on the fly from a single camera feed, eliminating the need for post-processing. This is accomplished by monitoring the motion of the camera between frames and determining the homography, or transformation, required to align consecutive frames. New frames are taken, aligned, and flawlessly integrated into the panorama in real time as the camera travels.

Advances in numerous major areas of technology have driven the development of real-time panorama creation systems. For starters, advances in camera technology, notably the introduction of high-resolution digital cameras, have enabled the capturing of detailed and high-quality images that may be utilized to produce panoramic images. Second, advances in computer vision and image processing techniques have allowed for effective tracking of camera movements and homographies estimate. Finally, the increased processing capacity of current devices has enabled these complicated computations to be performed in real time.

Despite these advances, real-time panorama generation remains a difficult challenge. Handling parallax effects, which occur as the camera moves and objects at various distances change relative to one other, is one of the most difficult challenges [6]. This might result in panoramic misalignment and distortion. Dealing with variations in lighting and exposure between frames, which can result in obvious seams in the panoramic, is another problem. Additionally, the system must be tuned to work effectively on a variety of devices, providing seamless and rapid panorama production.

To solve these issues, several ways have been offered. Some systems employ a revolving line camera to sweep across a subject, but others employ a conventional camera and rely on the user to physically move the camera in an arc. A few systems are totally hands-free, relying on sensors to detect camera movements and generate panoramas with no human interaction. These systems, which are tailored to run in real time, use powerful algorithms to handle parallax effects, distortions, and exposure discrepancies [7].

The applications for real-time panorama generation are numerous. This technology may be utilized in video conferencing to give an immersive experience, robotic navigation to provide a broad field of vision, and virtual reality to create immersive surroundings, in addition to its typical usage in photography and filmmaking [8]. The development of strong and efficient real-time panorama creation systems is more important than ever, given the growing need for immersive and interactive visual experiences.

This project intends to make a contribution to this field by creating a real-time panorama generation system that meets the aforementioned issues and may be utilized in a range of applications. The parts that follow will go into the project's technical intricacies, addressing the approaches, algorithms, and implementation strategies used to enable real-time panorama production.

1.2 Problem Statement

To develop a system that is capable of generating panoramic images at real time that provides fast processing speed and better efficiency than offline stitching methods.

1.3 Problem Description

The main goal of this research is to create a system that can generate panoramic images in real time from a single camera feed [9]. This entails overcoming a number of technological obstacles and restrictions inherent in traditional panorama generation approaches.

Traditional panorama generation process involved taking many photographs of a scene from various viewpoints and then stitching them together with image processing tools. This procedure is frequently time-consuming, necessitates substantial post-processing, and is incompatible with real-time applications. Furthermore, it might cause noticeable seams or distortions in the final panorama as a result of image misalignment, changes in lighting and brightness, and parallax effects.

The problem can be broken down into several sub-problems:

1.3.1 Camera Motion Tracking

The system must precisely follow the camera's movement between frames. This is critical for predicting the modifications required to align neighboring frames and dealing with parallax issues.

1.3.2 Image Alignment and Blending

The system must match new frames with the old panorama and elegantly merge them. Handling distortions and exposure changes between frames, which might result in noticeable seams in the panoramic, is required.

1.3.3 Real-Time Processing

These sophisticated computations must be performed in real time by the system. This necessitates improving the algorithms as well as the system design to provide seamless and responsive panorama production, especially on low-power devices.

1.3.4 Handling Difficult Cases

The system must deal with challenging situations such as repeated textures, moving objects, and low-light surroundings. These circumstances might result in panoramic misalignment and distortion, necessitating extensive image processing techniques.

This project's purpose is to create a real-time panorama generation system that handles these sub-problems. The system should be capable of producing high-quality 360-degree images in real-time, allowing users to have an immersive and engaging visual experience. The project's success will be determined by the quality of the created panoramas, the speed with which they are generated, and the system's capacity to handle a wide range of scenarios and settings.

1.4 Project Objectives

The goal of the Real-Time Panorama Generation project is to create a system that can produce real-time panoramic images or scenes from a sequence of input photos or a video stream. By capturing a broad field of view, panoramic images give an immersive viewing experience by allowing viewers to explore a scene as if they were physically present in the scene. The project intends to use modern computer vision techniques and algorithms to stitch together several images and generate a seamless panoramic depiction.

This project's major objective is to achieve real-time performance, allowing users to view panoramic images as input frames are taken or streamed. For applications such as live video streaming, virtual reality, and augmented reality, where a delay in image processing can have a substantial influence on the user experience, real-time production is critical. The system intends to produce panoramas with low latency by improving the stitching process and exploiting parallel computing techniques, delivering a seamless and dynamic viewing experience.

Another important goal of the project is to guarantee that the created panoramas are accurate and of high quality. The system will use powerful feature identification and matching algorithms to correctly align and stitch the input images, reducing distortions and artifacts. It will also use image enhancement techniques to increase the visual quality of the panoramas, such as increasing details, color balance, and dynamic range, in order to generate aesthetically appealing and accurate representations of the captured settings.

Furthermore, the project aims to solve the issue of dealing with changing situations. Traditional panorama creation methods struggle with moving objects or changing lighting conditions, resulting in ghosting effects or poor stitching. The real-time panorama creation system will attempt to address these challenges by employing sophisticated techniques such as motion estimation and robust blending algorithms to deal with dynamic aspects in the scene while maintaining the coherence and continuity of the panoramic image.

The Real-Time Panorama Generation project's overall goal is to create an efficient and accurate system that can generate panoramic images in real time, giving the users an immersive viewing experience and a wider field-of-view that can be used across a wide range of applications. The system will advance the area of computer vision and enable superior visual experiences in multiple fields by reaching real-time performance, retaining high-quality results, and managing dynamic scenarios efficiently.

1.5 Project Mapping with Sustainable Development Goals

Keeping in view the responsibilities of an engineer towards the sustainability of environment, this project is designed to address maximum of these goals. The project mapping with regard to these goals is discussed below.

1.5.1 No Poverty: -

Real-time panorama generation can contribute indirectly to reducing poverty by creating opportunities for economic growth in various sectors. For instance, it can be used in tourism, promoting local businesses, and attracting investments, which can generate income and job opportunities for communities living in poverty.

1.5.2 Zero Hunger: -

Real-time panorama generation can support SDG 2 by helping to monitor agricultural activities and crop health. Farmers and agricultural organizations can use panoramic imagery to identify issues such as pests, diseases, and drought, enabling more efficient and productive farming practices.

1.5.3 Good Health and Well Being: -

Real-time panorama generation can aid in healthcare by providing 360-degree views of medical procedures, assisting in surgical training, and telemedicine. It can also help in disaster response by offering situational awareness through real-time panoramic views in crisis situations.

1.5.4 Quality Education: -

Real-time panorama generation can be used in educational settings to create immersive learning experiences. For instance, it can enable virtual field trips or simulations that enhance students' understanding of geography, history, and science.

1.5.5 Gender Equality: -

Real-time panorama generation can promote gender equality by providing a platform for women in photography and technology fields. Ensuring equal access and opportunities for women in these sectors can contribute to gender balance.

1.5.6 Decent Work and Economic Growth: -

Real-time panorama generation can create job opportunities in various sectors, including tourism, technology, and content creation. Additionally, it can enhance productivity and efficiency in industries that rely on panoramic imagery for marketing and promotion.

1.5.7 Industry, Innovation and Infrastructure: -

Real-time panorama generation often relies on advanced technology and innovation in computer vision, image processing, and hardware development. These innovations can contribute to the development of more efficient and sustainable infrastructure, such as smart cities and transportation systems.

1.5.8 Sustainable Cities and Communities: -

Real-time panorama generation technology can be integrated into smart city planning and management, contributing to the creation of more sustainable and livable urban environments. For example, it can be used for real-time traffic monitoring, urban planning, and disaster management.

1.5.9 Responsible Consumption and Production: -

Real-time panorama generation can contribute to responsible consumption and production by reducing the need for physical travel through virtual tourism and remote monitoring of sites, potentially reducing carbon emissions.

1.6 Project Scope

The Real Time Panorama Generation Project's scope includes the design, development, and testing of a system capable of creating real-time panoramic images from a single camera feed [10]. The project's goal is to overcome the limits of existing panorama generating methods in order to create a more efficient and user-friendly alternative for producing immersive visual experiences.

The project will entail creating a real-time panorama generation system. Defining the system architecture, selecting the proper algorithms for camera motion tracking, image alignment, image blending, and developing the user interface are all part of this process. The needs of real-time processing, user-friendliness, and the capacity to manage a wide range of scenarios and conditions will influence the system design.

