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Design Interactive User-Interface for Tracking Oil Refineries Stages and Operations

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Abstract:
This study presents the design and implementation of an intelligent user interface (IUI) to track and visualize the stages and operations of oil refineries. The aim is to enhance the educational and operational understanding of refinery processes by integrating Artificial Intelligence (AI) concepts into user interface design. The proposed system, developed using Python and the Tkinter library, provides interactive windows and detailed visualizations for each major refining stage--including atmospheric distillation, vacuum distillation, catalytic reforming, cracking, desulfurization, and steam cracking. Each module includes technical descriptions, product data, process illustrations, and AI-driven solutions to address industrial challenges such as efficiency, emissions, and optimization. The research bridges the gap between petroleum refining knowledge and digital innovation, offering a user-friendly educational platform for engineering students and professionals. It also sets a foundation for future enhancements including real-time data integration, smart monitoring, and sustainability-focused modules.

Keywords: Intelligent User Interface, Oil Refinery Optimization, UI Tracking Algorithms, Process Modeling, Industrial Digitalization, Chemical Automation..

1. Introduction

Oil has been used for lighting purposes for many thousands of years. In areas where oil is found in shallow reservoirs, seeps of crude oil or gas may naturally develop, and some oil could simply be collected from seepage or tar ponds.

An oil refinery is an industrial facility that processes crude oil into useful petroleum products such as gasoline, diesel, jet fuel, asphalt, and petrochemical feedstock. Crude oil, in its natural state, contains a complex mixture of hydrocarbons, impurities, and other substances that require refining to separate and purify different components.

Historically, we know the tales of eternal fires where oil and gas seeps ignited and burned. One example is the site where the famous oracle of Delphi was built around 1,000 B.C. Written sources from 500 B.C. describe how the Chinese used natural gas to boil water.

It was not until 1859 that "Colonel" Edwin Drake drilled the first successful oil well, with the sole purpose of finding oil. The Drake Well was located in the middle of quiet farm country in northwestern Pennsylvania, and sparked the international search for an industrial use for petroleum [1-4].

1.1 Oil Refineries

oil refineries play a crucial role in the petroleum industry by processing crude oil into a wide range of valuable products, including gasoline, diesel, jet fuel, and petrochemicals. These facilities employ complex refining processes, such as distillation, cracking, and treatment to separate and enhance the quality of petroleum fractions [1].

1.1.1 Structure of the Oil Refinery

Generally, main structure of the oil refinery include seven units named based on the operation done in these unit (Figure-1). Oil refinery units are:

1. Primary Separation (Atmospheric Distillation): The crude oil is heated to high temperatures in an atmospheric distillation column, where its components separate based on boiling points.

2. Vacuum Distillation : The heavier fractions left after atmospheric distillation are processed under reduced pressure to produce additional heavy and intermediate materials.

3. Chemical Treatment (Desulfurization) : This stage removes sulfur, nitrogen, and metal impurities from the crude fractions, enhancing product quality.

4. Catalytic Reforming : Naphtha is converted into high-octane gasoline using catalysts, improving its efficiency as fuel.

5. Thermal and Catalytic Cracking : Heat or catalysts break down large hydrocarbon molecules in heavy oils into lighter compounds.

6. Steam Cracking : Light hydrocarbons are heated to very high temperatures (above 800°C) to produce olefins, used in the petrochemical industry.

7. Final Condensation and Cooling : After all refining processes are completed, products are cooled, condensed, and stored.

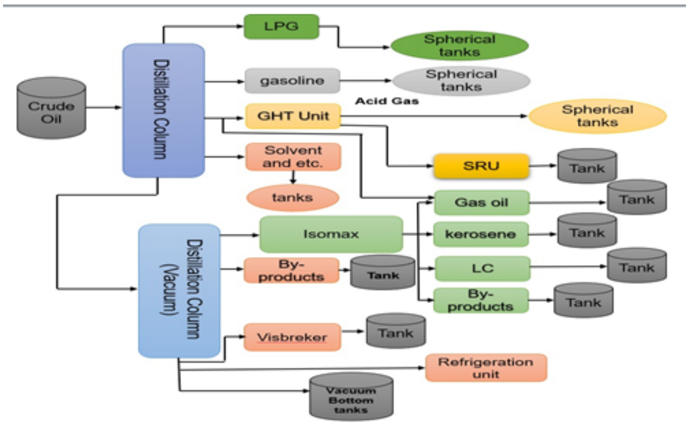

Figure 1 *Sketch of main units in the oil refinery*

1.1.2 Key Processes in Oil Refining:

There are many processes occur in the oil refineries, briefly, mainly processes include three processes as follow: [4-7]

A. Separation (Fractional Distillation): Firstly, crude oil is heated in a distillation tower to separate its components. Secondly, lighter fractions like gasoline and kerosene rise to the top.

B. Conversion (Cracking & Reforming): Firstly, heavy fractions are broken down into lighter. Secondly, Cracking: Breaks large hydrocarbon molecules into smaller ones (thermal cracking and catalytic cracking). Also, third: Reforming: Converts low-quality hydrocarbons into high-octane fuels.

