Capítulo 5 Control de movimiento de los divisores de salida de un separador tipo espiral usando IoT

Chapter 5 Motion control of output splitters of a spiral separator using IoT

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Resumen

Los divisores de salida en los separadores tipo espiral son manipulados manualmente por los operadores para realizar la separación de mineral. La posición de estos separadores es establecida por la inspección visual del flujo de mineral identificando la estratificación de partículas en la salida, o bien, por el análisis químico del mineral según el yacimiento de procedencia, que define la distribución de densidades de las partículas, estableciendo un ángulo de posición para cada uno de estos. Un sistema de control de movimiento de los divisores mediante servomotores controlados con una Tarjeta Arduino e interfaz gráfica en Matlab con conexión directa del sistema, así como un sistema de control inalámbrico usando conexión vía Bluetooth bajo una aplicación Android mostraron restricciones en la viabilidad del sistema de control, por lo que en este trabajo de investigación se propone un sistema de movimiento de los divisores utilizando motores a paso controlados a través de una página Web enlazada a una tarjeta Arduino con monitoreo en la salida en tiempo real empleando una video cámara bajo un esquema IoT. Esta opción mostró que el monitoreo y control de los separadores de salida puede ser realizado vía remota desde cualquier dispositivo conectado a internet en cualquier parte del mundo y monitorear la sección de salida y los cambios en tiempo real reduciendo el tiempo de respuesta para realizar los cambios en los divisores cuando cambian las características del mineral en la alimentación mejorando la eficiencia de separación.

Monitoreo, sistema de control, separador tipo espiral, IoT.

Abstract

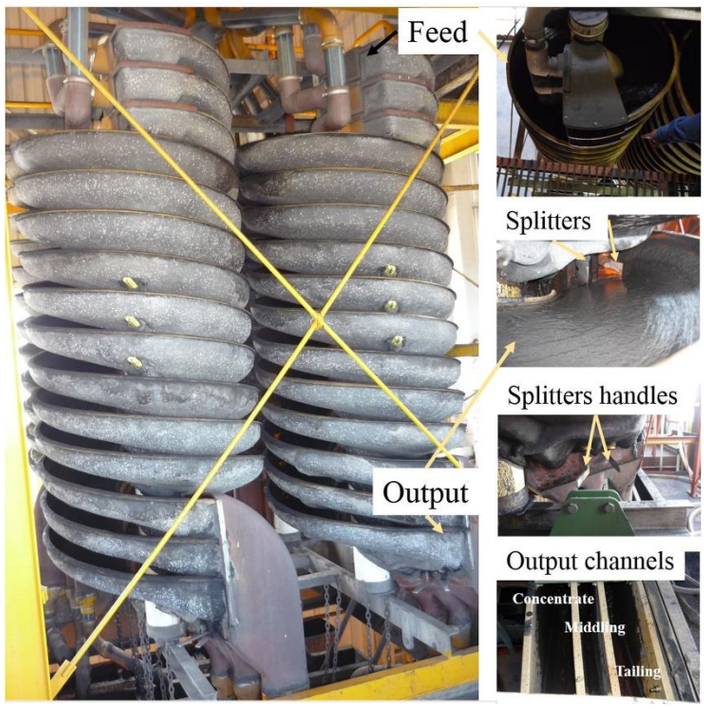
The output splitters in the spiral separators are manually manipulated by the operators to perform ore separation. The position of these separators is established by the visual inspection of the mineral flow identifying the stratification of particles at the outlet, or by the chemical analysis of the mineral according to the source deposit, which defines the distribution of densities of the particles, establishing a position angle for each of these. A system of movement control of the splitters by means of servo motors controlled with an Arduino card and graphical interface in Matlab, with direct connection of the system, as well as, a wireless control system, using Bluetooth connection under an Android application showed restrictions on the viability of the control system. This research paper proposes a system of movement of the splitters using servomotors controlled through a web page linked to an Arduino card with real-time output monitoring using a video camera under an IoT scheme. This option showed that monitoring and controlling the output separators can be performed remotely from any internet-connected device anywhere in the world, as well as, monitor the output section and changes in real time reducing the response time to make changes to the splitters when the characteristics of the mineral in the feed tank change improving separation efficiency.

Monitoring; control system; spiral separator; splitters; IoT.

5. Introducción

The Carboniferous Region, located in Northern Mexico, contributes 95% to the national production of mineral coal used in the industry of electricity generation, as well as in the metallurgical industry. In this region there are several plants that perform coked and coal washing activities through which quality of the product (coal) must be ensured; one of the coal cleaning stages is gravimetric separation by spiral type separators. The spiral separator used in mineral coal processing, operates under the principle of differences in particle densities and centrifugal force to perform the separation of valuable mineral from gangue ([1]Bazin et al., 2016; [2]Boucher et al., 2014; [3]Dixit et al., 2015). This device is shown in Figure 1.1 and consists of an open helical channel that descends and is fastened on its inner side to a certain inclination. In the output there are two dividers or splitters that are responsible for channeling the particles to the concentration channels according to their densities.

Figure 5.1 Spiral separator and its output section.