The project will require the creation of algorithms for tracking camera movements, image alignment, and multi-band blending. These algorithms will be intended to manage parallax effects, distortions, and exposure variations across frames and will be optimized for real-time processing. To address tough instances such as repeated textures, moving objects, and low light conditions, advanced image processing techniques will be applied.

Based on the system architecture and algorithms, the project will comprise the construction of a real-time panorama generating system using the concept of concurrent programming. The system will be built with appropriate programming languages and software development tools. The development process will adhere to software development best practices, such as version control, code reviews, and continuous integration.

The real-time panorama creation technology will be rigorously tested as part of the project. This involves unit testing of individual components, system integration testing, and performance testing to assess the system's speed and responsiveness. The system's panoramic quality will also be examined, and user testing will be performed to assess the system's usability and user-friendliness.

The project will necessitate the compilation of extensive documentation. Technical documentation describing the system architecture and algorithms, user manuals for running the system, and project documentation recording the project's progress, obstacles, and lessons gained are all part of this.

Users will be trained on how to utilize the real-time panorama creation system as part of the project. This involves both the provision of training materials and the delivery of training sessions.

The project will not include the creation of hardware components like cameras or sensors. The system will be intended to work with current camera hardware, and we have used a stereo camera, the Intel Realsense D415 camera for acquiring the images. The project will also not include the creation of a mobile app or a web-based system interface. The system will be a stand-alone piece of software that can be installed on a computer.

The project's success will be determined by the quality of the created panoramas, the speed with which they are generated, and the system's capacity to handle a wide range of scenarios and settings. User comments will also be analyzed to determine the system's usability and friendliness.

The project is anticipated to provide a contribution to the area of panoramic imaging by developing a reliable and efficient method for real-time panorama generation. This technology has a wide range of possible applications, from immersive video conferencing and virtual tours to robotic navigation and cinematic special effects. This project intends to expand the possibilities for interactive and immersive visual experiences by building a real-time panorama generation system.

1.7 Overview of the Report

This project's purpose is to investigate and develop the state-of-the-art in panoramic image production. This report will briefly explain the idea and motivation behind this project, current methods and techniques for recording, stitching, and producing panoramic images and videos, the process of developing our proposed system to improve the mechanism of generating panoramas.

This will be followed by an evaluation process to determine the system's performance and compare it with existing methods and techniques. Finally, future research and development directions in the field of panoramic image generation at real time will be discussed.

In the beginning, an outline to the report is presented. The first chapter, introduction, includes the background, problem description, scope and objective, and applications of panoramic imaging. The next chapter explain a brief summary of recent methods and technologies being used for panoramic image generation and how they work. The next chapter concentrates on the functional and non-functional requirements, and the user requirements of the system. The next chapter describes the design of the panorama generation system. It also explain the architecture and the implementation methodology of the system. The next chapter describes the testing and evaluation of the system. It enlists the results achieved in comparison with the existing systems. The last chapter concludes the report and highlights a few ways in which the future work can be carried out.

CHAPTER 2

LITERATURE REVIEW

High-quality panoramic image production is a fast emerging topic that has piqued the interest of both academics and business in recent years [11]. Panoramic images offer a more immersive and dynamic viewing experience, allowing viewers to explore a subject from many angles and viewpoints. This is especially important in sectors such as virtual reality, tourism, and real estate, where reaching a high degree of engagement and involvement requires an accurate and precise portrayal of a scene.

Initially, efforts in panoramic images generation were restricted to basic image stitching algorithms that integrated numerous images into a single panoramic image [12]. Researchers have created increasingly complex algorithms that combine depth information, scene alignment, and real-time rendering as the field has matured. These advancements have enabled the generation of high-quality panoramic photographs that, when compared to typical offline panoramic images, give a more immersive and engaging experience.

To obtain flawless real-time results, real-time panorama generation is a complicated process that requires fast algorithms and hardware acceleration [13]. Researchers have made considerable advances in this subject over the years by proposing various image-stitching algorithms, improving image alignment, and inventing real-time rendering approaches. GPUs and hardware acceleration have been very critical in obtaining real-time performance. However, there is always space for growth, particularly when dealing with difficult conditions such as dynamic sceneries and large-scale panoramas. Future research should concentrate on building more robust and efficient algorithms to solve these issues and enable real-time panorama synthesis for a variety of applications.

Recent research has concentrated on building algorithms that can automatically and precisely stitch numerous photos or videos together to create a seamless panoramic image [14]. One strategy is to use feature-based algorithms to match and align features across many photos or videos, whilst another option is to use direct methods to align the images or videos based on the geometry of the scene. Furthermore, researchers have created algorithms that can effectively assess the depth information of a scene, which is required for generating a realistic real-time experience.

Maintaining excellent picture quality while lowering storage and bandwidth needs is one of the most difficult challenges faced by panoramic image creation. Advanced compression and optimization techniques, such as picture warping, image pyramids, and lossless compression, are required. Deep learning methods, such as convolutional neural networks (CNNs) [15], have also been investigated for increasing the quality and realism of panoramic images.

Despite advancements in the industry, some crucial difficulties have to be solved in order to attain the necessary degree of realism, accuracy, and interaction. These include increasing the accuracy and resilience of image stitching algorithms, enhancing algorithm quality and accuracy, and developing efficient and scalable algorithms for large-scale real-time panoramic image creation.

During our research for real time panorama generation techniques, we got help from a numbers of journals and research papers. We are listing the important information from the papers below.

2.1 High Quality Panoramic Imaging using Depth Map

Hao Ma designed a technique route to generate high-quality panoramic image with depth information in his paper, "A Method of Generating Measurable Panoramic Image for Indoor Mobile Measurement System" [16], which involved two critical research hotspots: fusion of LiDAR and image data and image stitching. He used a parametric self-adaptive framework to generate a 2D dense depth map from the merging of 3D points and picture data. For the stitching purpose, he used a graph-cuts-based approach to find the best seam line for the overlapping region, and he used image blending based on the pyramid multi-band to avoid photometric effects around the stitching line. He then tested the suggested approach using data from the data gathering platform and revealed promising application possibilities.

2.2 Panoramic Image Creation using SIFT and RANSAC

Sruthi P. provided an excellent approach for creating panoramic images in her paper "Panoramic Image Creation" [17]. She employed the SIFT (Scale Invariant feature transform) approach for automated feature recognition and feature mating. She demonstrated a seven-step technique to stitch the images that includes the following steps: capturing the input image, feature detection, feature matching, image registration, computation homography using RANSAC, image warping, and lastly image labeling using optimum seam. The goal of this study was to write a Matlab script that stitched two or more photos together to form a bigger image.

2.3 Deep Learning based PanoStitchNet System for Stitching

The use of deep learning for the generation of panoramic image at real time has become a key trend. Du, Chengyao, and colleagues published a paper titled "GPU-based parallel optimization for real-time panoramic video stitching."[18], which proposed PanoStitchNet, a deep learning system for real-time panoramic video stitching. Their technique employs two convolutional neural networks, the first of which calculates homographies between frames and the second of which executes seamless stitching. PanoStitchNet can stitch 4K footage in real time and create high-quality panoramas.

2.4 Panorama Generation using DeepStitch Architecture

DeepStitch is an end-to-end deep learning architecture developed by Xu et al. for real-time panorama production [19]. Their methodology takes numerous overlapping photos and instantly creates a stitched panorama, eliminating the requirement for traditional techniques like feature matching. DeepStitch produces cutting-edge outcomes in terms of both speed and panoramic quality.

2.5 Semantic Segmentation for Image Stitching

Another new development is the utilization of semantic information. Zhang et al. suggested a semantic-aware real-time panorama creation approach [20]. Semantic segmentation is used to guide the stitching process in their technique. Their technology, which aligns semantically comparable locations, can produce higher-quality panoramas than existing approaches.

2.6 RTPan for Mobile Devices

Architectures that are efficient have also been investigated. Li et al. (2020) presented Real-Time Panorama (RTPan), a lightweight model for quick panorama synthesis on mobile devices [21]. RTPan offers real-time performance on mobile GPUs with equivalent quality to much bigger models by employing an efficient encoder-decoder architecture with channel pruning.

To summarize, the topic of panoramic 3D picture production is a fast-emerging and changing area of study with the potential to alter how we view and interact with our environment [22]. Recent improvements in computer vision and computer graphics have enabled the creation of high-quality 3D panoramic photographs that when compared to typical 2D panoramic images, give a more immersive and engaging experience. However, many crucial difficulties need to be solved in order to attain the necessary degree of realism, accuracy, and interaction, and there is plenty of room for additional study and development in this sector.