C. Treating & Purification: Firstly, removes contaminants like sulfur, nitrogen, and metals. Secondly, desulfurization reduces sulfur emissions from fuels.

1.1.3 Major Products of Oil Refining:

Gasoline - Used in automobiles.

Diesel - Powers trucks, ships, and industrial machinery.

Jet Fuel - Aviation fuel for aircraft.

LPG (Liquefied Petroleum Gas) - Used for cooking and heating.

Asphalt - Used in road construction.

Petrochemicals - Raw materials for plastics, chemicals, and synthetic products.

Figure-2 illustrates main processes and main products in the oil refineries.

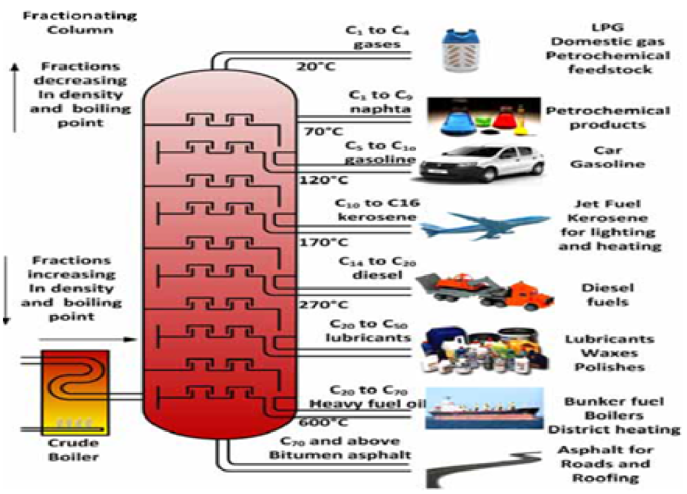

Figure 2*main processes and products of the oil refinery[1]*

1.1 Intelligent User Interfaces:

Intelligent User Interfaces (IUIs) refers to the fusion of human computer interaction (HCI) and artificial intelligence (AI) - two major fields within computer science. HCI is mostly concerned with solutions for the efficient and enjoyable usage of interfaces, techniques and artifacts, whereas research within the field of AI mainly centers around techniques for automation or building intelligent agents to aid users with the execution of various tasks.

In particular, the term IUI suggests that an interface is perceived, somehow, as "intelligent" by the user - may it be in the actual interaction, its automation and output, or the interface/interaction as a whole. As such, a good understanding of the (individual) user is needed in order to meet their goals and requirements to make the system, agent or interface appear as "intelligent" [9]. Figure-3 illustrates conceptual sketch of relationships among an adaptive user interfaces.

Intelligent User Interfaces (IUIs) are advanced interfaces that incorporate artificial intelligence (AI) techniques to enhance user experience, increase efficiency, and facilitate more natural interactions between humans and computers. Unlike traditional user interfaces, which follow predetermined, static responses, IUIs can adapt, learn, and make decisions based on user behavior, context, and preferences.

The goal of IUIs is to create systems that are intuitive, personalized, and responsive to the needs of users. They can include voice assistants, adaptive interfaces, gesture recognition systems, natural language processing (NLP), and recommendation engines. These interfaces aim to minimize the cognitive load on users, making technology more accessible and user-friendly.

IUIs are widely used in various domains, such as virtual assistants like Siri or Alexa, adaptive learning systems, healthcare applications, smart home devices, and more. They rely on AI technologies such as machine learning, computer vision, and data analytics to understand, predict, and respond effectively to user inputs.

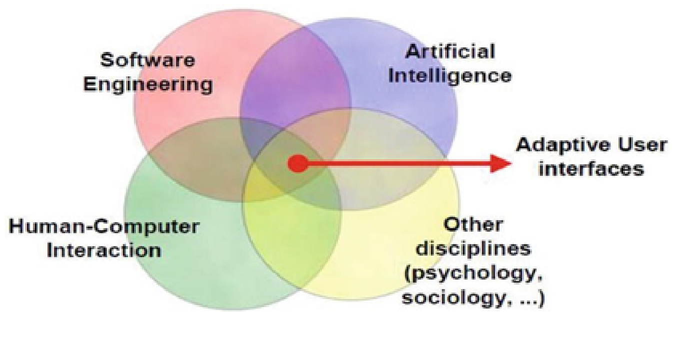

Figure 3 *Adaptive User Interfaces [16]*

As technology advances, IUIs continue to evolve, offering increasingly personalized, context-aware, and efficient interactions. They represent a significant step toward more seamless, human-centric computing. Also, there are many advantages of the user interfaces in the oil refineries include: Real-time data monitoring optimizes workflows, AI-driven predictive maintenance prevents unexpected failures, Automated alerts prevent hazardous incidents, Digital twins and AI dashboards provide actionable insights, and Monitoring tools ensure adherence to emission regulations [29,30]. Industrial Control System Interfaces include Supervisory

Control and Data Acquisition (SCADA) and Distributed Control Systems (DCS) provide real-time monitoring and control of refinery operations [31].

