SUMMARY

of the main results and scientific contributions

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Publications

In [1] were developed models to predict the vacuum residue conversion level under different operating condition. Ebullated bed vacuum residue hydrocracking and fluid catalytic cracking (FCC) are among the most profitable processes in modern refining. Their optimal performance is vital for petroleum refining profitability. That is why a better understanding of their combined action and the interrelations between these two heavy oil conversion processes in a real-world refinery could provide valuable information for further performance optimization. Nine distinct petroleum crudes belonging to the extra light, light, and medium petroleum crude types were processed in the LUKOIL Neftohim Burgas refinery to study the combined performance of two processes: FCC of vacuum gas oil and ebullated bed vacuum residue H-Oil hydrocracking. The operating conditions along with the characterization data of the feeds and products of both processes were evaluated through the employment of intercriteria analysis to define the variables with statistically significant relationships. Maple 2023 Academic Edition mathematics software was used to develop models to predict the vacuum residue conversion level under different operating conditions. The plug flow reactor model with an activation energy of 215 kJ/mol and a reaction order of 1.59 was found to provide the highest accuracy of vacuum residue conversion, with an average absolute deviation of 2.2%. H-Oil yields were found to correlate with the vacuum residue conversion level and the content of FCC slurry oil (SLO), the recycling of partially blended fuel oil, a material boiling point below 360 ◦ C, and the vacuum gas oil (VGO) in the H-Oil feed. FCC

conversion was found to depend on the H-Oil VGO content in the FCC feed and the content of FCC SLO in the H-Oil feed.

In [2], intercriteria analysis was used to assess data from a commercial vacuum residue hydrocracker during processing blends from three vacuum residues: Urals, Siberian Light, and Basra Heavy. The analysis revealed that the main contributors to conversion enhancement is hydrodemetallization (HDM) and the first reactor ΔT augmentation. The increase of HDM from 40 to 98% and the first reactor ΔT (ΔT(R1)) from 49 to 91 ◦ C were associated with a vacuum residue conversion enhancement of 62.0 to 82.7 wt.%. The developed nonlinear regression prediction of conversion from HDM and ΔT(R1) suggests a bigger influence of ΔT(R1) enhancement on conversion augmentation than the HDM increase. The intercriteria analysis evaluation revealed that the higher first reactor ΔT suppresses the sediment formation rate to a greater extent than the higher HDM. During processing Basrah Heavy vacuum residue, a reduction in hydrodeasphaltization (HDAs) from 73.6 to 55.2% and HDM from 88 to 81% was observed. It was confirmed that HDM and HDAs are interrelated. It was found that the attainment of conversion of 80 wt.% and higher during processing Urals and Siberian Light vacuum residues is possible when the HDM is about 90% and LHSV $\leq 0.19\ h^{-1}$.

In [3], empirical correlations, and metaheuristic models were developed to predict the refractive index of petroleum fluids based on density, boiling point, and SARA fraction composition. The refractive index is an important physical property that is used to estimate the structural characteristics, thermodynamic, and transport properties of petroleum fluids, and to determine the onset of asphaltene flocculation. Unfortunately, the refractive index of opaque petroleum fluids cannot be measured unless special experimental techniques or dilution is used. For that reason, empirical correlations, and metaheuristic models were developed to predict the refractive index of petroleum fluids based on density, boiling point, and SARA fraction composition. The capability of these methods to accurately predict refractive index is discussed in this research with the aim of contrasting the empirical correlations with the artificial neural network modelling approach.
Three data sets consisting of specific gravity and boiling point of 254 petroleum fractions, individual hydrocarbons, and hetero-compounds (Set 1); specific gravity and molecular weight of 136 crude oils (Set 2); and specific gravity, molecular weight, and SARA composition data of 102 crude oils (Set 3) were used to test eight empirical correlations available in the literature to predict