CHAPTER 3

REQUIREMENT ANALYSIS

The purpose of the requirement analysis for real-time panorama production is to establish the project's goals, scope, and limitations. This document gives a thorough grasp of the project requirements and acts as a roadmap for project development.

The primary goal of the project is to create a system for creating real-time panoramic photographs, to deliver high-quality and realistic panoramic images, and to integrate the system into current photographic apps. The system should be able to create panoramic pictures by combining numerous photographs. The system must be capable of processing photos in real time. Image formats such as JPG, PNG, and BMP should be supported by the system. The technology should be able to create 360-degree photographs. The system must be able to create pictures from the perspective of a virtual camera.

3.1 System Requirements

The requirements of a system serves as the backbone in a successful system development and guarantee that the system satisfies the needs and expectations of the users. To produce the proper panorama, the user-required activities are performed. The system's functional and non-functional requirements are as follows:

Image Acquisition: The system should be able to capture images from the camera in real-time.

Image Pre-processing: The system should be capable of performing image pre-processing operations such as noise reduction and picture correction.

Image Stitching: The system should be capable of generating the panorama by stitching multiple images together.

Viewpoint Control: The system should enable the user to control the camera's perspective in order to view the panoramic image from various angles.

Image Output: The system must be capable of saving the generated panoramic image in a standard format and displaying it to the user in real time.

User Interface: The system must have an interactive user interface that is understandable by the user and easy to interact with.

Performance: The system should be able to create real-time panoramic photos while taking less time to analyze each image/point cloud.

Compatibility: The system should be compatible with a regular personal computer and be able to work on a variety of operating systems, including Windows, Mac, and Linux.

Scalability: The system should be scalable in order to handle a growing amount of photos.

Reliability: The system should be dependable and regularly give correct results.

3.2 User Requirements

The system will be able to create high-quality panoramic images at real time and point clouds in real time, as well as incorporate the image creation system into current workflows. Furthermore, the system is designed to give a 360-degree perspective of a real world, interactive navigation within the panoramic environment, high-quality rendering and graphics, and a variety of other features [23]. These are the user-specific needs. The behavioral specification may be used to validate requirements to see if the systems can deliver certain results. The system should be able to accept image or video frame input and stitch several point clouds or images into a single panoramic image. It should be capable of correcting lens distortion as well as camera misalignment. It should deliver real-time results.

The system's performance is measured using performance metrics [24]. In our project, the system's performance is determined by the following factors:

Image quality: The sharpness, clarity, and resolution of the created panorama are all evaluated.

Stitching accuracy: This metric assesses the degree of overlap and alignment between the different images used to generate the panoramic [25].

Field of view (FOV): This metric assesses the overall visual area covered by the panorama as well as its resemblance to the source scene [26].

Distortion: It is the measure of degree of warping or stretching in the final panoramic picture [27].

Load time: The time required to create the panorama from separate pictures and load it for viewing [28].

User experience: Evaluates the overall easiness in the usability and the satisfaction of user towards the real-time panorama creation system.

3.3 Project Requirements

Our Project is a hardware and software integrated project. We used a number of hardware and software components and tools in our project. The list of those tools and equipment is given below.

3.3.1 Hardware Requirements

The hardware components used in the system are,

3.3.1.1 Intel Realsense D415 Camera

The Intel RealSense D415 is a stereo depth camera from Intel Corporation that is intended for use in robotics, augmented and virtual reality, and computer vision [29]. It has two depth-sensing cameras, a standard RGB camera, and an IR sensor that transmit IR radiations and can be set on a tripod stand as shown in Figure 3.1, which allows it to build precise 3D point clouds and deliver depth information for each pixel in a scene. Its great precision and performance make it a popular choice for applications requiring depth sensing and 3D perception. We selected this camera since we are working with a 3D point cloud that requires a high level of accuracy and performance.

Figure 3.1 Intel Realsense D415 camera [29]

3.3.1.2 Computer System

The implementation and processing of the image processing algorithms requires huge processing capabilities, we employed a high-end computer system as shown in Figure 3.2. We will install the necessary software on the machine and write our algorithm on it.

Figure 3.2 Computer System [30]

3.3.1.3 Mechanical Structure for Rotation

It is a physical gadget that spins the camera to collect a sequence of photographs in order to produce a panoramic view. This mechanism enables the camera to spin in a controlled and consistent manner, allowing images to be captured from various angles and viewpoints. The mechanical framework consist of a motor that enables the structure to rotate and controls the motion, an encoder, a slip ring, microcontroller and the required wires for the connection and communication. The computer system and the camera is mounted on this structure as shown in Figure 3.3. The framework keeps the camera stationary and moving smoothly during the picture capturing process, resulting in high-quality panoramic photographs.

Figure 3.3 Mechanical Structure for Rotation

3.3.2 Software Requirements

The software requirements used in the system are,

3.3.2.1 Ubuntu 20.04

Ubuntu 20.04 is an April 2020 edition of the popular open-source operating system Ubuntu. It is a long-term support (LTS) release, which implies it will be supported and updated for the next five years [31]. The Linux kernel serves as the foundation for Ubuntu 20.04. We picked this version of Ubuntu because it contains several upgrades and improvements over its predecessor, such as an updated user interface, greater speed and stability, and compatibility with new hardware. It has an easy-to-use interface and can run on a wide range of platforms, including PCs, laptops, servers, and smartphones.

3.3.2.2 Eclipse C++ IDE

Eclipse C++ IDE (Integrated Development Environment) is a free and open-source C++ programming development environment [32]. It includes an editor, compiler, debugger, and code analysis tools to assist programmers in writing, debugging, and managing their code. Eclipse C++ IDE is compatible with a variety of operating systems, including Windows, macOS, and Linux. We utilized the Eclipse IDE to write our C++ algorithms.

3.3.2.3 OpenCV 4.16

OpenCV (Open Source Computer Vision Library) is a free and open-source software library for computer vision and machine learning [33]. It supports a wide range of computer vision applications, including image and video processing, object identification and recognition, and computational photography. OpenCV is built in C++ and provides bindings for several computer languages, including Python, Java, and MATLAB, making it simple for developers to utilize [34]. It is frequently utilized in computer vision and graphics, as well as robotics, scientific computing, and image processing applications. For image processing and stitching, we utilized OpenCV.

3.3.2.4 Realsense SDK

The Intel RealSense SDK (Software Development Kit) is a software library that provides tools and APIs for accessing the features of Intel RealSense cameras, which are depth-sensing cameras that capture 3D data and provide advanced image processing capabilities using structured light, stereo vision, and time-of-flight technologies [35]. The SDK offers tools for recording and analyzing depth and color data, as well as APIs and libraries for exploiting this data in applications including augmented reality, robotics, 3D scanning, and gesture recognition. The SDK is compatible with a wide range of operating systems, including Windows, Linux, and MacOS, and it can be used with a number of programming languages, including C++, Python, and C#.

The complete specifications and the requirement of the developed system was listed in this chapter. The system requirements along with functional and non-functional requirements, then the user requirements and at last the requirements of the projects were mentioned. All the details of software and hardware used and how they operate was given in this chapter. In the upcoming section we will discuss how we designed the system using these specifications, what the system looks like, the flow of data between different components of the system and its complete working methodology.

CHAPTER 4

SYSTEM DESIGN AND IMPLEMENTATION

Till now, we have discussed the background, problems, scope and applications of the project. A detail review of the techniques and methodologies that are in use now a days was also discussed. Then the requirements of the system were discussed in details. Going forward, we will discuss the system design, its architecture, data flow, and implementation methodology in this chapter. The next chapter enlist the test conducted and results obtained.

The following phases are commonly included in the design and execution of a real-time panorama generation system:

Acquisition of images or frames: In real-time panorama production, the image acquisition stage entails acquiring a sequence of photos from one or more cameras [36]. To begin, the cameras are positioned such that they cover the necessary field of vision. After that, camera calibration is undertaken to ascertain each camera's intrinsic and extrinsic properties, ensuring precise picture stitching later on. The real picture capturing process starts, with images taken either concurrently or sequentially. To achieve appropriate alignment during stitching, any camera movement or shaking between pictures must be minimized. Our designed rotation structure ensures minimum shaking and movement. A sufficient overlap between consecutive photos is required for successful alignment and blending. Image preprocessing can be used to improve image quality or correct distortions. The image acquisition step in a real-time panoramic project should be adjusted for speed and efficiency. Continuous image collection at regular intervals enables dynamic sceneries to be collected and stitched in real-time, producing an up-to-date panoramic depiction. It is frequently required to integrate image processing and stitching techniques in order to smoothly blend the obtained pictures into a panoramic view.