2. Objectives of the Study

This study aims to explore the structure, processes, challenges, and optimization strategies of oil refineries. The key objectives include:

Understanding Refinery Structures: Identifying the main components and units involved in refining operations .

Analyzing Refining Processes: Examining the primary processes such as distillation, cracking, and treatment .

Identifying Common Refinery Challenges: Investigating technical, environmental, and economic issues affecting refinery performance .

Exploring Sustainable Solutions: Proposing innovative solutions to enhance refinery efficiency and sustainability .

3. Design an Intelligent User Interface

3.1Main Window

This window represent main user interface of the system, contain the general information about the system as the title and authors names, as in the screen-1. A**full-screen mode**was implemented to maximize space utilization and ensure clear visibility of all displayed information. The window has been assigned a clear title that reflects the nature of the project.

3.1.1Drawing Canvas: A**Canvas**element was utilized to create an interactive background that allows the seamless addition of images and graphical components, enhancing the overall appearance of the interface.

3.1.2Displaying Illustrative Images: A set of images representing the stages and operations of oil refineries was loaded into the application. Some images were resized to fit the window dimensions and optimize performance. These images were positioned strategically to enhance the visual understanding of the project. Also, these images are screened from the system interfaces, as well be viewed in the following sections.

3.1.3Displaying Essential Information: this interface views essential information about the project as the title and authors names.

Figure 4 *Main interface of the system*

3.1.4 Enhancing User Experience: To provide a smooth user experience, elements were arranged manually using a**coordinate-based layout**, ensuring a well-structured interface. Text and images were carefully placed to maintain a consistent and professional appearance.

3.2Oil Refinery Process Tracking Interface

3.2.1 Interface Description: This interface represents one of the interactive screens in the application, displaying a list of the key oil refining stages on the left side, along with an illustrative background image of an oil refinery on the right. This setup provides an interactive experience for users, enabling them to easily track and understand the refining processes. As illustrated in screen-2

3.2.2 Interface Components

A. Refining Process Stages List: The interface includes**six main buttons**, arranged vertically, each representing a fundamental stage in the refining process:

Primary Separation (Atmospheric Distillation): The initial stage for separating crude oil components.

Vacuum Distillation: A process used to separate heavy fractions under low pressure.

Chemical Treatment (Desulfurization): The removal of sulfur and other impurities from petroleum products.

Catalytic Reforming: Enhancing fuel quality and increasing the octane number.

Thermal and Catalytic Cracking: Breaking down heavy molecules into lighter products such as gasoline.

Steam Cracking: Producing olefins used in petrochemical industries.

B. BackButton: this bottom allowing users to return to the previous screen.

C. Illustrative Background: The interface displays a**high-quality image of an oil refinery**, providing a realistic visualization that helps users understand the different industrial processes involved in oil refining.

Figure 5 *Oil Refinery Process Tracking Interface*

3.3Primary Separation (Atmospheric Distillation) Interface

3.3.1 Interface Description: This interface represents one of the interactive screens in the application, displaying detailed information about the**atmospheric distillation**process, which is the first stage of crude oil refining. The interface includes text and an illustrative image of the distillation tower, making it easier for users to understand the mechanism of separating crude oil components based on their boiling points. Screen-3 illustrates this interface.

3.3.2 Interface Components

A. Process Description Section: The interface presents text explaining the principles of**atmospheric distillation**, where crude oil is heated inside the distillation tower until its various components evaporate and separate at different levels within the tower according to their boiling points. This information is structured in an organized manner, helping users easily grasp the basics of the process.

B. Visual Representation of the Distillation Tower: An illustrative image of the atmospheric distillation tower is displayed, showing the locations where different petroleum products are separated, such as**naphtha, kerosene, diesel, and heavy oils**. This visual element helps**simplify technical concepts**and enhances users' understanding of the process.

C. Product Separation List: The interface includes a list displaying the petroleum products extracted at this stage, along with the**boiling range**for each product, as follows:

Light Gases(< 40°C)

Naphtha(60-100°C)

Kerosene(175-325°C)

Diesel Fuel(250-350°C)

Heavy Oils(370-600°C)

Heavy Residues(> 600°C)

D. Interactive Product Information Buttons: The interface includes**a set of interactive buttons**, allowing users to click on each button to access additional information about a selected petroleum product, such as**its properties and industrial applications**.

E. Back Button:this bottom allowing users to return to the previous screen.

F. Technical Challenges and AI Solutions Button: This button enables users to explore the technical challenges associated with the atmospheric distillation process, such as**pollution, heat loss, and separation efficiency**. It also provides insights into**AI-based solutions**aimed at improving process performance and reducing energy losses.

3.3.3 Enhancements and User Experience Improvements

Dynamic Interaction: The interface is designed to provide an interactive user experience through buttons, images, and explanatory texts.

Ease of Navigation: Users can smoothly switch between different products using dedicated buttons.

Improved Information Comprehension: Combining**images, text, and interactive buttons**creates a comprehensive learning experience.