The main parameters of this separation process consist in the feed flow rate of the mineral pulp, density of the pulp and the position of the splitters at the outlet ([4]Atasoy and Spottiswood, 1995; [5]Burt and Ottley, 1974; [6]Tripathy and Rama Murthy, 2012). Generally speaking, the mineral pulp is fed into the propeller and centrifugal forces perform stratification of the particles. Denser particles flow to the inner part of the spiral and low-density particles on the outside, presenting a mixture of the two in the middle ([7]Doheim et al., 2013; [8]Sadeghi et al., 2016). The splitters in the outputs are placed in different positions to channel the particles to the containers corresponding to the concentrate, media and tails. This is one of the most efficient simple and environmentally friendly devices, which can be used as a simple system or under different configurations with two or more spirals in the same tower (Ibid 4; [9]Falconer, 2003; [10]Kwon et al., 2017; Ibid 6).

It has been reported that the position of the splitters in the output has an important influence on the quality of the concentrate. These positions may improve or worsen the degree of the concentrate, or the degree may increase by sacrificing recovery by a certain amount. Some research has been carried out to establish the stratification of particles in the fluid using tracers, as well as establish their behavior on their way through the spiral to manipulate the splitters and perform an efficient recovery ([11]Boucher et al., 2016, Ibid 2). The locations of the splitters can be established by monitoring using artificial vision capable of detecting the interfaces between particle densities, in the case of ilmenite and chromite minerals ([12]Nienaber et al., 2017; [13]Nienaber and Auret, 2016). The splitters are handled manually or by actuator devices that are directly operated at the separator output (Ibid 13).

In order to propose an option for the position of the output splitters, Estrada-Ruiz et al. ([14]Estrada-Ruiz et al., 2015), developed a motion control system for the splitters using a direct connection of two servo motors linked to a Arduino Uno card by means of a graphical interface in the Matlab software and thus establish the angle of position of the splitters according to the source of the coal ore considering a simultaneous movement of the servomotors. The servomotors were connected to the Arduino Uno card and this in turn to the computer, so it was necessary to have all the equipment in the same space as the spiral output and there make the movement modifications.

Subsequently, Estrada-Ruiz et al. (Ibid 14), proposed another option to perform the movement control of the splitters with different degrees of movement for each servomotor, as well as its control remotely. This was done by using the ATMEGA328P-PU microcontroller of the Arduino Uno card, an RN-41 FLY-477 Bluetooth device, and an Android system Electronic Tablet.

The card link with the Bluetooth communication module was established and the tablet with the Android system was subsequently synchronized with the card using the AMARINO program. With this, the tablet was set to monitor mode, which allowed data to be sent to the microprocessor through the module and thus enable the outputs and indicate the degrees that the splitters were desired to move. The method of establishing communication with the Tablet and Arduino card was the one presented by Kaufman and Buechley ([15]Kaufmann and Buechley, 2015), which allows to communicate Android systems with Arduino microcontrollers. This requires the AMARINO application and an Arduino library called MeetAndroid. This application sends data from mobile devices with Android system using a graphical interface to a specific Arduino by handling Bluetooth connections.

Estrada Ruiz et al. (Ibid 14), designed and built a laboratory-level spiral prototype in which connections of both systems were made for testing and separating mineral coal (Figure 5.2).

Figure 5.2. System of monitoring and control of the movement of splitters by direct and remote connection via Bluetooth (Ibid 145).

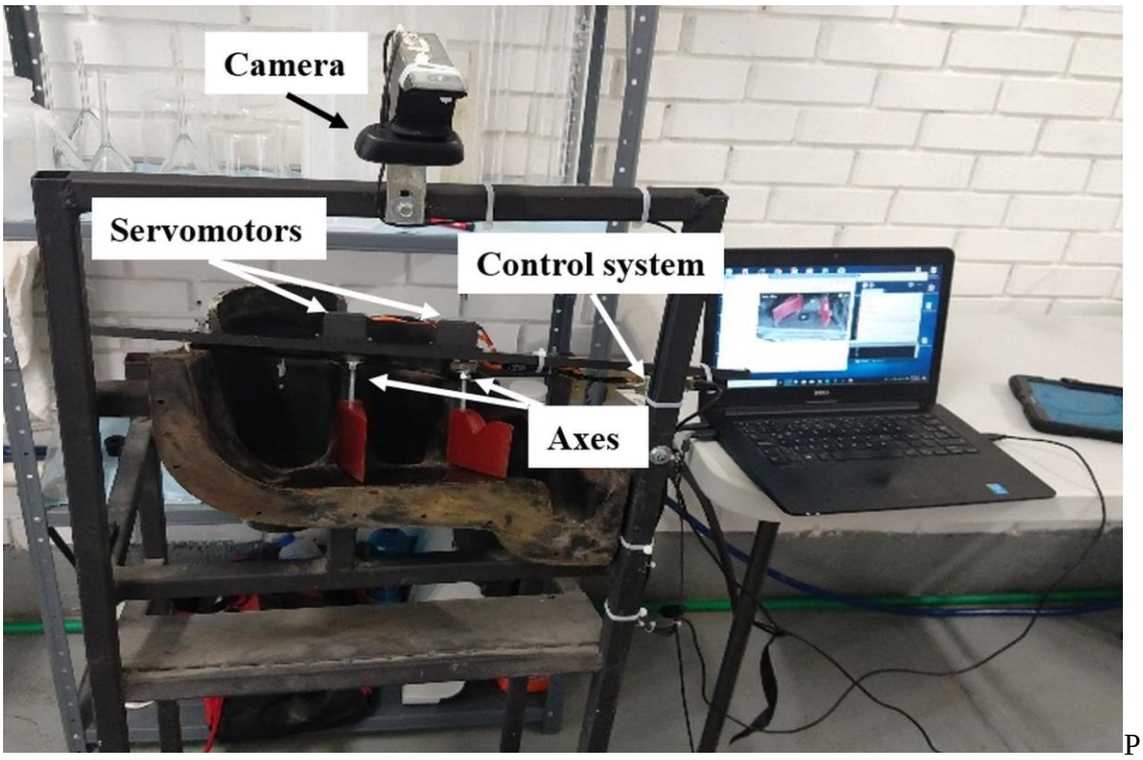
However, these control options proved unfeasible because operators had to continue to move to the control system at the spiral output to make changes to the splitters, moving large distances, when the option was direct connection control. On the other hand, the option of remote control via Bluetooth with an Andorid System was also discarded by users due to communication interferences by structures and distances in the plant. For this reason, the Research work herein proposes a system of movement control of splitters via the Internet of Things (IoT) with the support of monitoring by camcorder in real time, and with options of movement of splitters, by source deposit or by indicating degrees of movement specified by the user. This will allow to control not only the spiral output splitters from anywhere in the world, with access to internet, but also a near-immediate response time to make the changes required by the process.