Feature Extraction: The feature extraction process is a critical component of real-time panorama-generating systems. It entails a number of fundamental steps that allow for the development of seamless panoramic views [37]. The images captured are first preprocessed to improve their quality and decrease noise. Following that, feature identification algorithms are used to discover conspicuous spots or places of interest in the photos that have distinct features. These algorithms look for different characteristics by analyzing differences in color, intensity, and texture.

Descriptors are calculated after the feature points have been detected to capture their local appearance and attributes. These descriptors serve as a foundation for matching and alignment by providing succinct representations of the main aspects [38]. To locate corresponding pairs, the feature descriptors are compared across many pictures using matching algorithms. Outliers are removed, and geometric transformation parameters are computed using RANSAC [39]. Transformation matrices that indicate translation, rotation, and scaling are then used to align the pictures. Finally, the aligned photos are flawlessly merged together using techniques such as feathering and cross-dissolving to create the panoramic view. To manage the computing needs of these operations and attain real-time performance, real-time panorama-generating systems require efficient algorithms, hardware acceleration, and parallel processing.

Feature Matching: An important element in a real-time panorama creation system is the feature matching step, which seeks correspondences between feature descriptors retrieved from distinct pictures. After obtaining the feature points and their descriptors, matching algorithms are used to discover which points in one picture correspond to those in another [40]. The objective is to develop exact matches between the features to guarantee optimal picture alignment and stitching. Nearest neighbor matching is a common matching approach in which the distances of descriptors are compared to locate the closest matches. However, not all matches are trustworthy owing to noise, occlusions, or fluctuations in lighting conditions. Outlier rejection approaches such as RANSAC (Random Sample Consensus) are frequently used to resolve this. RANSAC assists in the elimination of inaccurate matches by iteratively estimating a geometric model from randomly selected matches and finding inliers that fit the model well. Because it establishes the correlation between important spots across numerous pictures, the feature matching stage is critical for establishing precise alignment and robust panorama production.

Image Blending: Image blending is an important stage in the real-time panorama creation system because it smoothly integrates many photos to generate a panoramic view [41]. The purpose of image blending is to remove obvious seams or artifacts when neighboring images overlap. The photos are aligned depending on their properties, such as corners or key points, and then blended together using various approaches. Multi-band blending is a popular technique that divides pictures into distinct frequency bands and blends them independently. By progressively fading the pixel intensities across the overlapping areas, this method guarantees smooth transitions [42]. Furthermore, complex methods such as graph-cut optimization or Poisson blending can be used to tackle difficult instances such as moving objects or exposure discrepancies. Overall, the image blending process is critical in producing aesthetically pleasing and coherent panoramas, allowing viewers to enjoy a smooth and immersive panoramic view in real-time applications.

Rendering: In a real-time panorama creation system, the rendering stage is in charge of converting the stitched panoramic image into a format suitable for display or further processing. When the image blending process is finished, the panoramic image may have a greater field of view than the original input photographs. Rendering is comprised of two major components: projection and resampling.

Optimization: The system may be optimized for specific criteria such as real-time speed, memory use, or computational efficiency during implementation.

The construction of a real-time panoramic image-generating system will be determined by the application's unique needs, the type of system employed, and the available processing resources. The implementation will also be influenced by the programming languages, libraries, and algorithms used [43].

4.1 Existing System

Real-time panorama generation systems are designed to stitch together multiple images in real-time to create a panoramic view. Here are some of the existing systems and how they work:

4.1.1 Microsoft's Image Composite Editor (ICE):

This system employs an image stitching approach, in which numerous photos are aligned and blended together [44]. It detects and describes local characteristics in pictures using SIFT [45] (Scale-Invariant Feature Transform), which are then matched across multiple images. The matching characteristics are utilized to estimate camera motion, and the pictures are warped and blended together to form a panoramic.

4.1.2 PTGui:

PTGui employs a similar strategy to ICE, but allows for more manual control over the stitching process [46]. It aligns photos by using control points (points that are the same in two overlapping images). To enhance alignment, the user can manually add or delete control points. HDR (High Dynamic Range) and tone mapping are also supported by PTGui.

4.1.3 Google's Photo Sphere:

This is a Google Camera app feature that allows users to make 360-degree panoramas [47]. The user shoots several photographs in all directions, which are then stitched together in real time by the program. It guides the user to capture images at the optimal angles by utilizing the device's gyroscope.

4.1.4 Real-time Video Stitching Systems:

These systems, such as those seen in 360-degree video cameras, merge video streams from several cameras together in real-time [48]. They accomplish real-time performance by combining hardware and software. The stitching method is identical to image stitching, however, it must be completed considerably faster.

4.1.5 Deep Learning Based Systems:

Recent breakthroughs in deep learning have resulted in the creation of neural network-based panorama generating systems [49]. These systems are taught using enormous datasets of photos and panoramas. Once trained, they can build real-time panoramas from new photos. These technologies have the ability to generate higher-quality panoramas than traditional approaches, particularly in difficult settings such as low light or with moving objects in the image.

Each of these methods has advantages and disadvantages, and the optimal option is determined by the task's unique needs. One recurrent difficulty with these existing systems is the issue of "parallax error." When the camera is moved between capturing the series of images that will be stitched together to make the panorama, this happens.

The apparent shift in the position of an item induced by a change in the observer's point of view is referred to as a parallax error [50]. This can result in noticeable seams, ghosting, or other abnormalities in the final stitched image in the context of panorama production.

This issue is most noticeable in situations with a lot of depth, where objects are at different distances from the camera. It can be reduced by using a tripod and rotating the camera about its optical center, although this is not always practicable, particularly for casual users or in real-time video stitching systems.

Even with improved algorithms and deep learning approaches, dealing with parallax in real-time panorama production remains a difficult task.

4.2 Discrepancies of Existing System

Each of the existing systems for real-time panorama generation has its own set of discrepancies or limitations:

4.2.1 Microsoft's Image Composite Editor (ICE):

While ICE is strong and easy to use, it struggles with complicated scenes, especially ones with a lot of movement or varied depths [51]. It also lacks the manual control that some other applications has, which might be a disadvantage for professional users.

4.2.2 PTGui:

PTGui provides a lot of control, however this might make it more complicated and difficult to use for novices [52]. It also struggles to manage movement in the scene, which might result in ghosting or other abnormalities in the finished panorama.

4.2.3 Google's Photo Sphere:

The quality of the panoramas created by Photo Sphere may be restricted by the device's camera. It also makes use of the smartphone's gyroscope, which might cause errors if the device is not kept firmly. It also has issues with intricate sceneries or situations with a lot of movement.

4.2.4 Real-time Video Stitching Systems:

These systems must handle a large amount of data fast, which might lead to sacrifices in the final panorama's quality. They may also have trouble with complicated sceneries with a lot of movement or varied depths. Hardware restrictions, particularly in consumer-grade systems, might also be a concern.

4.2.5 Deep Learning Based Systems:

To function successfully, these systems require a huge quantity of training data, and they might struggle with scenarios that are drastically different from their training data. They also necessitate a large amount of processing resources, which might be a constraint for real-time applications.

The key differences between these systems are how they handle complicated situations, particularly ones with a lot of movement or varied depths, and how they balance the requirement for speed and quality in real-time applications.

4.3 Proposed System

To overcome these limitations a system needs to be designed that have the following properties,

4.3.1 Hybrid Feature Detection and Matching:

Combine classical feature identification approaches (such as SIFT or SURF) with deep learning-based feature detection. This has the potential to increase the robustness of feature matching, particularly in complicated scenarios [53].

4.3.2 Advanced Parallax Compensation:

Implement complex parallax correction methods, such as multi-plane projection or depth map estimation [54]. This may assist to eliminate parallax errors when the camera is shifted between photos.

4.3.3 AI-based Image Blending:

Use AI approaches to enhance the image blending process. This may entail teaching a neural network to detect and repair typical blending errors like exposure disparities or color mismatches.

4.3.4 Real-time Processing Optimization:

Use hardware acceleration (such as GPU processing) and software optimization techniques to guarantee that pictures can be processed in real-time, especially when working with high-resolution photographs or video.

4.3.5 User-guided Stitching:

Allow users to manually alter image stitching as needed. This might be especially beneficial in complicated settings where automated stitching may fail.

4.3.6 Motion Compensation:

To handle scenarios with a lot of movement, use complex motion compensation algorithms. This may include employing optical flow estimates or other motion estimating techniques.

4.3.7 Lighting Adjustment:

To manage situations with fluctuating lighting conditions, use HDR methods and AI-based lighting correction [55].

