ENGINEERING SCIENCE AND TECHNOLOGY DIVISION

ESTD-1

FOREST FIRE MODELING AND SIMULATION USING NONLINEAR CELLULAR AUTOMATA

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Forest fire modeling and simulation have been in the research trend for the past years, especially now with the advent of digital computers and high-speed microprocessors. From manual explicit mathematical model using partial differential equations, forest fire modeling was developed in the form of cellular automata. Since modeling using partial differential equations based on real, continuous-time dynamical properties of forest fires are difficult to simulate, there is a need to have a simple modeling strategy that will be able to incorporate other practical conditions in forest fire modeling such as the effects of wind, non-flat landscape, and having different rates of fire spread, i.e. having a heterogeneous forest. Therefore, cellular automata were used in this study because the models are well-known to be an effective alternative to partial differential equations, which have been used successfully in modeling physical systems and processes. This paper presents a forest fire model using nonlinear cellular automata, more specifically, a nonlinear, two-dimensional square cellular automata with circular fire front treatment. Although other cellular automata models were already available, the consideration of a hypothetical circular fire front is necessary especially for a flat, homogenous terrain with a single ignition source. Simulation results are also presented which then include the effects of external winds, non-flat forest terrain, and heterogeneous landscapes. Discussions involve the mathematical representation of the model and graphical illustrations portrayed by simulation results to further explain a more realistic cellular automaton model as compared to the other existing models.

Keywords: Cellular automata, forest fire, fire modeling, fire front, local transition function

ESTD-2

A LOW-COST MACHINE VISION SYSTEM FOR REAL-TIME FIRE DETECTION

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Progress in fire detection technologies has been substantial over the last decade due to advances in sensor, microelectronics and information technologies, as well as a greater understanding of fire physics. However, acquiring systems that integrate these technologies is still costly, while most of these systems cater only to fire events that are not common locally. We designed, implemented and tested a system for real-time detection of fire for a wide range of local fire and false alarm events using robust algorithms that integrate state-of-the-art software technologies and running under cheap off-the-shelf hardware. The spectral, spatial and temporal properties of fire events are automatically extracted by the system using color video streams captured from a cheap USB-mounted web camera. The use of color video streams has significant advantages over the traditional ultraviolet and infrared fire detectors due to the former's improved detection and fewer false alarms, while additional descriptive information about fire location, size, and growth rate can be obtained. We used the color probability density of fire pixels to represent the spectral model of fire events. We "trained" a machine vision algorithm by creating, normalizing, and thresholding the color histogram of collected video sequences of fire to produce a color look-up table that will determine the fire-colored pixels. Our spatial and temporal models respectively capture the spatial structure and the temporal signature of a fire region. The ratio between the intersection and difference of fire-colored pixels in consecutive video frames served as a criterion for deciding if the group of fire-colored pixels possess the fire's spatial and temporal behavior. This criterion can be adjusted to improve detection under a specific environment. The system uses an audio stream to output alarm signals of varying loudness appropriate for the detected rate of fire growth. Additionally, the system can record the detected fire events to help decision makers on how to avoid future fire damages and to aid arson and forensic investigators. We tested our system under different local indoor and outdoor fire events consisting of thousands of image frames. Our system detected real fire events and ignored non-fire events 84% of the time. The system detected no-fire events as fire events (i.e., false alarms) 12% of the time and ignored real fire events 4% of the time. The ignored fire events, however, are from controlled fire such as

the blue flame from a torch welder and a motion-less flame from a gas stove. Based on our tests, our vision-based fire detection system from off-the-shelf hardware can be a cheap yet flexible alternative to traditional ones.

Keywords: machine vision, real-time fire detection, image processing, fire physics, fire spectral characterisics, fire temporal chracteristics, fire spatial characteristics

ESTD-3

AUTOMATING THE CLASSIFICATION OF TOMATO (*Lycopersicon esculentum*) MATURITY USING IMAGE ANALYSIS AND NEURAL NETWORKS

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Color in tomato is the most important external characteristic to assess ripeness and postharvest life, and is a major factor in the consumer's purchase decision. The degree of ripening is usually estimated visually by human graders comparing the tomato color to a chart that classify fresh tomatoes into six maturity stages according to the USDA standard classification: Green, Breakers, Turning, Pink, Light Red, and Red. This manual practice of tomato maturity classification often results into errors due to human subjectivitiy, visual stress, and tiredness. We developed a color image analysis procedure and a neural network model to automate the classification of tomato maturity. We captured using a computer-connected digital camera 6,000 color images of locally grown and harvested tomatoes equally representing the six maturity stages (1,000 each). The average classification by five expert graders from a local commercial farm was used as the maturity classification of each tomato. Using the red, green and blue (RGB) spectral values of the captured images as inputs, we trained a neural network-based tomato maturity classifier to indicate the degree of maturity within each stage and to provide a continuous index over the complete maturity range. We trained a 3-layer neural network via the feed-forward, back propagation training algorithm using 70% of the captured images as the training set (4,200 images) and 10% as the test set (600 images), equally representing each maturity stage. The test set was used during training to avoid model over-fitting. Validation results agreed with manual grading in 97% of the remaining tomatoes (1,200 images), while the remaining 3% were classified wrongly but within one maturity stage difference. With this result, an

automatic vision system for tomato grading could be a potent alternative to manual grading.