Responsive Design:Text and image sizesare adjusted to fit various screen sizes, ensuring a comfortable user experience.

Figure 6 Primary Separation (Atmospheric Distillation) Interface[17]

3.3.4 Product Description Windows Implementation of Primary Separation

(Atmospheric Distillation) Interface

This section of the interface is composed of multiple fullscreen pop-up windows, each implemented using the Toplevel() class from Tkinter to display detailed descriptions of specific petroleum products. These windows include visual aids, structured text, and scrollable content to ensure accessibility and user engagement. The interface modules are organized as follows:

Light Gases : Displays descriptive information about gases like methane, ethane, propane, and butane. Images representing each gas are included and arranged horizontally using the place() method. The text explains their origin in the distillation column and their use in fuel and petrochemicals.

Light and Heavy Naphtha: Provides comparative descriptions of light and heavy naphtha, including their hydrocarbon range, boiling points, and industrial applications such as steam cracking and catalytic reforming. Text sections are styled with highlighted headers for clarity.

Kerosene: Utilizes a scrollable canvas to manage extensive content. Covers kerosene's chemical properties, production by fractional distillation, and common uses (e.g., jet fuel, heating, military). Additional sections detail safety, toxicity, spill management, and environmental impact.

Diesel Fuel : Similar to kerosene, this window uses a scrollable layout. Describes production temperatures, fuel properties like cetane number and energy density, applications, pollution concerns (e.g., NOx and particulates), and future developments like biodiesel and cleaner combustion technologies.

Fuel Oil : Describes heavy fuel oil obtained as a residue from crude distillation. Explains its physical properties, types (distillate vs. residual), main applications (e.g., power plants, marine engines), and environmental efforts for sulfur reduction and use of low-emission alternatives.

Heavy Residuals : Details residual products such as vacuum residue, asphalt, and heavy oils. Describes their applications in energy and infrastructure, and includes technological methods like deep conversion and thermal cracking used to process them into lighter products.

Interactive TextDisplay : Presents an interactive fullscreen window designed using Tkinter, featuring a scrollable Text widget within a resizable Frame. This interface is used to display extensive textual content in a structured and readable format. A vertical scrollbar is included to facilitate navigation through large blocks of information. The text is styled using a legible font and wrapped at word boundaries to enhance readability. Additionally, a "Back" button is placed at the top-left corner to allow users to exit the view. The layout is managed with pack() and dynamic expansion options to ensure adaptability across screen sizes. This window serves as a flexible module for presenting in-depth explanations, making it suitable for educational and reference-based content within the application.

Each window includes a "Back" button for user navigation and, where applicable, associated images loaded via PhotoImage and resized using .subsample() for layout compatibility. The

layout strategy primarily relies on place() for manual positioning, with Canvas and Scrollbar used to manage long text content. This modular design approach enhances user comprehension and allows each product category to be explored independently within the interface

3.4. Secondary Separation (Vacuum Distillation) Interface

3.4.1 Interface Description: This interface provides an interactive representation of the**vacuum distillation**process, a critical step in refining heavy fractions left after atmospheric distillation. The interface includes textual explanations, product categories, an illustrative image, and interactive buttons to enhance user engagement. Vacuum distillation operates under reduced pressure to enable the separation of heavier fractions at lower temperatures, preventing thermal decomposition and improving product quality. The screen-4 views this interface as follow.

3.4.2 Interface Components

A. Process Description Section: The interface presents a textual overview of**vacuum distillation**, explaining that it processes the heavier fractions remaining after atmospheric distillation under low pressure to produce additional valuable materials. The information is displayed clearly, helping users understand the necessity and functionality of this process.

B. Product Categories: The interface categorizes the main products obtained from vacuum distillation, along with their industrial significance. These products include:

Lubricating Oils: Essential for reducing friction in engines and machinery.

Asphalt Components: Used in road construction and waterproofing applications.

Heavy Fuel Oil: Utilized in marine engines and industrial heating applications.

C. Visual Representation of the Process: An illustrative image is integrated into the interface, providing a**visual breakdown of the vacuum distillation process**. The image supports the textual explanation, allowing users to visualize how heavy fractions are separated at different vacuum levels.

D. Interactive Description Buttons: To enhance interactivity, the interface includes buttons linked to additional details about each product:

Lubricating Oils Description Button: Redirects users to an interface with in-depth information on lubricating oils.

Asphalt Components Description Button: Provides insights into the formation, properties, and applications of asphalt materials.

Heavy Fuel Oil Description Button: Offers details on the uses and processing of heavy fuel oil.

E. Challenges and AI Solutions Button: This button allows users to explore technical challenges associated with vacuum distillation, such as**operational inefficiencies, vacuum system maintenance, and product contamination risks**. It also introduces AI-driven solutions designed to enhance process efficiency and optimize product yields.

3.4.3 Enhancements and User Experience Improvements

Structured Layout: Information is systematically organized, making it easy for users to follow.

Interactive Design: Buttons provide access to additional knowledge, encouraging user engagement.

Visual Learning Aid: The inclusion of an image enhances comprehension of the process.