4.3.8 Robustness to Camera Distortions:

Algorithms for correcting typical camera distortions, such as lens distortion or perspective distortion [56], should be implemented.

Our designed system will overcome the limitations by using all these techniques. We are using a hybrid algorithm for feature detection, ORB [57] (Oriented FAST and Rotated BRIEF) that is a combination of two techniques, FAST and BRIEF. We will use a depth camera that have multiple sensors including the IR sensor which allows the night vision capability that overcome the limitation of Light Field Camera technique. In our proposed technique we are using the Computer Vision algorithm for blending that uses AI techniques. It will also be able to work in real-time applications and allow users to navigate through the panoramic point cloud in real time.

4.4 System Architecture

A real-time panorama-generating project's design includes numerous components that work together to provide a smooth and engaging experience for the user. The data acquisition step of the system begins with the capturing of pictures from various angles and positions utilizing a dedicated camera rig or a set of cameras. The collected photos are stitched together to create a single panoramic image, which is subsequently processed to eliminate lens distortion, camera misalignment, and other anomalies.

After the construction of the panoramic scene, it is rendered using powerful computer vision techniques to generate a photorealistic panoramic scene. The produced picture is then integrated with user interaction features like pan and zoom controls, hotspots, annotations, and other elements to provide the user with a completely immersive and engaging experience. To do this, the system handles the rendering and user interface components with a front-end framework like as Unity, Unreal Engine, or Three.js [58].

The system's backend is in charge of storing and processing the data generated throughout the panoramic scene generation and rendering stages. The data is saved in a database or a cloud-based storage solution (or in RAM as in our case) and may be retrieved and updated in real time by the front-end framework. The backend also provides a collection of algorithms and machine learning models that may be used to analyze data and extract useful information, such as object identification, semantic segmentation, and scene categorization. This data may then be utilized to improve the user experience by giving more environmental information and insights.

The system is designed to be very modular in order to assure scalability and dependability, and it may be readily extended and combined with additional components as needed. The system, for example, may be connected with augmented reality (AR) or virtual reality (VR) devices to give the user with an even more immersive experience. Furthermore, the system may be set to function with a number of devices, such as smartphones, tablets, and desktop computers, allowing it to be utilized by a diverse spectrum of users with varying hardware needs.

Finally, the real-time panorama creation system is a complicated and extremely sophisticated system that integrates powerful computer vision, computer graphics, and software engineering approaches to provide a seamless and engaging experience for the viewer. The system provides a highly realistic and engaging experience that can be utilized for a number of applications such as real estate, tourism, and virtual events by integrating data collecting, 3D environment reconstruction, rendering, and user interaction components. Architecture is of this system is shown in Figure 4.1.

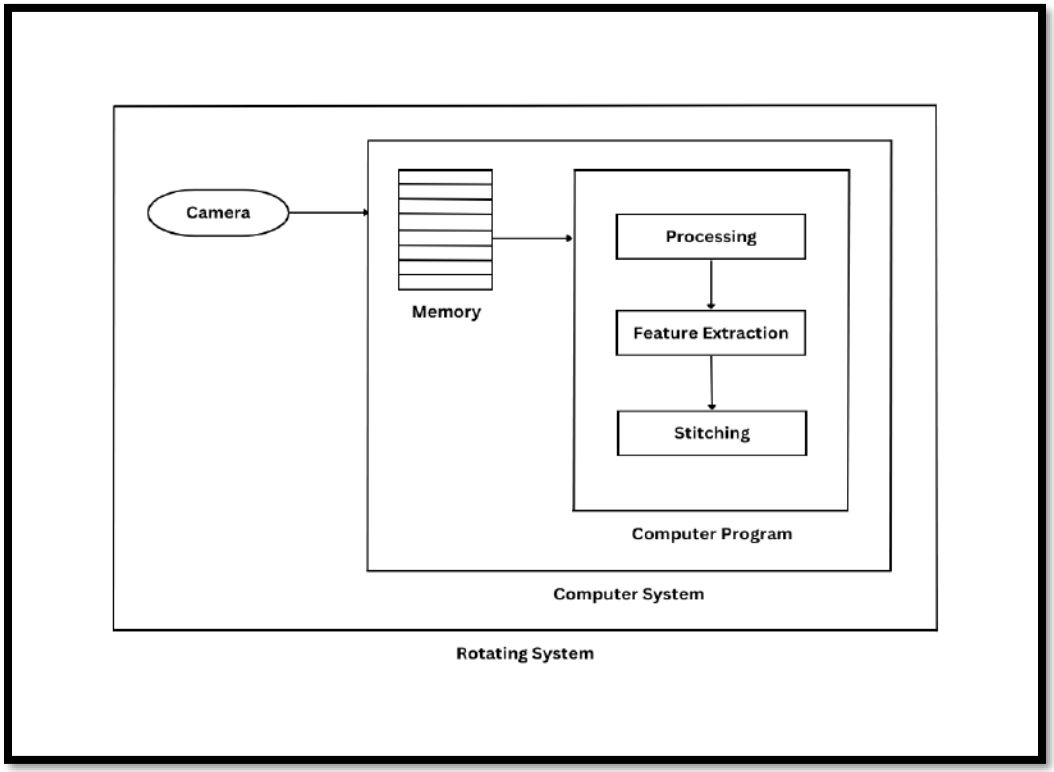

Figure 4.1 Architecture of Real-Time Panorama Generation System

4.5 Functional Decomposition

Real time panorama generation requires a series of steps and functions to be implemented to provide a complete 360-degree view of the scene or environment in 3D [59]. A number of instruments are involved while performing each function. Here we have divided our project into separate function for the better understanding of the system implementation. The functions along with the components required are stated below.

4.5.1 Image Acquisition

The initial stage in the panoramic picture production process is image acquisition. Using a depth sensor camera, the Intel RealSense D415, we acquire numerous photos of a scene from various angles in this stage. Typically, the photos are acquired with overlapping fields of view to guarantee that enough information is recorded to allow for smooth stitching of the images into a panoramic image. To reduce changes in brightness and color among photographs, ensure that they are recorded with similar lighting conditions and exposure settings. In certain circumstances, many photographs at varying distances from the scene may be required to capture the whole depth range of the scene. The acquired photos are then processed in the following processes to produce the final panoramic image.

4.5.2 Preprocessing

Before the photographs are stitched together, they must be well-prepped so that the end result is exact and flawless. Preprocessing photos before stitching is critical to ensuring that the final panoramic image is of excellent quality and devoid of artifacts caused by image distortions, noise, misalignment, or brightness and color discrepancies. Various preprocessing approaches are utilized depending on the difficulty encountered by the users and the equipment being used. The preprocessing techniques used in panorama production are detailed below.

4.5.2.1 Camera Calibration

This includes establishing the camera's intrinsic and extrinsic characteristics, such as focal length, main point, camera posture, all of which are necessary for image rectification [60].

4.5.2.2 Image Rectification

Image Rectification is the process of converting photographs acquired from various perspectives into a single coordinate system while eliminating the effects of camera rotation and perspective [61].

4.5.2.3 Image Correction

This includes compensating for lens vignetting and reducing visual distortions induced by the camera lens, such as a barrel or pincushion distortion [62].

4.5.2.4 Image Filtering

This includes lowering the noise in the image, boosting image contrast, and enhancing image details before stitching to improve image quality [63].

4.5.2.5 Image Alignment

This entails aligning the photos such that they all face the same way and have the same scale. This is required for the photos to be stitched together seamlessly into a panoramic image [64].

4.5.2.6 Color Correction

This entails altering the brightness and color of the photos such that the intensity and color are constant across the full collection of photographs [65]. This is necessary to avoid picture incompatibilities while stitching the photos together.

4.5.3 Image Stitching

In the image-stitching process of panoramic image production, numerous photos recorded from different perspectives are combined into a single, seamless panoramic image. This is accomplished by following the steps outlined below.

The initial stage in stitching is picture registration, which involves aligning the images. This entails locating correspondences between picture elements and using these correspondences to align the images.

After aligning the photos, they must be blended together to form a smooth panoramic image. This entails smoothly transitioning between pictures and removing any seams or discontinuities between them.

In certain circumstances, the photos may need to be bent to compensate for perspective discrepancies or distortion produced by the camera lens.

4.5.4 Image Enhancement

Image enhancement is a phase in panoramic picture production that involves changing the brightness, contrast, color balance, and other image attributes to improve the visual quality of the final panoramic image. This process can increase the image's overall clarity and detail, making it easier to notice key elements and structures in the picture. Image enhancement can also assist to eliminate visual artifacts in the source photographs such as noise, blur, and color imbalance.