5.1 Methodology

5.2 Experimental device

The device used for experimental tests is an industrial spiral output section, which was donated by a company from the Carboniferous Region of Coahuila, Mexico. This device has three outputs: concentrate, media and tails, as well as two splitters that allow the flow to be routed to each of the outputs. This device was installed with two servomotors, connected to each of the splitters, a control system and a video camera, as shown in Figure 5.3.

Figure 5.3 Output section of the spiral separator with motion control system and video camera.



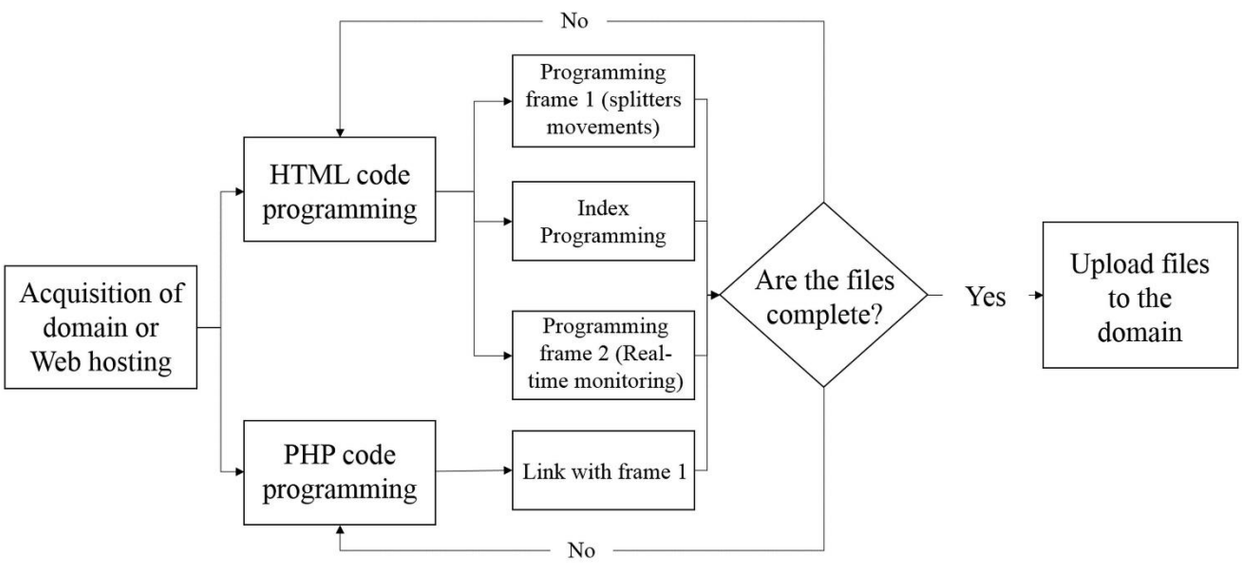
P

5.3 Programming

5.4 Website

The diagram in Figure 5.4 shows how to program a web page with the particular case of the motion control site. First, a domain was acquired proceeding to simultaneously program PHP code and HTML ([16]Powers, 2010). The HTML program was divided into boxes for data refresh topics, once split it was verified that its functions were operated correctly in order to subsequently upload the files into the domain by means of a file manager to carry out performance tests. PHP code is the dynamic configuration of the page where user-machine interaction is allowed.

Figure 5.4 Sequence to program web page.