Efficient Navigation: The back button ensures smooth transitions between different sections.

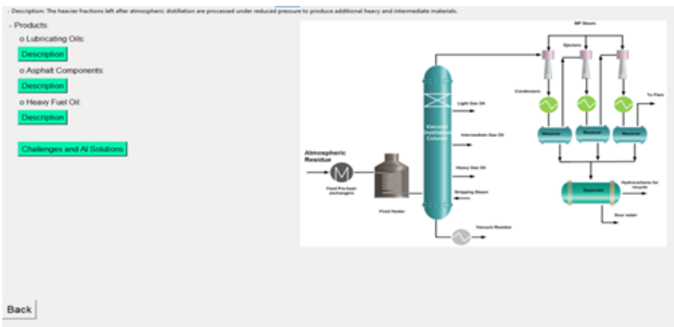

***Figure 7** Secondary Separation (Vacuum Distillation) Interface[35]*

3.4.4 Product Description Windows Implementation of Vacuum Distillation

At this stage of the project, an interactive interface was developed using the Tkinter library in the Python programming language. The goal was to present detailed information about some petroleum derivatives obtained from crude oil refining processes, namely lubricating oils and greases, heavy fuel oil, and asphalt. Three separate sub-windows were designed, each dedicated to displaying information related to one of these products, within a unified software framework that allows smooth navigation between windows using clear control buttons.

Each window includes graphical elements such as a frame, canvas, and vertical scrollbar to facilitate browsing long text content. The information is organized into subheadings and simplified paragraphs, supported by examples and technical clarifications.

Lubricating Oils and Greases Window: This window explains the stages of oil production, from fractional distillation to hydrotreatment, detailing the types of oils (mineral, synthetic, and semi-synthetic) and their applications in industrial systems and engines.

Heavy Fuel Oil Window: This section presents the properties of heavy fuel oil, such as viscosity, density, and sulfur content, in addition to its uses in marine transportation and power generation. It also highlights environmental restrictions imposed on its use, such as those issued by the International Maritime Organization (IMO).

Asphalt Window: This window provides information on the chemical composition of asphalt, including aromatics, maltenes, and resins. It distinguishes between natural and refined asphalt and outlines its main applications in road paving, waterproofing, and construction.

Each sub-window is equipped with a "Back" button to return the user to the main interface, enhancing the overall user experience and ensuring easy interaction with the system's content.

This interface represents a prototype of an educational interactive system that can be further expanded in the future to include additional petroleum derivatives, with support for visual media such as diagrams and dynamic illustrations.

3.5. Chemical Treatment (Desulfurization) Interface

3.5.1 Interface Description: This interface presents an interactive overview of the**chemical treatment (desulfurization) process**, a critical refining stage aimed at removing sulfur, nitrogen, and metal impurities from crude oil fractions. This treatment enhances the quality of petroleum products and reduces environmental pollutants. The interface includes textual explanations, product descriptions, and interactive elements to improve user engagement.

3.5.2 Interface Components

A. Process Description Section: The interface provides a textual summary explaining that**desulfurization**is responsible for eliminating sulfur and other contaminants from crude oil fractions. This process enhances fuel quality, prevents corrosion in refinery equipment, and reduces harmful emissions from combustion.

B. Product Categories: The interface highlights the main products resulting from the desulfurization process:

Hydrogen Sulfide Gas (H_2S):

A**colorless, highly toxic gas**with a distinctive rotten egg odor.

Flammable and commonly found in**oil refineries, wastewater treatment, and volcanic areas**.

Requires careful handling due to its hazardous effects on human health and the environment.

Refined Fractions:

Petroleum fractions with**improved quality**due to the removal of sulfur and metal impurities.

Used in**industrial and transportation sectors**to produce cleaner fuels.

C. Visual Representation of the Process: The interface integrates an**illustrative image**, offering a**visual explanation of the desulfurization process**. This helps users comprehend how sulfur is removed and transformed into byproducts like hydrogen sulfide gas.

D. Challenges and AI Solutions Button: This interactive button directs users to a section addressing the**technical challenges**associated with desulfurization, such as:

High energy consumptionduring hydrogenation reactions.

Catalyst deactivationdue to metal deposition.

Environmental risksfrom handling toxic byproducts like H_2S.

Additionally, the interface provides AI-driven solutions, including**predictive maintenance for catalysts, real-time monitoring of sulfur content, and process optimization techniques**to enhance efficiency.

3.5.3 Enhancements and User Experience Improvements

Organized Information Layout: Content is structured for clarity and ease of understanding.

Interactive Features: Users can explore additional insights via buttons and visual elements.

Enhanced Learning Experience: The combination of**text, images, and buttons**provides a comprehensive educational tool.

Efficient Navigation: The back button ensures easy access to other sections of the application.

3.6 Catalytic Reforming Interface

3.6.1 Interface Description: This interface provides an interactive overview of the**catalytic reforming process**, a crucial refinery operation that converts**low-octane naphtha into high-octane gasoline**using catalysts. This process improves fuel efficiency and yields valuable hydrogen as a byproduct. The interface presents a structured layout, offering users**descriptive content, interactive buttons, and a visual representation**to enhance understanding.