Keywords: tomato grading, neural network, image processing, feed-forward, back-propagation

ESTD-4

CONSTRUCTION OF AUTOMATIC MANGO SORTER

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A micrometer-based instrument that measures weight of mangoes (*Magnifica indica* L.) and sort in three different categories was implemented using an Atmel ATMEGA 16L microcontroller. The objective of the study was to design and implement an instrument that used a load cell as a weight sensor and actuators to transfer the mangoes from the platform to a conveyor belt and places them in their respective categories. The study was composed of five main phases namely 1) software development, 2) mechanical hardware design and construction, 3) controller design and construction, 4) sensor calibration , and 5) data gathering and testing. On the software part, the weight in the different categories can be set manually or using the default standard weight classifications of mangoes. All actuators in the sorting instrument were controlled by the microcontroller unit (MCU). An LCD and four buttons were placed for user interface. On the hardware part, a load cell attached to the platform was used to measure the weight of the mangoes. Then a pushing mechanism powered by a DC motor was activated to transport the mangoes from the platform to the conveyor belt powered by an AC speed control motor. Two solenoid motors attached with flippers were used to sort mangoes into their respective category. The calibration of the ADC and the sensor was done using a set of metal weights and a software program. The microcontroller-based automated mango sorter was tested using thirty mangoes and successfully sorted 289 times out of 300 trials thus giving the sorting machine 96.33 % success rate.

Keywords: mango sorting, microcontroller

ESTD-5

EFFECTS OF CO-SOLVENTS ON THE TRANSESTERIFICATION REACTION TIME, TEMPERATURE, AND FREE GLYCERIN CONTENT OF CRUDE METHYL ESTER PRODUCED FROM COCONUT (*Cocos nucifera* L.) OIL

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Transesterification of coconut oil was carried out with different cosolvents namely hexane, petroleum ether and diethyl ether to investigate their effect on the reaction time and temperature, and free glycerol content of crude methyl ester. This study aimed to shorten the transesterification reaction time and produce a low glycerin content methyl ester from coconut oil using hexane, petroleum ether and diethyl ether as cosolvents.

Reactions were carried out with different cosolvent-to-methanol ratios (1:20, 1:10, 1:6.7, 1:5 and 1:4) at room temperature (30°C) and at 60°C. For all the reactions, methanol-to-oil ratio was maintained at 0.28:1 and sodium hydroxide catalyst added was 0.5% of the amount of oil taken.

Washing of the crude methyl ester by bubble wash and mist wash was done to compare the washing time and amount of water required, respectively, to lower the percentage free glycerol content of crude methyl ester obtained from different ratios of cosolvent to methanol, to the same level, and the effect of salts (sodium chloride, calcium chloride and potassium iodide), glycerol and temperature on the breaking of emulsions formed after washing, were also studied.

The percentage yield of crude methyl ester increased with increase in cosolvent:methanol ratio. It was found that 1:5 cosolvent to methanol ratio was the optimum ratio and the room temperature (30°C) was the optimum temperature. Volume of water required for mist wash and the time required to bubble wash the crude methyl ester reduced with the increase in cosolvent to methanol ratio. Mixing of the glycerol was very effective in breaking of emulsions formed during the washing.

Keywords: coconut oil, cosolvent, glycerin, methyl ester, transesterification

ESTD-6

SACCHARIFICATION AND FERMENTATION OF CORN (*Zea mays*) WASTE MIXTURES FOR ETHANOL PRODUCTION

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The importance of bioethanol production is underscored with the enactment of the Biofuels Act. With such law mandating at least 5% (by volume) blend with all gasoline fuels within 2 years, and 10% blend within 4 years of its effectivity, there is a need to strengthen R & D efforts on the utilization of all possible substrates to produce the large amount of bioethanol for the national biofuel program.

Corn waste mixtures which consist of the residual starch not extracted during milling, the depithed corncobs, and the husks are the substrates considered in this study. Corncobs, together with the husks and the starch contain extractable sugars for fermentation.

This study aimed to evaluate the effect of pretreatment and enzyme concentration on subsequent saccharification and fermentation using corn wastes as raw materials. The effect of pretreatment (hot water; 0.5% H_2SO_4) was evaluated on ethanol production of corn waste mixtures. Then the effect of cellulase concentration (10%, 20%) on saccharification of corn waste mixtures was determined, along with the fermentation profile for ethanol concentration, reducing sugar concentration and biomass concentration.

Results showed that the highest ethanol concentration produced was 4.897% (v/v) using hydrolysates from the combination of dilute acid 0.5% (v/v) H_2SO_4 pretreatment and the use of 10% cellulase in corn waste mixture hydrolysis. The computed ethanol productivity for dilute acid pretreated corn waste samples that used 10% and 20% cellulase are 0.4192 and 0.4014, respectively. For hot water pretreated samples, using 10% and 20% cellulase treatment during saccharification, ethanol productivity was 0.3889 and 0.3730, respectively.