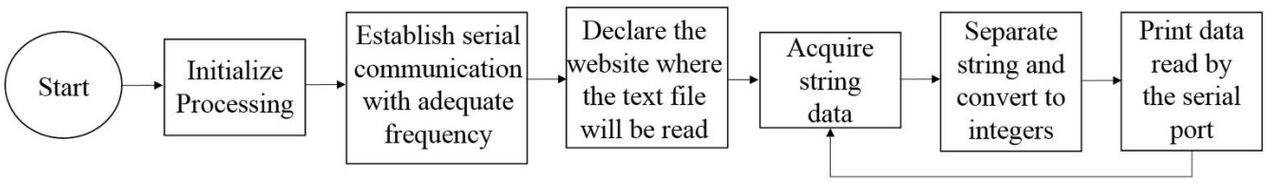


5.5 Programming in the Processing software to communicate with the Arduino card

The diagram in Figure 2.3 shows the programming process in the Processing software, the first thing was to start the program to subsequently establish serial communication with the Arduino card.

For the communication to generate, both frequencies must be the same otherwise the communication will not exist. Afterwards, the website from which the information will be obtained was stated; information is obtained in a chain way that allows to separate the values and convert them to integers. Once the values have been converted, they are printed by the serial port, which will send the information to the Arduino card.

Figure 5.5 Programming sequence in Processing.



5.6 Streaming video via a streaming channel

For video transmission a free server such as YouTube was used, which allows, with the use of an account, to perform live transmission and emission (broadcasts); broadcasts of up to 8 hours were performed for the tests carried out in this research.

In order to make a transmission a YouTube account was created, once logged on the YouTube page the following procedure was carried out: Get in the section “create a video or a post”, then choose the option “transmit live,” then proceeded to extract the embed code which is located in the share section, there is a link to share the transmission. This embed code was introduced to the web page that was created for this work, so that when you enter on the website, it will give you the option to start viewing the live broadcast.

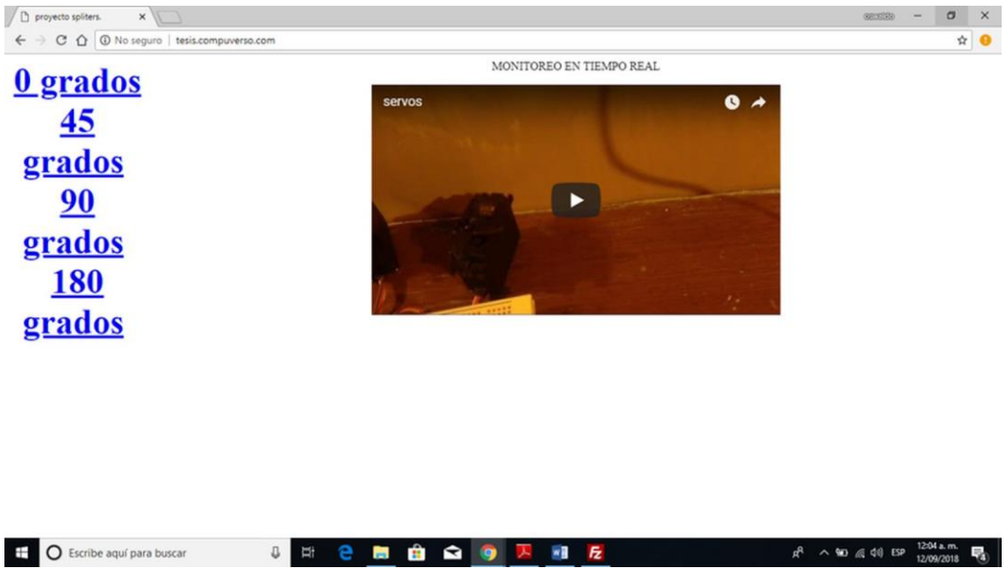
5.7 Results

On a visit to a mineral coal washing plant, it was indicated that the movements of the output splitters are carried out manually by the operators and that they have to move considerable distances from where they are and climb approximately 15 m to the location of the spiral separators. The determination of the splitters’ position is carried out in two ways, one of which is when a chemical analysis of the ore is carried out according to the source deposit and the positions of the splitters are established based on the separation experience for the densities presented. The other option is when the position of the splitters is set based on the experience of the operator in the visual inspection of flow at the output section.

5.8 Website programming with motion control with angles set

To create the web page, the HTML code was programmed to show what the user sees when accessing the page. The page was divided into two parts, one for data and another for the video, so that the video signal was not interrupted in real time when updated as data were sent. On the page, two frames were created, the first shows the page titles, it aligns the text, presents the links regarding the degrees of movement of the servomotors (0°, 45°, 90°, and 180°). The second frame displays the real-time monitoring title and the real-time video of the separator output system (Figure 3.1). In the Processing software, programming was carried out to be able to monitor the value that is saved on the web page, interpret it and compare it with the conditionals that were set for the movement of the splitters. Based on these conditionals, the signal is sent through the serial port so that the Arduino Uno card interprets and performs the indicated movement actions on the servo motors according to the degree of motion assigned. To power the servo motors, PWM port enabling was included in the programming of the card microcontroller for each port, the communication frequency was established, thus being able to read the serial port, to assign variables, values of degrees of motion and conditionals. Part of the programming code is shown in Appendix 1.

Figure 5.6 Website with preset servo motor movement degrees and real-time monitoring.