3.6.2 Interface Components

A. Process Description Section: The interface introduces**catalytic reforming**as a refinery process that upgrades**naphtha**by rearranging hydrocarbon molecules to increase its**octane rating**. This results in a**more efficient and higher-quality fuel**suitable for modern internal combustion engines.

B. Product Categories: The interface highlights the key products obtained from the catalytic reforming process:

High-Octane Gasoline:

Fuel with**increased resistance to knocking**, improving engine efficiency and longevity.

Essential for**high-performance and turbocharged engines**.

Hydrogen (H_2):

A valuable byproduct used in**hydrotreatingprocesses**to remove impurities from crude oil fractions.

Plays a crucial role in the production of**cleaner fuels**and**petrochemical synthesis**.

C. Visual Representation of the Process: An**illustrative image**is included in the interface to visually explain how**catalytic reforming**occurs. This aids users in grasping the molecular transformation of naphtha into high-octane fuel and hydrogen.

D. Interactive Buttons

Description Button:

Opens a detailed explanation of**high-octane gasoline**, including its importance, octane number concept, regional variations, and common misconceptions.

The explanation is presented in a**scrollable window**to accommodate in-depth content.

Challenges and AI Solutions Button:

Opens a section discussing**technical challenges in catalytic reforming**, such as:

Catalyst deactivationdue to carbon deposition.

Process inefficienciesleading to suboptimal fuel conversion rates.

Environmental concernsrelated to hydrogen gas handling.

Explores**AI-driven solutions**such as:

Predictive catalyst monitoringto enhance efficiency.

Machine learning optimizationfor reforming conditions.

Real-time hydrogen recovery enhancement techniques.

E. Back Button:this bottom allowing users to return to the previous screen.

3.6.3 Enhancements and User Experience Improvements

Clear and Concise Content: Well-structured descriptions for easy understanding.

Interactive Features: Buttons enable deeper exploration of key concepts.

Visual Support: Graphical representation of the process aids comprehension.

Smooth Navigation: Scrollable content and back button improve accessibility. 4.6.4 Interactive Catalytic Reforming Interface

In this stage of the project, an additional interactive window was developed using the Tkinter library to present detailed information regarding high-octane gasoline, a key product in the petroleum refining and fuel industry. The design was implemented through a new top-level window (Toplevel()), which enables the user to access in-depth technical content in an organized and visually accessible manner.

The interface features a full-screen layout for better readability and interaction. It consists of a scrollable canvas embedded inside a frame, allowing the display of extensive content that exceeds the screen dimensions. Inside this canvas, a secondary frame was created to hold multiple labeled text blocks (Label widgets), each presenting structured educational content about high-octane gasoline.

The window addresses several key aspects:

Definition and Function: High-octane gasoline is introduced as a fuel with greater resistance to knocking in internal combustion engines, a property measured by the octane number.

Octane Number Concept: The text explains the use of iso-octane as a reference standard (octane number = 100) and heptane (octane number = 0), highlighting the significance of this scale in assessing fuel performance.

Importance in Engines: The content emphasizes the role of high-octane fuel in protecting high-compression engines from premature ignition, which can lead to mechanical failure.

Regional Variations: It clarifies the difference in octane rating systems across regions, such as the Anti-Knock Index (AKI) used in the U.S. and the Research Octane Number (RON) commonly applied in Europe.

Misconceptions: The window also addresses common misunderstandings, such as the false belief that higher octane always equates to higher power, emphasizing that fuel selection must align with engine design specifications.

An illustrative image (screen-5) was included to enhance the visual understanding of the subject matter, followed by a "Back" button to return the user to the main interface. The structure promotes easy navigation, clear presentation of technical content, and interactive learning. This window represents another component of the educational toolkit designed to enrich the user's understanding of refined petroleum products through a visual and functional Python interface.

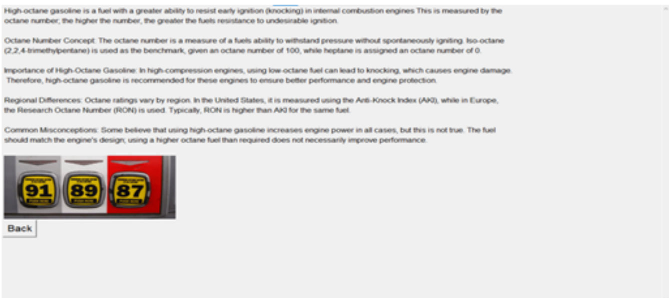

Figure 8 *High-Octane Gasoline[43,44]*

3.7 Thermal and Catalytic Cracking Interface

3.7.1 Interface Description: This interface provides an interactive display of the *Thermal and Catalytic Cracking* process, which is a crucial refinery operation used to break down large, heavy hydrocarbon molecules found in heavy oils into lighter, more valuable products. The interface is structured in a clear layout, presenting the process overview, interactive buttons that open detailed windows for each product, and graphical elements to enhance the understanding of chemical reactions and industrial applications. Screen-6 illustrates this interface.