the refractive index. Additionally, three new empirical correlations and three artificial neural network (ANN) models were developed for the three data sets using computer algebra system Maple, NLPSolve with Modified Newton Iterative Method. For Set 1, the most accurate refractive index prediction was achieved by the ANN model, with %AAD of 0.26% followed by the new developed correlation for Set 1 with %AAD of 0.37%. The best literature empirical correlation found for Set 1 was that of Riazi and Daubert (1987), which had %AAD of 0.40%. For Set 2, the best performers were the models of ANN, and the new developed correlation of Set 2 with %AAD of refractive index prediction was 0.21%, and 0.22%, respectively. For Set 3, the ANN model exhibited %AAD of refractive index prediction of 0.156% followed by the newly developed correlation for Set 3 with %AAD of 0.163%.

In works [4,5,7] a comparative analysis of known pre-trained model of deep learning neural networks used to facial emotions recognition has been done. The aim of the study is to select appropriate lightweight models to be used for offline facial emotions recognition of the students during their semestrial learning. The basic facial emotions can be grouped as positive (happiness and surprise), neutral, and negative (fear, anger, sadness and disgust). Based on these three groups of emotions corrective actions by adapting and personalizing the lecture material are undertaken.

On the base of this analysis, two pre-trained models of CNN for FER were selected. One based on DeepFace CNN and another on VGG. We trained and verified the models on FER-2013 and CK+ datasets. Additionally, we verified the models using our private dataset with students' images. In the considered dataset of images collected during the Summer Poster Session at UCTM, both models achieve higher accuracy in determining emotions. This is due to the fact that most of the participants in the poster session are smiling, calm and satisfied, and the models used have about 10% higher accuracy in recognizing these types of emotions. This would not be the case at events where participants are put under pressure, stress, anger, indifference or dissatisfaction (e.g. job interviews, exam sessions, etc.).

To improve human emotion recognition such as revealing neutral and negative emotions - fatigue, boredom, etc. in [5] a hybrid multimodal model recognizing human emotions based on facial expression and body language is proposed. A suitable pre-trained BER DNN model is selected that can be used together with our FER-based one. Combining the two models, we create a hybrid bimodal system that is used to enhance students' personalize learning based on their positive, neutral, or negative facial and body emotions.

The additional BER channel improves the accuracy of the recognized emotions up to 10%. Our decision module is responsible for comparing 26 BER emotions with seven FER emotions. It uses IF-THEN rules to form the end result of an emotion.

In order to achieve greater accuracy in human emotion recognition, a bimodal system was developed in [4] that considers facial emotions in combination with weather conditions. Current bimodal system is based on two deep learning neural networks /DNN/. First DNN recognizes seven basic facial emotions (*angry*, *disgust*, *fear*, *happy*, *sad*, *surprise*, *neutral*) and second DNN recognizes five weather conditions (*cloudy*, *rain*, *snow*, *sunny*, *hot)*.

The architecture of proposed bimodal system includes selected FER and weather (ResNet50) DNNs. The FER DNN takes as input 48x48 BW image and predicts mentioned above 7 facial emotions. The ResNet50 takes 100x100 RGB image and predicts 5 weather conditions.

As result a 5x7 Possibility Matrix /PM/ is formed with 5 rows corresponding to 5 weather conditions and 7 columns, corresponding to 7 facial emotions. The coefficients of each row of the matrix depend on recognized weather (0-cloudy, 1-rain, 2-snow, 3-sunny, 4- hot). The sum of the weighting coefficients for each row is 1. The coefficients themselves were determined empirically.

As an advantage of the bimodal system, it can be stated that these coefficients can be changed depending on the type of event being held - sports competition, conference, wedding, celebration, vacation, etc., which will increase the accuracy of the combined model.

Proposed in this paper bimodal system for facial emotion recognition based on FER and weather recognition neural networks increases the total emotion recognition from 69.85% to more than 80-83%, when classified by ResNet weather conditions are applied to human emotions using empirically defined coefficients of Possibility Matrix.