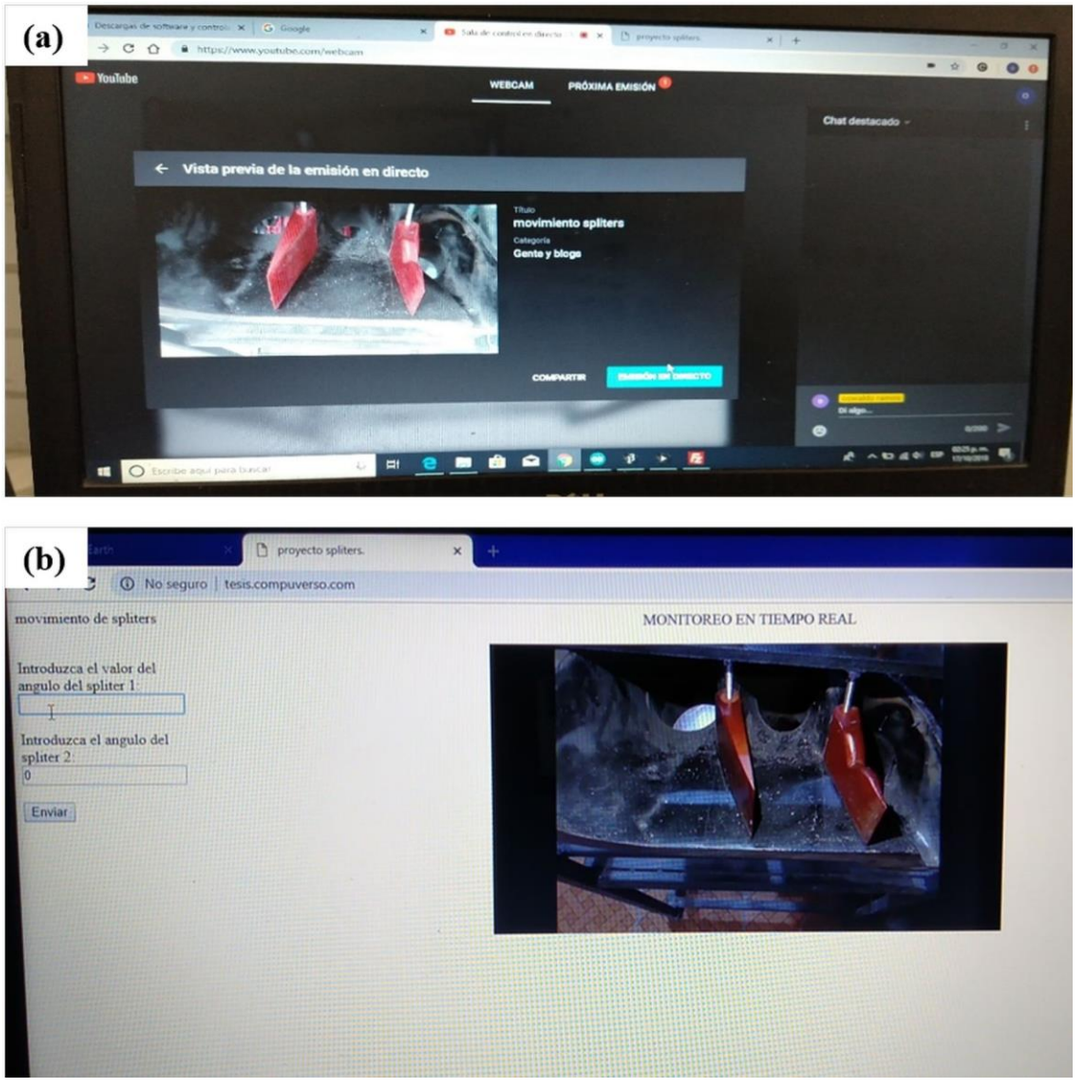
5.9 Programming of web page with motion control with position angles indicated by the user

In this part of the work, the movement of the splitters was considered independently with user-specified angles of motion. For this, changes were made to the programming on the web page in order to create data forms to input the value of degrees for the movement of each splitter. In addition, the PHP code was modified to be able to read the data of these forms and state the variables that are entered in the text boxes to be monitored.

Significant changes were made in the Processing software programming section, one of them was to set the synchronization times between Processing and Arduino, as well as being able to assign values for each splitter. The serial port connection was limited to the moment when only the values entered change, for this purpose auxiliary variables were used to store the data and compare them when new values are received and thus make the change of the angle of the splitter by moving the servomotors. This program reads the value entered on the website and prints it by the serial port, it first starts the servo motor 1 and waits for a while to print the next data from servo motor 2, because if the two data were printed simultaneously the microprocessor would not be able to identify which servomotor to move. On the Arduino card the programming in question was changed from the way the order was sent from the movements of the servomotors. To do this, a direct connection was established, without conditionals, to perform free movements of each, establishing that the data of the servomotor one and then the two must be read first.