Results showed that pretreatment using dilute acid (0.5% H_2SO_4) and hot water, and saccharification using 10% and 20% (w/w) cellulase were not significantly different.

Keywords: bioethanol, cellulase, corn wastes, fermentation, saccharification

ESTD-7

ELECTROLYTIC DECOLORIZATION OF DISTILLERY SEQUENTIAL BATCH REACTOR (SBR) EFFLUENT IN A CONTINUOUS REACTOR

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Electrolytic decolorization of saline-supplemented alcohol distillery effluent after passage from a Sequential Batch Reactor (SBR) was investigated in a continuous reactor. The electrolytic system utilizes the concept of indirect electro-oxidation where the chloride ion from the saline supplementation is converted electrochemically into oxidants, which subsequently act to destroy the chromophoric pollutants in the wastewater. The reactor was run at different flow (or color-loading) rates (underload, balanced, overload) and different operating currents. Then the steady-state decolorization efficiencies and other water quality parameters were obtained at each flow rate. Decolorization efficiencies of 95% was achieved under underload condition, 78% under balanced condition and 52% under overload condition. Steady-state temperature values were: overload-56°C; balanced-62°C; and underload-81°C. Steady-state pH values ranged from 7 to 8. An engineering relationship useful for scale up and operation was derived from the steady-state results

Keywords: distillery slops, electro-oxidation, sequential batch reactor , continuous reactor, decolorization

ESTD-8

ELECTROCHEMICAL TREATMENT OF SOY SAUCE PROCESSING WASTEWATER

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The high salt content and presence of color in soy sauce processing wastewater can be considered one of the reasons why treatment efficiencies are not very high using conventional biological methods (i.e. activated sludge, etc). In this study the application of electrochemical method as an alternative treatment option was explored. The electrochemical method is based principally on the concept of electrooxidation where the chloride ions present in the effluent are electrolytically converted to oxidants for decolorization and organic matter removal. Batch electrolysis experiments were conducted at different operating currents and wastewater parameters like color, total suspended solids (TSS) and pH were monitored. Initially, color was initially used as an index of organic matter content. Results showed high pollutant removals (>80%) for color and TSS. The pH remained stable at about 8, although there was a slight increase in temperature. The results were used to obtain engineering relationships useful for operation and scale up using the concept of charge dose.

Keywords: electrooxidation, electrolysis, soy sauce effluent, charge dose

ESTD-9

METAL REMOVAL FROM GOLD SMELTING INDUSTRY WASTEWATER BY ELECTROCHEMICAL DEPOSITION

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Removal of metals from gold smelting industry wastewater (mainly copper) was investigated using electrochemical deposition. Batch electrolysis experiments were performed at an operating current of 4 A. Temperature and pH were also monitored during electrolysis. Results showed high copper removal efficiencies (>85%) could be obtained. The high copper removal verified by the drastic decrease in the blue color of the effluent (indicator of high copper concentration) and the deposition of copper at the cathode. No drastic changes in pH and temperature were observed during the electrolysis experiments. The copper concentration data were used to determine the current efficiency, charge dose, energy requirement and to obtain engineering relationships useful for operation and scale up.

The metal removal efficiencies by electrodeposition were also compared with another method using alkali precipitation as benchmark.

Keywords: spontaneous redox reactions, electrolysis, gold smelting industry effluent, charge dose

ESTD-10

BIOSORPTION OF HEAVY METALS FROM GOLD SMELTING INDUSTRY EFFLUENT BY UNTREATED AND TREATED *Azolla filiculoides* WITH $H_2O_2/MgCl_2$

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The adsorption of heavy metals from gold smelting industry effluent onto dried milled *Azolla filiculoides*, as a cosmopolitan free-floating water fern, was investigated in the batch biosorption experiment. Copper, as the heavy toxic metal with the highest concentration (>3000 ppm) in the effluent, was analyzed for possible removal. Ten different mass loadings were tested for the uptake time and equilibrium concentration determination in a daily and hourly sampling interval. Higher and lower initial metal concentration were utilized. The pH of the solution was also varied to determine the most effective working condition for the adsorption process. The copper uptake capacity of the biomass was approximately 98 mg/g (dry *Azolla*). The metal removal (>70%) was observed to be moderately rapid at low pH and low initial Cu^{2+} concentrations. On the other hand, the adsorption of heavy metal onto treated *Azolla filiculoides* by $H_2O_2/MgCl_2$ as an activator material (mineral and oxidant agents) was also investigated. Cellulose are important polysaccharides constituent of plant cell walls, made of fragments of polygalacturonic acid chains, which interact with Ca^{2+} and Mg^{2+} to form a three dimensional polymer by $(-COO)_2Ca$ and or $(-COO)_2Mg$ bindings as the ion exchanging bases. Results showed that increased use of H_2O_2 in the treatment process had no remarkable effect on the removal of heavy metals. But the increasing use of H_2O_2 increased heavy metal biosorption (>80%), remarkably in cases when Mg ions as the exchanger ions were increased proportionately.

Keywords: *Azolla filiculoides*, batch biosorption, heavy metals, uptake capacity