The proposed development can be used to adapt the study material in order to easily perceive it and increase student performance, as well to assist lecturers in presenting the study material by changing at the pace of teaching.

Facial emotions recognized by the multimodal system can be used for various purposes. For example, to detecting an early stage of some diseases or recognize the attitude of students to some events happening outdoors, as well as the influence of weather on people's emotional states.

In [6], a comparative analysis of known platforms used for distance learning in an electronic environment has been done. The aim of the survey is to make a comparative analysis of the most

used platforms in Bulgaria. Based on this analysis to make a choice of the qualities that should possess the "ideal" platform for Distance Learning in Electronic Environment DLEE.

The aim of [8] was to determine the amounts of different classes of phenolic compounds in ethanolic extracts from red grape marc and its components, peels and seeds, and to compare with wine musts, and red wine of the same variety of grapes. The results showed that the red grape marc was rich in polyphenolic compounds. Grape seeds demonstrated the highest contents of proanthocyanidines, (a type of flavonoid with high antioxidant activity).
Red and rose wines have a different quantity of phenolic composition, which is characteristic for each variety and each technology. Statistical models to determine the content of polyphenols, flavonoids and anthocyanins in wine (red or rosé) based on red color have been developed.

In paper [9], a multiple linear regression involving new variables of interaction and quadratic functions (MLR+NP) has been applied to the modeling of hour-by-hour concentrations of PM_{10} in Sofia depending on the meteorological indices: temperature (T), humidity (W), wind velocity (V) and radiation (R) and one pollutant, CO. The study has been carried out within a one-year period - between 04.2016 and 03.2017. The results show that 70 % up to 89 % of the variation of PM_{10} could be explained by the factors T, W, V, R, CO and their quadratic functions and interactions. The monthly models are able to forecast the concentrations of PM_{10} for the separate months with greater precision and reliability in comparison with the model obtained using database values referring to the whole year. The elaborated models are a potential instrument both for forecasting the concentrations of PM10, as well as for the development of systems for pollution control and management.

In [10], the intercriteria analysis developed on the base of intuitionistic fuzziness and index matrices was applied to evaluate processing data of the LUKOIL Neftohim Burgas H-Oil ebullated bed vacuum residue hydrocracker with the aim of revealing the reasons for increased fouling registered during the 3rd cycle of the H-Oil hydrocracker. It was found that when the ratio of the ΔT of the 1st reactor to the ΔT of the 2nd reactor gets lower than 2.0, an excessive H-Oil equipment fouling

occurs. The fouling was also found to be favored by processing of lower Conradson carbon content vacuum residual oils and increased throughput and depressed by increasing the dosage of the HCAT nanodispersed catalyst. The fouling in the atmospheric tower bottom section is facilitated by a lower aromatic content in the atmospheric tower bottom product. The addition of FCC slurry oil not only increases aromatic content but also dissolves some of the asphaltenes in the atmospheric residual hydrocracked oil and decreases its colloidal instability index. The fouling in the vacuum tower bottom section is facilitated by a higher saturate content in the VTB. Surprisingly, it was found that the asphaltene content in the VTB depresses the fouling rate. No relation was found of the sediment content in the hydrocracked residual oils measured by hot filtration tests and by the centrifuge method to the equipment fouling of the H-Oil