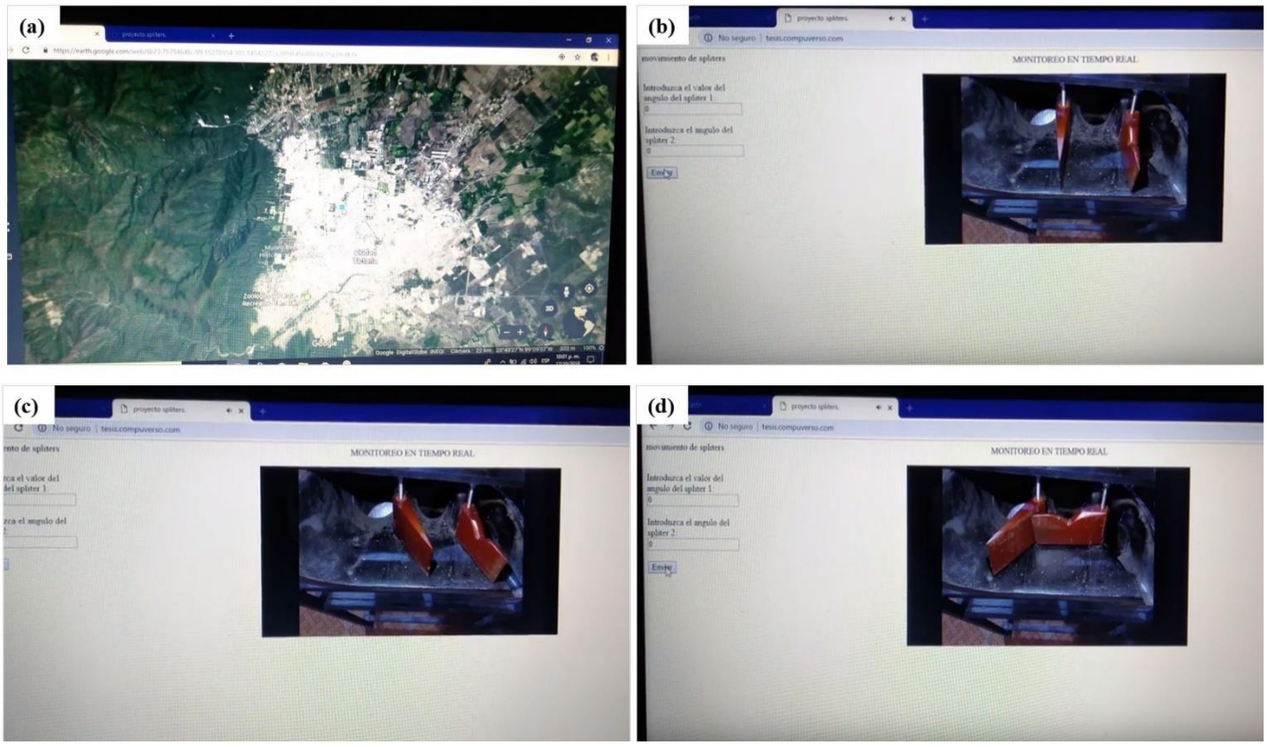
For video transmission, a YouTube channel was used to access a free channel that would allow to upload video and live streams, hence the Embed code that is added to the monitoring page to be able to view the channel. Figure 3.2a) shows a screenshot image of the YouTube web page in which the real-time transmission of the splitters is observed; the code is extracted from this page. This code is inserted into the web page and, along with the options to enter the degrees of movement of each servomotor, you can observe how the splitters move to new positions after the angle data are fed in the corresponding section (Figure 5.7 b). Part of the programming code is presented in Appendix 2.

Figure 5.7 (a) Channel on YouTube for real-time monitoring and (b) web page with text boxes to set the degrees of movement of splitters and real-time monitoring



To validate the proper functioning of the system, a test was performed in which a person controlled the movement from Ciudad Victoria, Tamaulipas, Mexico, controlling a sequence of values in the servomotors. First, the location of the computer equipment was determined (Figure 5.7 a); then, the web page was accessed and the values in degrees of motion were entered with reference to the starting position in which the servomotors were located. These were the observations: When the values are entered and the option “Enviar” is clicked, the movement of the first servomotor is performed and then the second, since these movements, as mentioned above, are not simultaneous. When the splitters reach their new position, the spaces for entering new values in the text box have a value of zero, this to determine that the new "zero" position of the splitters is presented in the current condition. By re-entering new values and operating "send" or “Enviar”, the servomotors will rotate the defined degrees generating a new "zero" position of the servo motors. Figures 3.3b, 3.3c, and 3.3d show different positions of the splitters, obtained by the movement of the servo motor 1 and servo motor 2 in 90°: 90°, 70°: 70°, and 120°: 165° degrees, respectively.

Figure 5.8 Real-time manipulation of the output splitters, (a) location of the access to the website, (b) position at 90°, (c) position at 70° and (d) position 120° splitter 1 and 165° splitter 2



It should be noted that in the programming of the page conditionals were introduced to prevent the splitters from colliding with each other, so that when you enter a value that creates this problem, the page will display an error, and ask for a new value or datum.

At the moment, we are working with a graphical interface that does what this work involves, including image analysis techniques that allow to determine the stratification of the particles in the fluid and therefore its dividing interface in order to take the best decision of position angles to get a better degree in recovery in mineral coal washing.

5.10 Conclusions

It is feasible to create a dynamic web page to monitor the output section of a spiral type separator in real time.