4.5.5 Data Storage

Data storage is an important phase in the panoramic image generation process at real time because it includes saving the processed data in a manner that other processes can readily access and utilize. This involves saving the raw photos as well as the intermediate results and the final panoramic image. The captured images will be saved in memory, as will the final resulting panoramic image for future use.

4.6 Data-Flow Model

In our system, data are the images that are acquired, processed and stored. This section will describe how this data flow through different components and functions of the system. The Intel Realsense D415 camera is connected to the computer system and set up on a rotating mechanical structure. Images are captured from this camera and are stored in the memory for a while. After capturing multiple images, the images are transferred to the computer program running on the computer system. Image are rectified in the preprocessing step and then passed on to registration step where features of each images are extracted. After feature extraction, the images are passed on to the stitching function where features are matched and aligned using image blending. When images are stitched and panoramic image is obtained, then in the image enhancement step the noise and distortion are removed. At last these enhanced panoramic images are stored and these steps is repeatedly performed to obtain a continuous view of the scene or environment. The below Figure 4.2 is Data Flow Diagram of Real Time Panoramic Generation.

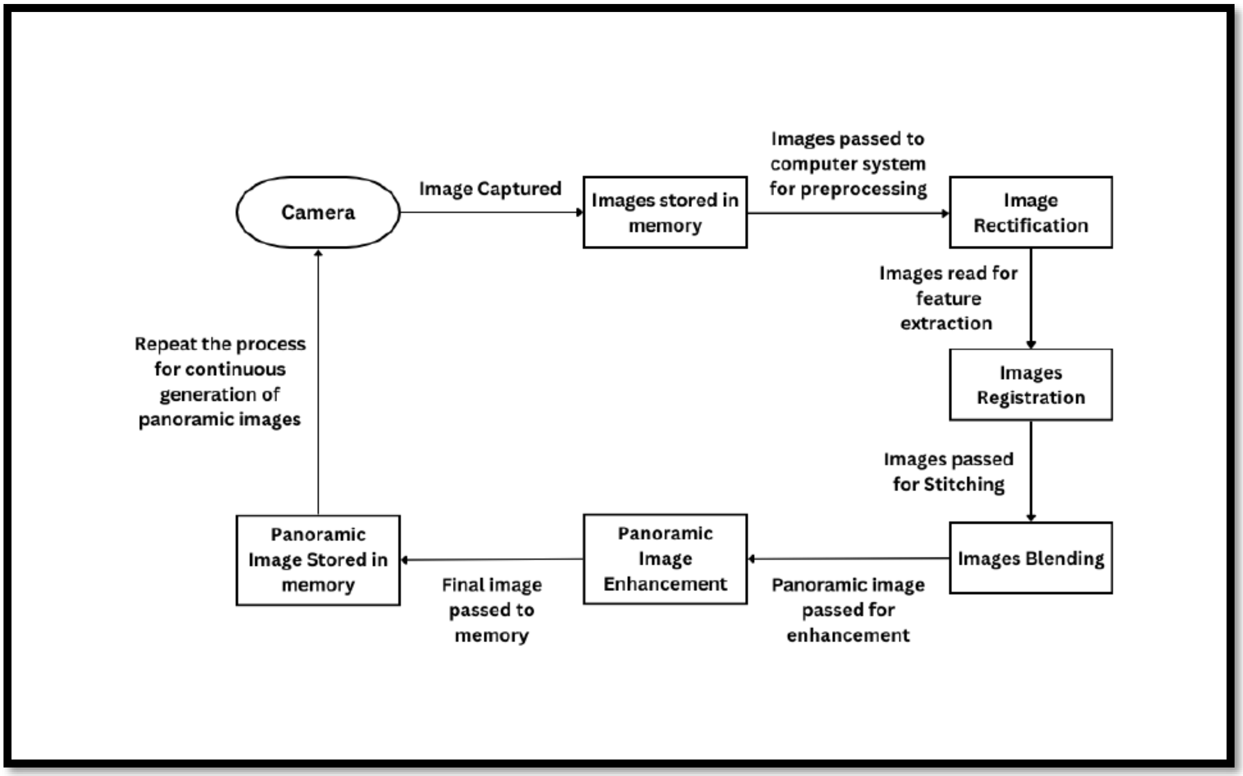

Figure 4.2 Data Flow Diagram of Real Time Panorama Generation

4.7 Block Diagram

The proposed system can be represented in the form of blocks for better understanding of important system components and functionalities. The block diagram is a visual representation of our system that represents the various components and their interactions. The block diagram of the designed system is shown in Figure 4.3.

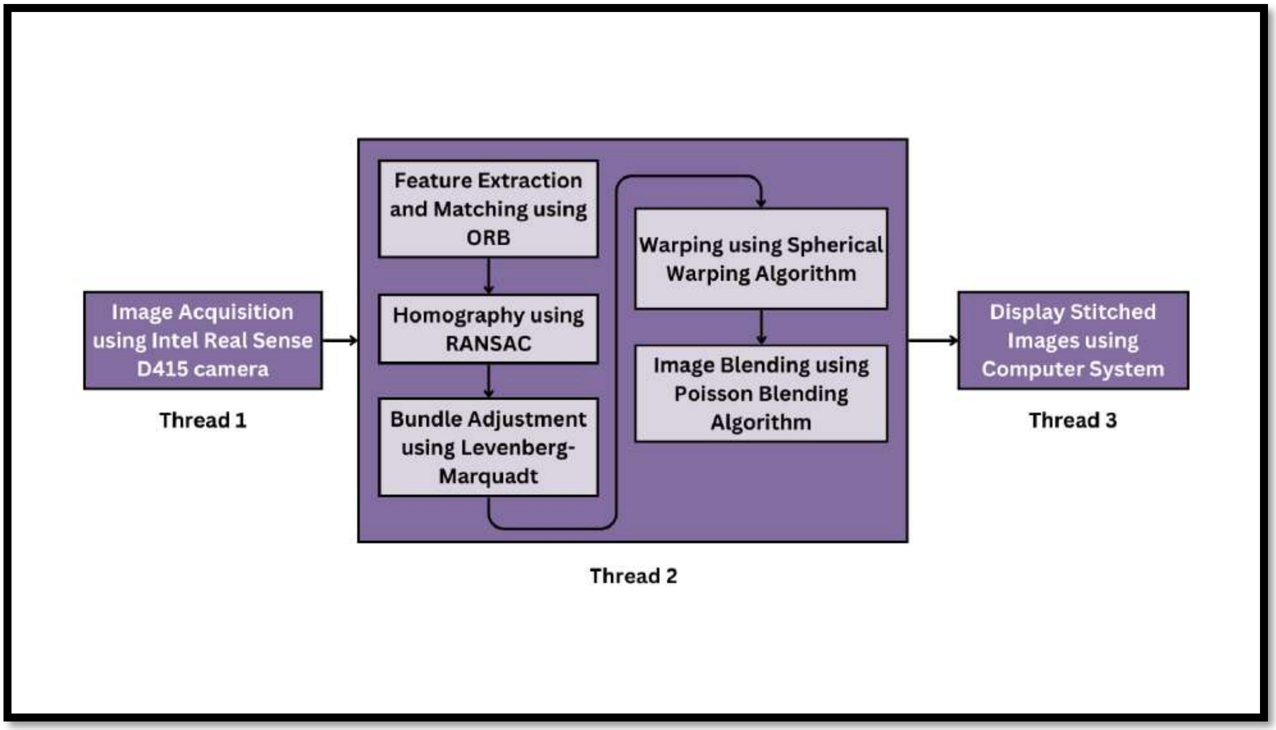

Figure 4.3 Block Diagram of real time panorama generation

The first block represent the hardware module that consists of the Intel Realsense D415 camera and the rotating structure. The camera will capture the image and transfer it to the computer system that as a whole can be considered as a block. The computer system is further divided into three blocks. First block is a hardware that is the memory where the images will be stored. Next block is the processing block in which the image processing algorithms will be implemented to align and filter the image. The last block is the stitching block where the multi-band blending algorithm will be used to align and blend the images.

4.8 Implementation Methodology

Our designed system is capable of acquiring images at real time from different angles and then stitching them together to generate a panoramic view. The methodology we followed to design this system consist of several important functions that are described below in detail.

The system is based on modular approach for optimal accuracy and processing speed. It is divided into three modules, with each module responsible for performing a certain operation. The First module consist of the hardware components and the second and third modules are completely software based. The complete process of real time panorama generation is divided into threads.