3.7.2 Interface Components

A. Process Description Section: At the top of the interface, a label describes the cracking process: "Heat or catalysts break down large hydrocarbon molecules in heavy oils into lighter compounds."

B. Products Section: This section outlines the primary outputs of the cracking process with dedicated labels:

Light and Heavy Naphtha: A button opens a window explaining their composition (C_5-C_{12} range), boiling points, and uses in steam cracking, catalytic reforming, and the production of solvents and aromatics.

Diesel: A button opens a scrollable window with an extensive description of diesel fuel, including its production via distillation (200-350 °C), physical properties (energy density, cetane number), industrial and transportation uses, environmental concerns, and sustainable trends like biodiesel.

Light Hydrocarbon Gases: A button opens a new window describing the separation of gases like:

Methane (CH_4)

Ethane (C_2H_6)

Propane (C_3H_8)

Butane (C_4H_{10})

Each gas is explained in terms of its production in the distillation column and its industrial application.

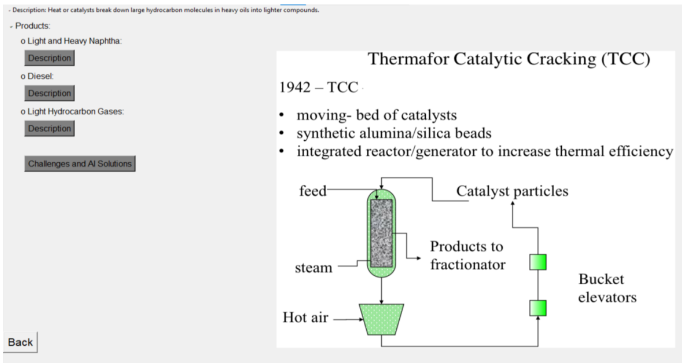

Figure 9 *Thermal and Catalytic Cracking Interface*

C.AI-Based Solutions Button: A button labeled*"Challenges and AI Solutions"*opens a fullscreen window that contains a scrollable Text widget, where advanced insights are shown (content pulled from a global text_content5 variable). This section likely outlines operational challenges in cracking and how artificial intelligence can optimize the process.

D.Visuals and Images: The interface incorporates images relevant to cracking outputs (light gases, diesel, etc.), loaded using global PhotoImage objects and resized using .subsample() to fit the layout properly.

E.Navigation

A "Back" button allows users to close the current window.

Pressing the Escape key also exits the interface for user convenience.

3.7.3 Functional Overview

Each interactive button triggers a new window (Toplevel() or Tk()), offering:

Detailed textual explanations with headings, color-coded sections, and formatting.

Scrollable content areas where necessary (e.g., diesel description).

Integrated images to visually support the textual data.

Navigation buttons for user-friendly return to the main interface.

3.7.4 Interactive Thermal and Catalytic Cracking Interface

As part of the software interface aiming to deliver technical education on petroleum-derived products, an interactive window was developed using the Tkinter library to present structured information on lubricating oils and greases. This window is instantiated using the Toplevel() function to open a new, full-screen interface that allows users to explore detailed content in an accessible and scrollable format.

The layout utilizes a Canvas widget combined with a vertical Scrollbar nested inside a primary frame. This setup enables the presentation of vertically extended content, making it ideal for displaying long, categorized textual sections. Inside the scrollable canvas, a secondary frame is created to organize and render multiple Label widgets that deliver educational content.

This window specifically covers:

Definition and Role: The window introduces lubricating oils and greases as heavy petroleum fractions used primarily to reduce friction and wear in mechanical systems.

Lubricating Oils:

Described as refined fractions obtained from vacuum distillation followed by solvent dewaxing and hydroprocessing.

Properties discussed include viscosity, thermal stability, oxidation resistance, and flash point.

Applications span automotive engines, machinery, hydraulic systems, and industrial equipment.

Greases:

Explained as semi-solid lubricants consisting of a base oil, a thickener (often metallic soaps), and performance additives.

The formulation allows them to stay in place under high pressure and temperature, making them suitable for bearings, joints, and seals.

Comparative Usage:

The text provides a comparative view of oils versus greases, including scenarios where one is preferred over the other based on application type, temperature, or load conditions.

To complement the theoretical content, an illustrative image is embedded into the interface to support visual learning. At the end of the content, a "Back" button is provided to allow the user to exit the window and return to the main interface, ensuring smooth navigation.

This educational module enhances the learning experience by providing a visually structured and technically sound overview of lubricants, emphasizing their critical importance in industrial and automotive applications.

3.8 Steam cracking Interface

3.8.3Interface Description: This interface delivers a comprehensive and interactive overview of the hydrocracking process--a vital refining operation that breaks down heavy oil fractions into lighter, more valuable products such as diesel, jet fuel, and naphtha. Utilizing both hydrogen and specialized catalysts, hydrocracking significantly enhances product yield and quality. The interface is designed with an intuitive layout that includes detailed descriptions, interactive elements, and visual aids to facilitate a deeper understanding of the process.