It is also feasible to control the movement of the separator output splitters remotely anywhere in the world from any internet-connected device.

The feasibility of defining the angle of position in each of the splitters increases the efficiency of mineral separation at the spiral output.

The immediate adjustment of the splitters ensures a more effective recovery and grade of mineral avoiding losses in the quality of the final product with respect to the manual adjustment that is performed conventionally in a Processing plant.

The use of this technology eliminates interference caused by buildings, cables, structures and other obstacles that prevent the signal from reaching the splitter control system.

The incorporation of IoT into mineral benefit processes in spiral separators increases process efficiency by including real-time monitoring and control.

5.11 Acknoledgements

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5.12 References

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Appendix 1. Website programming with motion control with angles set.

PROGRAMACIÓN DE PÁGINA WEB PARA EL MOVIMIENTO DE LOS DIVISORES CON ÁNGULOS PREESTABLECIDOS

Programación en HTML	Programación en PHP	Programación en Propcessing	Programación en tarjeta Arduino

Frame 1 movimiento de servomotores
 	
<html>
 	
<head>
 	
<title>movimiento de servomotores</title> titulo de la pagina
 	
</head>
 	
<body>
 	
 alineación del texto
 	

 	
0 grados /link o vinculo referente a 0 grados
 	
45 gradoslink o vinculo referente a 45 grados
 	
90 grados /link o vinculo referente a 90 grados
 	
180 grados link o vinculo referente a 180 grados
 	

 	
Frame 2 monitoreo en tiempo real
 	
<html>
 	
<head>
 	
<title>monitoreo</title> titulo de la pagina
 	
</head>
 	
<body>
 	
<body background="logo.jpg"> imagen de fondo
 	
MONITOREO EN TIEMPO REAL texto mostrado en el sitio
 	
	<?php
	
	$onoroff = $_GET["state"]; // declaramos la variable proveniente del archivo html
	
	$textfile = "servostate.txt"; // se declara la localizacion del archivo de texto.
	
	$fileLocation = "$textfile";
	
	$fh = fopen($fileLocation, 'w ') or die("Something went wrong!"); // se abre el archivo de texto y se sobre escribe el valor anterior.
	
	$stringToWrite = "$onoroff"; // se escribe la variable dependiendo cual sea la selecccion en el index.
	
	fwrite($fh, $stringToWrite); // escribimos en el
		import processing.serial.*; se importa la libreria
		
		Serial port; se declara el nombre del serial
		
		void setup() { configuracion
		
		port = new Serial(this, Serial.list()[0], 9600); // se declara el Puerto serial y se configure a la frecuencia adecuada para trabajar.
		
		}
		
		void draw() { rutina
		
		String onoroff[] = loadStrings("http://servomov.w.pw/movimientostate.txt"); // la variable adquiere el valor leyéndolo de la página de internet.
		
		print(onoroff[0]); // se imprime el valor
		
		if (onoroff[0].equals("1") == true) { se compara el valor recibido
		
		println(" - 90 grados"); se imprime el valor para conocimiento
		
		port.write('1'); // se imprime el valor en el puerto serial
		
		}
		
		else if (onoroff[0].equals("2") == true) {
		
		println(" - 135 grados");
		
		port.write('2');
		
		}
		
		else if (onoroff[0].equals("3") == true) {
		
		println(" - 180 grados");
		
		port.write('3');
		
		}
			#include<Servo.h> // se incluye la libreria para manejar servomotores
			
			int inconmingByte; // se declara la variable entera
			
			Servo myServo;//se declara el nombre del servomotor
			
			void setup()// iniciamos la configuracion de la tarjeta
			
			{
			
			myServo.attach(5);// se asigna una salida al servomotor
			
			Serial.begin(9600);// se inicializa la comunicacion serial con una frecuencia.
			
			}
			
			void loop()// comienza la rutina que realizara la tarjeta constanmente
			
			{
			
			if (Serial.available()>0)// instruccion para revisar si la comunicacion serial esta disponible
			
			{

<object type="application/x-shockwave-flash" data="http://www.justin.tv/swflibs/JustinPlayer.swf?channel=oswaldo2329" id="live_embed_player_flash" height="300" width="400" bgcolor="#000000"><param name="allowFullScreen" value="true"/><param name="allowScriptAccess" value="always" /><param name="allowNetworking" value="all" /><param name="movie" value="http://www.justin.tv/swflibs/JustinPlayer.swf" /><param name="flashvars" value="hostname=www.justin.tv&channel=oswaldo2329&auto_play=false&start_volume=25" /></object>Watch live video from oswaldo2329 on www.justin.tv

Codigo Fuente del canal de video para monitoreo

</body>

Index

<html>

<head>

<title>proyecto spliters.</title> titulo de la pagina

</head>

<frameset cols="200,100%"border=0> división de las columnas

<frame name="movimientos" src="frame1.html">selección de frame y ubicación

<frame name="monitoreo" src="frame2.html">selección de frame y ubicación

<noframes>

Si tu navegador no acepta frames, estarás viendo este mensaje. ¡Lo sentimos!