Multithreading technique is used to perform each operation independently and concurrently. The mutex technique is used for the communication between the threads. Mutex (mutual exclusion) is a synchronization mechanism used in computer programming to ensure that only one thread of execution can access a shared resource at a time, avoiding race conditions and other synchronization-related problems.

The first thread is responsible for image acquisition and storing it into the memory. The main hardware component of the first module is the Intel Realsense D415 depth camera. This camera is connected with the computer system. The camera and the computer system as a whole is integrated with the mechanical structure. The mechanical structure is a rotating system that will be controlled by the user. The camera will acquire images starting from 0 degree. The acquired image will be stored in the memory of the computer system. After that the camera will be rotated at a certain angle and again the camera will acquire the second image. The Realsense camera will be operated using the Realsense SDK. Images will be captured and saved using the Computer Vision library i.e. OpenCV.

The next thread is the main processing module of panorama generation. In this module the images are prepared for accurate and perfect stitching. Different algorithms are applied on the type of processing applied on the images. OpenCV is used to apply these image processing techniques. By eliminating the effects of camera rotation and perspective, homography is used to translate pictures acquired from disparate viewpoints into a similar coordinate system [66]. Radial Distortion Correction is a technique for correcting visual distortions induced by camera lenses, such as barrel or pincushion distortion. To improve the quality of the photos before stitching, median filtering is used to reduce image noise, increase image contrast, and enhance image details. Color Calibration is the process of changing the brightness and color of photographs such that they have consistent intensity and color across the whole set. Direct Image Alignment is used to align images such that they all face the same way and have the same scale [67]. After all of the preprocessing is completed the main process begins. The processed images are then ready for feature extraction. For feature extraction we have used ORB algorithm.

The ORB algorithm (Oriented FAST and Rotated BRIEF) is a common approach in computer vision for applications such as object detection and tracking. It is made up of multiple phases for detecting and describing characteristics in a picture. The FAST corner identification technique is used first to locate keypoints, which are pixels with substantial intensity variations from their neighbors. These keypoints serve as distinguishing features in the picture. The keypoints are then given orientations based on the main direction of slopes in their respective neighbors. This phase enables the algorithm to deal with picture rotations. BRIEF descriptors are calculated for each keypoint once they have been identified and orientated. BRIEF descriptors are binary representations of keypoints that capture their local appearance. They are produced by comparing pairs of pixels at each keypoint and encoding the results as binary values. The descriptors are calculated relative to the specified orientations to provide rotation invariance. Finally, using techniques such as nearest neighbor matching, the calculated descriptors may be utilized to match keypoints between pictures. Overall, the ORB approach is frequently utilized in computer vision applications because it combines efficient corner recognition with compact and rotation-invariant descriptors.

Following the extraction of the features, another algorithm is used to match the features between the frames and pictures. For this, we employed the RANSAC algorithm. The RANSAC (Random Sample Consensus) algorithm is an effective approach for estimating model parameters from a dataset including outliers. Its major goal is to discover the best-fitting model parameters by picking random subsets of data points repeatedly and assessing the model's fit. To begin, a small selection of data points is chosen at random to build a prospective model. These points are then utilized to fit a model based on a mathematical representation, which is usually accomplished by solving an optimization problem. The remaining data points are then compared to the fitted model, with points that fall inside a certain threshold termed inliers and those that fall outside defined as outliers. All inliers that match the model's fit requirements are aggregated to form the consensus set. This method is performed several times until the model with the biggest consensus set, indicating the best match, is found. Finally, the method refines the model by including all of the outliers from the best model produced via iterations. RANSAC is commonly used in computer vision and geometric estimating applications that need resilience against outliers, such as line fitting, plane fitting, and motion estimation. Its capacity to deal with noisy data makes it a useful tool in a variety of applications.

After the characteristics are matched, the photos are mixed together with these features to create a stitched image. The following frame is acquired, preprocessing on that frame is performed, features are retrieved and then matched, and the image is stitched with the resultant stitched image generated in the previous phase. We achieve a 360-degree broad view by repeating this technique.

We just used 5 photographs and did not get a 360-degree broad view, but by applying this approach and the correct equipment, we can construct a panoramic view in real time.

The third and the last thread is responsible for reading the saved panoramic images from the memory and displaying it continuously so that it look like a real time video. Due to the time taken by stitching process, there might be a delay in the display process.

CHAPTER 5

TESTING AND RESULTS

The system designed is a hardware and software integrated system. The hardware consist of the camera connected with the system and assembled on a rotating mechanical structure. The system is able generate a panorama in real time. The system is able to satisfy the functional and non-functional requirements. The system is user friendly and user can interact to generate a panoramic view.

The major achievement of our project is the fast processing time. This is due to the concurrent programming that is implemented using the concept of multithreading. The complete explanation of the process is given in the system design and implementation chapter. The test case is shown in the Table 5.1 below.

Table 5.1 Test Case

Stitching Technique	Time Taken	Remarks
Offline Stitching	11.5 seconds	Takes more processing time
Real Time Stitching	3.6 seconds	Takes less processing time

By analyzing the above test case we can conclude that real time stitching is 3 times faster than the offline stitching and hence can generate panorama more quickly than offline method.

Other results that have been obtained are given below.

5.1 2D Depth map

A 2D depth map is a computer representation of the relative distances of objects in a scene to a reference perspective, shown as a 2D grayscale or colored picture [68]. It stores the depth information of objects in a picture by assigning each pixel a value that corresponds to its distance from the reference perspective, with brighter pixels indicating closer items and darker pixels indicating farther away things. These maps may be utilized for a variety of purposes, including 3D reconstruction, robotic navigation, and AR/VR experiences. We produced a depth in real time by utilizing the Realsense SDK. The generated depth map is shown below in Figure 5.1.

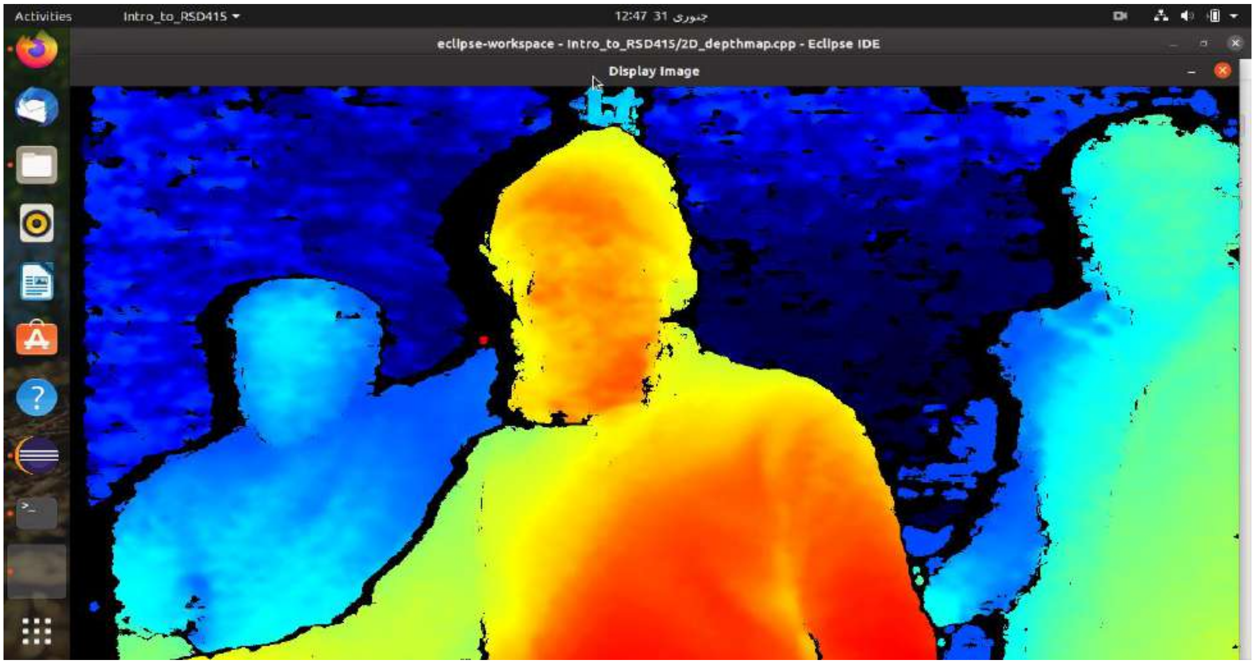

Figure 5.1 2D Depth map results

5.2 2D Panoramic Depth map

A 2D panoramic depth map depicts the relative distances between items in a 360-degree panoramic view of a scene [69]. It is a two-dimensional picture that stores the depth information of objects in a scene by giving a value to each pixel based on its distance from a reference perspective. We were able to stitch depth map pictures using the ORB feature extraction technique, RANSAC feature matching algorithm and homography, and the multi-band blending algorithm after capturing photos of depth maps. The two input depth maps are shown in Figure 5.2a and 5.2b. It's worth noting that the two depth maps have some common ground. The result obtained from stitching the 2D depth maps is shown below in Figure 5.2c.