In [11], forty-eight crude oils with variations in specific gravity ($0.782 \leq SG \leq 1.002$), sulphur content ($0.03 \leq S \leq 5.6$ wt.%), saturate content ($23.5 \leq Sat. \leq 92.9$ wt.%), asphaltene content ($0.1 \leq As \leq 22.2$ wt.%), and vacuum residue content ($1.4 \leq VR \leq 60.7$ wt.%) were characterized with HTSD, TBP, and SARA analyses. A modified SARA analysis of petroleum that allows for the attainment of a mass balance ≥97 wt.% for light crude oils was proposed, a procedure for the simulation of petroleum TBP curves from HTSD data using nonlinear regression and Riazi's distribution model was developed, and a new correlation to predict petroleum saturate content from specific gravity and pour point with an average absolute deviation of 2.5 wt.%, maximum absolute deviation of 6.6 wt.%, and bias of 0.01 wt.% was developed. Intercriteria analysis was employed to evaluate the presence of statistically meaningful relations between the different petroleum properties and to evaluate the extent of similarity between the studied petroleum crudes. It was found that the extent of similarity between the crude oils based on HTSD analysis data could be discerned from data on the Kw characterization factor of narrow crude oil fractions. The results from this study showed that contrary to the generally accepted concept of the constant Kw characterization factor, the Kw factors of narrow fractions differ from that of crude oil. Moreover, the distributions of Kw factors of the different crudes were different.

In [12], various straight-run and hydrocracked vacuum residual oils mixed with dissimilar light oils were tested for their viscosity using an Engler specific viscometer, generating 158 heavy oil blend viscosity data points. Twenty-one available from the literature empirical correlations were tested for their capability to accurately predict viscosity. It was confirmed that the heavy oil blend viscosity

exponentially decreases with the diluent concentration enhancement. The linearized form of double logarithm Walther’s equation, using the concept of viscosity blending index, was found to be suitable to model not only the viscosity of distinct residual oils and bitumen with diverse light oil diluents but also heavy crude oil blend viscosity with an accuracy very close to that of the equation with interaction parameters. The model parameters, however, are found to be specific to the experimental data and must be tuned to the particular viscosity dataset. The results of this work confirm the assertion of other researchers that the artificial neural network (ANN) approach provides a higher accuracy of viscosity prediction of mixtures of heavy oil and diluent, compared with empirical correlations. For a set of 109 viscosity data points of vacuum residual oil−diluent mixtures, the best empirical correlation shows an average absolute deviation percentage (% AAD) of 6.7, while the ANN model shows a value of % AAD = 2.2.

A facial recognition security system for cyber-physical security is provided [13], which includes a neural network and intelligent algorithms for assessing the severity level of security breaches. The system also includes alarms with severity levels ranging from 1 (low severity) to 4 (critical), based on facial recognition and data from carbon dioxide and temperature sensors. In the event of a security breach, an incident response plan is presented. The proposed system is applicable to offices, workspaces, server rooms, data centers and other areas where information is stored, to enhance physical security and protect against cybersecurity threats. The proposed architecture allows for flexibility regarding the parameters used in the process of determining the threat level associated with the cyber-physical security of a site. The criteria regarding the threat level can be easily and quickly adapted when security policies change, and the adaptation of the CNN associated with the facial recognition of visitors provides new perspectives for the development of cyber-physical security assurance systems.

The integration of AI methods, specifically face recognition techniques combined with additional data from CO2 and temperature sensors and neural networks in cyber-physical security, brings several benefits including improved accuracy, reduced response time and enhanced threat detection capabilities.

Study Aid

The study aid [П1] is intended for bachelor students from the UCTM - Sofia. It can be useful for anyone interested in a basic computer science course. The following main topics are covered:

- Computer systems - organization and principle of operation
- Arithmetic and logical basics of computer systems
- Operating Systems
- Computer networks and their use
- Technological process of information processing with the help of a computer system
- C/C++ programming
    - Basic elements of the language
    - Data types in C/C++
    - Operations and expressions in the C/C++ language
    - Control structures
    - Complex data types

A module for graphical presentation of results was developed, allowing the visualization of the results of the written by the students C/C++ programs through line (possibility of using one or two axes) and contour charts. The module is built on the basis of the MatPlotlib library and is platform-independent (can be used in Windows, Linux, etc.). Documentation has been written describing the process of installing and using the module.