3.8.2Interface Components

Process Description Section: The interface introduces hydrocracking as a high-pressure catalytic process where heavy hydrocarbons are cracked in the presence of hydrogen. This not only increases the production of desirable lighter fractions but also removes sulfur and nitrogen compounds, contributing to cleaner fuel standards.

B.Product Categories: The interface outlines the major products derived from hydrocracking (Diesel Fuel, Jet Fuel, Naphtha)

C.Visual Representation of the Process: A process diagram is incorporated into the interface, visually illustrating the feedstock entry, catalytic reaction zones, hydrogen injection, and separation units. This graphical layout helps users understand the transformation of heavy hydrocarbons into clean fuels.

Interactive Buttons

• **Description Button::** Opens a scrollable window providing an in-depth explanation of hydrocracking catalysts, reaction mechanisms, and process configurations (single-stage vs. two-stage). And includes real-world applications and economic significance of the process.

• **Challenges and AI Solutions Button:** Presents current operational challenges such as:

Catalyst poisoning due to impurities.

High operational costs and energy consumption.

Real-time control and monitoring complexities.

Highlights AI-driven innovations, including:

Predictive maintenance for reactor integrity.

Optimization of hydrogen consumption using machine learning.

Process modeling for product yield maximization.

E.Back Button:this bottom allowing users to return to the previous screen.

3.8.3 Enhancements and User Experience Improvements

• **Structured Information:** Each section is clearly defined to support focused learning.• **Interactive Design:** Buttons offer expandable content for users seeking detailed knowledge.• **Visual Learning Aid:** Diagrams enhance understanding of technical flow.• **User Accessibility:** Smooth navigation and scrollable windows ensure a streamlined interface journey.

3.8.4 Product Description Windows Implementation of Steam cracking

This section of the interface consists of multiple fullscreen pop-up windows, each implemented using the Toplevel() class from Tkinter to display detailed descriptions of the key olefin products: ethylene and propylene. These windows are designed to provide an engaging and informative experience by integrating visual media, structured text, and scrollable content for improved accessibility and readability. The interface modules are organized as follows:

Ethylene (winEthylene): This window displays a comprehensive description of ethylene (C_2H_4), covering its chemical identity, physical properties, and significance as one of the simplest and most widely used olefins. The text explains its production via thermal cracking of naphtha or ethane and outlines its major industrial applications such as polyethylene, ethylbenzene, ethylene oxide, and more. The content is structured with clear subheadings and presented within a scrollable Text widget using a vertical Scrollbar. A representative image of ethylene is included via PhotoImage, resized using .subsample() to fit the layout. A "Back" button is placed at the top of the interface for easy navigation. The layout uses the place() method for manual positioning of all components.

Propylene (winPropylene): Built with the same structure as the ethylene window, this interface displays detailed information about propylene (C_3H_6), the second most important olefin. It discusses its production as a byproduct of steam cracking or as a main product of catalytic cracking, and its applications in the manufacture of polypropylene, isopropanol, acrylonitrile, and others. The text is well-structured with readable fonts and word wrapping enabled. A visual representation of propylene is displayed, and the window includes a Canvas with a vertical Scrollbar to handle longer content. A "Back" button is provided at the top of the interface to facilitate smooth navigation. All layout elements are positioned using the place() method for precise control.

Interactive Text Display (root): This is a fullscreen interactive window designed using Tkinter, featuring a Text widget inside a resizable Frame with vertical scrolling support. It is used to present large amounts of textual content in a structured, easily readable format. A Scrollbar is included to facilitate content navigation. The text is styled with a user-friendly font and uses word-boundary wrapping (wrap=WORD). A functional "Back" button is placed at the top-left corner of the window to allow users to exit the view. The layout relies on pack() with dynamic expansion options to ensure adaptability to different screen sizes.

Overall Design Approach:

Image Management: Images are loaded via PhotoImage() and resized using .subsample() when needed to ensure layout compatibility.

Layout Strategy: The place() method is used for manual element positioning, while Canvas and Scrollbar are employed to handle long text content.

Flexibility and Navigation: Each window includes a "Back" button for seamless navigation. The modular design approach allows each product to be explored independently, enhancing comprehension and educational engagement.

4. Conclusions and Suggestion for Future Works

This section will state the conclusions of this work from view point the researcher:

In this project, designed new interactive user interface for tracking petroleum refinery operations and petrochemical industries. This work establish for building vital work to track an oil refinery processes by using intelligent user interface . The designed interface was programmed in**Python**programming language, this as challenge in the polymer engineering field. During this work, all details about the refineries and petrochemical industries are viewed simple manner. This work may be as teaching and training tool for undergraduate students of material engineering, chemical engineering, petroleum engineering, chemical science.

To enhance this work, can revise it as : This work may be include additional interfaces about the sustainability and green refineries. May contain some interactive windows or boxes about the error may occur in the refinery studies. It could be developed for including connecting with the refinery via the web networks to surveillance the units of the refinery. It may include artificial intelligence and/or machine learning techniques.

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