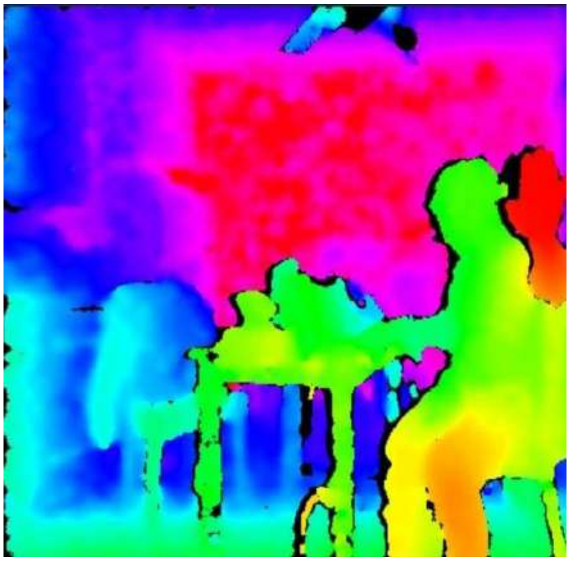

Figure 5.2a Depth map 1 for stitching

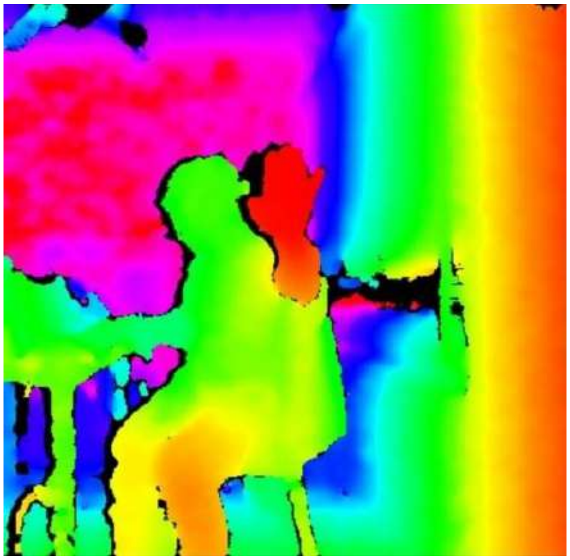

Figure 5.2b Depth map 2 for stitching

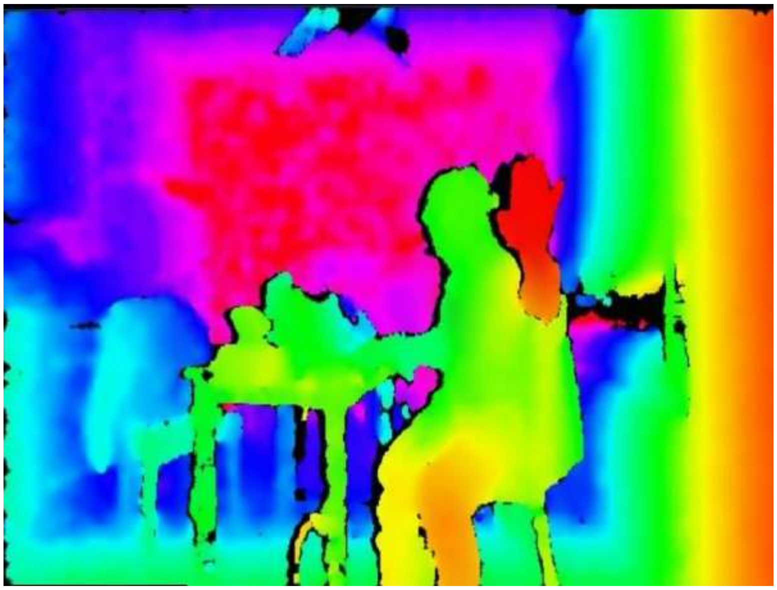

Figure 5.2c Resultant Stitched Depth map

5.3 2D Panorama

A 2D panorama is a wide-angle, 360-degree photograph that captures a scene in a single, seamless image [70]. It can be made by stitching together many images taken from a single point of view, or by utilizing specialist cameras that catch the whole scene in a single shot. In this case, we used 2D stitching to create panoramic photos. We took two photos that shared some common region or feature, and then used feature extraction, matching and blending algorithms to register and blend the images at the same time. The two input images are shown in Figure 5.3a and 5.3b and the resultant panoramic image are shown below in Figure 5.3c.

Figure 5.3a Image 1 for stitching

Figure 5.3b Image 2 for stitching

Figure 5.3c Resultant Stitched Image

5.4 3D Point Cloud

A 3D point cloud is a collection of 3D points that represent the surface of an item or scene [71]. Each cloud point is described by its three-dimensional coordinates (x, y, z) and can be color-coded to depict the scene's surface reflectance or texture. Various technologies, such as laser scanning, structured light, and stereo vision, can be used to create 3D point clouds. Using the stereo vision capability of the Intel Realsense D415 depth camera, we created a 3D point cloud. The point cloud can display a 3D perspective of the surroundings. Some screenshots of the generated point cloud are shown below in Figure 5.4.

Figure 5.4 3D point cloud

CHAPTER 6

CONCLUSION AND FUTURE WORK

6.1 Conclusion

Image stitching is a hot research topic in the fields of computer vision and graphics. Finally, real-time panorama generation is a fast-expanding topic with enormous promise for a wide range of applications. The ability to stitch photographs together in real-time to generate a seamless, wide-angle perspective of a scene is a powerful tool that may be utilized in a variety of applications ranging from virtual reality to surveillance, tourism, and beyond.

Despite great development in this area, there are still obstacles to overcome. These include increasing the speed and efficiency of real-time processing, more efficiently managing dynamic situations, boosting image quality, and moving into the area of 3D panorama production. Each of these topics offers an intriguing prospect for future research and growth.

Furthermore, combining real-time panorama production with other technologies like as 3D stitching and point cloud generation opens up new possibilities. These technologies may be used in tandem to create more immersive and engaging experiences, pushing the limits of what is currently achievable.

Real-time panorama production is more than just providing wide-angle images of a subject. It is about reinventing how we connect with and comprehend our surroundings. As this technology advances, we might anticipate a future in which our ability to record and comprehend the environment around us will be limited only by our imagination.

6.2 Future Work

Real-time panorama production has a bright future, with numerous possible enhancements and uses. We can build more immersive and engaging experiences by continuing to develop and perfect these tools. Real-time panorama production may also be incredibly useful for 3D stitching and producing 3D point clouds.

The following points outline the future work of real time panorama.

6.2.1 Improved Real-Time Processing:

Despite real-time panorama creation developments, there is always potential for improvement in terms of speed and efficiency. Future research might concentrate on building more efficient algorithms capable of handling bigger volumes of data in real time. This might include utilizing hardware developments such as GPUs or investigating more efficient software solutions such as parallel processing or machine learning methods.

6.2.2 Better Handling of Dynamic Scenes

Current panorama creation systems frequently struggle with dynamic situations containing moving objects or humans. Future research might concentrate on developing systems that can manage these scenarios better, such as algorithms that can detect and account for moving items.

6.2.3 Improved Image Quality:

While existing techniques are capable of producing high-quality panoramas, there is always an opportunity for advancement. Future work might concentrate on increasing the quality of the produced panoramas, such as minimizing artifacts and enhancing image blending.

6.2.4 3D Panorama Generation

The majority of existing panorama creation algorithms concentrate on 2D pictures. However, there is rising interest in the development of 3D panoramas, which might give a more immersive experience. Future research might concentrate on developing strategies for creating 3D panoramas in real-time.

6.2.5 Integration with Other Technologies:

To deliver more immersive experiences, panorama production might be combined with other technologies such as virtual reality or augmented reality. Future work might concentrate on improving these integrations.

6.2.6 3D Stitching:

Real-time panorama production can serve as the foundation for 3D stitching, which combines several 2D photos to generate a 3D model. This might be used for everything from virtual reality to 3D mapping.

6.2.7 Generating 3D Point Cloud

Real-time panorama production may also be used to create 3D point clouds, which are essential in many 3D modeling and computer vision applications. The ability to generate these point clouds in real time may enable more dynamic and interactive applications.

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