</noframes>

</frameset>

archivo de texto el valor

fclose($fh);

$para = 'servostate.txt';

header("Location: index.html"); // regresa a (index.html)

?>

else {

println(" - cero grados");

port.write('0');

}

delay(3000); //tiempo de espera para imprimir el valor }

inconmingByte= Serial.read();// se lee el Puerto serial y se asigna a la variable.

myServo.write(1);// se asigna a el servomotor el valor de 1

if (inconmingByte=='0')// se compara la variable si es igual a cero

{

myServo.write(1); // se asigna al servo el valor de 1 grado.

}

if (inconmingByte=='1')// si la variable es igual a 1

{

myServo.write(45);// se asigna al servo el valor de 45 grados

}

if (inconmingByte=='2')// si la variable es igual a 2

{

myServo.write(90);// se asigna al servo el valor de 90 grados

}

if (inconmingByte=='3')// si la variable es igual a 3

{

			myServo.write(180);// se asigna al servo el valor de 180 grados
			
			}
			
			}
			
			}

Appendix 2. Programming of web page with motion control with position angles indicated by the user.

MODIFICACIÓN EN LA PROGRAMACIÓN DE PÁGINA WEB PARA EL MOVIMIENTO DE LOS DIVISORES CON ÁNGULOS INTRODUCIDOR POR EL USUARIO

Programación en HTML	Programación en PHP	Programación en Processing	Programación en Arduino

<html>
 	
<head> <title>movimiento servomotores</title> </head> titulo de la pagina
 	
<body> <form name="formularioDatos" method="post" action="Le.php"> cuerpo de la pagina se declara el formulario y se hace referencia al archive php con el cual se enlazara.
 	
 movimiento de spliters
 	
 Introduzca el valor del angulo del spliter 1: <input type="text" name="onoroff" value="">
 primer formulario
 	
 Introduzca el valor del angulo del spliter 2: <input type="text" name="onoroff2" value="">
 segundo formulario
 	
 <input name= "enviar" id="enviar" value="Enviar"
	<?php
	
	if($_POST["enviar"] == "Enviar"){ se compara si los datos fueron enviados
	
	$ang1 = $_POST["onoroff"]; se asignan nombres a las variables del html
	
	$ang2 = $_POST["onoroff2"];
	
	if(!empty($ang1) and !empty($ang2)){ como ya no estan vacios las variables se procede a escribir en el archivo de texto los valores.
	
	$textfile = "movimientostate.txt"; $fileLocation = "$textfile"; $fh = fopen($fileLocation, 'w') or die("Something went wrong!"); $stringToWrite = "$ang1"."\n"."$ang2"; fwrite($fh, $stringToWrite); fclose($fh); header("Location:frame1.html");
	
	}
	
	}
	
	else{
	
	header("location:frame1.html");
	
	exit;
	
	}
		import processing.serial.*; añade libreria
		
		Serial port; se nombra el puerto
		
		int e=1; se declaran variables
		
		int i=1;
		
		int aux1=i; las variables se igualan para utilizar variables auxiliares
		
		int aux2=e;
		
		void setup() { configuracion del Puerto
		
		port = new Serial(this, Serial.list()[0], 9600);
		
		}
		
		void draw() {
		
		String x[] = loadStrings("http://servomov.w.pw//movimientostate.txt"); lectura del valor
		
		i=int(x[0]); se convierte la cadena a entero
		
		e=int(x[1]); se convierte el segundo dato a entero
		
		if(i!=aux1 && e!=aux2) se comprar el valor de las variables
		
		{
		
		port.write(i); se imprime en el puerto con un delay de un segundo
		
		delay(1000);
		
		port.write(e); se imprime el Segundo valor por el puerto
		
		aux1=i; las variables auxiliares adquieren los nuevos valores
			#include<Servo.h> se incluye la libreria del servo
			
			int inconmingByte; declaracion de variables
			
			int inconmingByte2; declaracion de variables
			
			int mov; declaracion de variables
			
			int mov2; declaracion de variables
			
			Servo myServo; se declaran el nombre de los servos
			
			Servo myServo2; se declaran el nombre de los servos
			
			void setup()
			
			{
			
			myServo.attach(5); se asigna la salida para los servomotores
			
			myServo2.attach(4); se asigna la salida para los servomotores
			
			Serial.begin(9600); comunicacion del Puerto serial
			
			}
			
			void loop()
			
			{

type="submit" /> </form> </body>
 	
</html> botón de enviar
	?>	aux2=e;
		
		print(x[1]+"\n"); imprimimos los valores en la pantalla para monitoreo
		
		print(x[0]+"\n");
		
		}}
			if (Serial.available()>0) si el Puerto esta disponible prosigue con la funcion
			
			{
			
			inconmingByte=Serial.read(); lee el Puerto y lo asigna a una variable
			
			mov=inconmingByte; se asigna el valor a otra variable
			
			myServo.write(mov); se manda mover el valor de la variable el primer servomotor
			
			delay(1200); con un retraso de un Segundo
			
			inconmingByte2=Serial.read(); se vuelve a leer el valor del Puerto
			
			mov2=inconmingByte; se asigna a la otra variable
			
			myServo2.write(mov2); se imprime en el segundo servomotor
			
			delay(1000); con un retraso de un Segundo
			
			}
			
			}