A Novel Technique to Detect Ovulation by Digital Image Analysis of Salivary Fern Pattern and Core Body Temperature

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***Abstract*—This paper uses image processing and data mining methods to develop an automatic image recognition system for woman's ovulation prediction. Detecting woman's ovulation can help fertility check, especially for woman who are conditioned to PCOD and abnormal thyroid levels ,diagnosis certain diseases and helps avoid undesired pregnancies. Saliva ferning test is a technique that monitors woman's saliva and looks for fern patterns which indicates ovulation. This involves the use of a digital camera with a 100x microscope to take saliva images and study them [2]. In the proposed method, important features in dried saliva images are automatically extracted by employing some image processing techniques which is then classified based on the density of the ferns, alongside measuring the basal body temperature of the subject in continuous intervals during the night and plotting the characteristics, an abnormal drop or discrepancy in the temperature shows the commencement of the ovulation period [3]. This system which uses two parameters and combines the results of the two increases the accuracy of the prediction. This methodology has a lot of importance in economical, medical and human aspects. In addition, this system can detect woman's ovulation period non-invasive, more safely, naturally and in a convenient and efficient manner.**

Keywords- Ovulation, Pattern Recognition, Fern Pattern, Basal Body Temperature

I. INTRODUCTION

Growth and development are the main factor that a human is conditioned during evolution. In women, a monthly menstrual cycle begins on the onset of puberty, in which ovulation is one among the four phases of menstrual cycle. When an egg is ready to be fertilized by sperm, it is said that the women is in her fertile phase. At the time of fertility, estrogen and progesterone hormones levels are high, which is observed in saliva too Saliva is used as a diagnostic fluid which can be used to assess fertile phase be assessed from the saliva. Saliva containing high estrogen hormones can form a fern-like pattern on saliva dried on object glass **[1]**. A reliable method of predicting ovulation can effectively help a woman ascertain fertility period for pregnancy as well as for right of autonomy for birth control.

Fertile period of a woman occurs when a mature egg cell is released from the ovarian follicle. Fertile period should be considered to plan a pregnancy. LH is important for the final growth of follicle and ovulation. Without this hormone, follicle will not proceed to ovulation phase even though FSH is available at a large amount. About 2 days before ovulation, LH secretion rate increases dramatically by 6-10 times and at its highest value 16 hours before ovulation. FSH also increases by 2-3 times at the same time, and then both FSH and LH will work synergistically leading up swelling of the follicle which occurs rapidly several days before ovulation. LH has a particular effect toward granulose and theca cell by transforming these 2 cells into progesterone-producing cells. Hence, estrogen secretion rate starts to decrease usually 1 day before ovulation, while progesterone hormone increases in amount of the secretion. Based on a research, a woman is in her fertility peak several days before ovulation or 14 days before menstruation **[1]**. To identify fertile period, a woman having regular menstruation might use a calendar method. Fertile period occurs from the 12th day to the 16th day after the first menstruation. Most women use a manual calculation of calendar method to know their fertile period. Sometimes infection might occur inside the reproductive tracts generating blockage in the ovary tract and hence woman will lose her fertility.

II. BACKGROUND RESEARCH

A. PHYSIOLOGY OF A HUMAN BODY

Menstrual Cycle

The menstrual cycle prompts certain progressions which eventuate in the body of a lady once in every month consistently to set itself up for a conceivable pregnancy.An egg is discharged from the ovary and the uterus or the womb is seen building up a covering in which the released egg could embed in the middle of each menstrual cycle. On the off chance that the egg isn't met by a sperm, the covering of the womb disintegrate to leave the body - this is generally known asMenstruation. Menstrual cycles typically begin in young women around the age of 12 years and reach stop at

menopause, which happens around 51 years old ordinarily. To figure out the length of a specific menstrual cycle, the first day of the flow is considered as day one and end of the cycle is the day preceding the following menstrual cycle that is yet to begin. The cycle can likewise be a short cycle of pretty much 21 days or can stretch out up to up to 42 days. Be that as it may, normally the cycle is viewed as 28 days, while roughly just 1 in 10 have a commonplace 28-day cycle. **[6]**

Average length of menstrual cycle

Menstrual flow usually last for 4 to 7 days. 7 days in the rarest cases. For most women, the menstrual flow lasts for about 5 days. On an average, woman tends to lose about 35-75 milliliter of menstrual fluid which varies from red to brick red to slightly brownish. The menstrual flow consists of mucus, blood with endometrium which is the inner lining of the uterus. In some women, menstrual cycles are known to have slight variations in each month with respect to length. Irregular and randomized cycles are common through the year after periods have started. The same is observed few years before menopause.

B. OVULATION

Ovulation is a part of the menstrual cycle. It occurs when an egg is released from the ovary. But when an egg is released, it may or may not be fertilized by sperm. If fertilized, the egg may travel to the uterus through the fallopian tube and implant to develop into a foetus. If unfertilized, the egg disintegrates and the uterine lining is shed during your period. Ovulation generally happens around the 14th day, which is the middle of the 28-day menstrual cycle. The menstrual cycle resets the day menstrual flow begins. Summing up, ovulation generally occurs during the middle of the entire menstrual cycle. Ovulation can cause a rise in the vaginal discharge. This discharge is often clear and stretchy that resembles the raw egg whites. After ovulation, the discharge may decrease in volume and appear thicker or whiter. Ovulation may also cause light bleeding or spotting, breast tenderness, increased sexual drive, ovary pain that causes discomfort or pain in one of the side of abdomen. It is observed that it is possible to ovulate more than once in a cycle and some may even have the potential to ovulate two or three times in a given menstrual cycle.

Glands involved in ovulation

Depending on the different kinds of activity of varied range of glands and their related hormones, ovulation takes place. Few of such factors are listed below.

- Hypothalamus that is located in the brain, uses hormones in order to communicate with the pituitary gland or the master gland to release required chemicals at certain intervals of time.
- The master gland of the endocrine system-Pituitary gland- is located between the hypothalamus and the pineal gland in the brain, just below the skull. The pituitary gland uses certain chemicals in order to provoke the ovaries to produce their hormone.
- The pair of ovaries,the almond shaped glands, on the other hand located in the pelvis area, contains the ova, this produces the Oestrogen and Progesterone which are two female sex hormones.**[2]**

C. SALIVARY FERN TEST

While the pre-ovulatory period still lasts, the ferning of saliva is observed. Before ovulation, there are two hormones- estrogen and adrenocorticotropic- that are known to stimulate the Aldosterone, which in turn helps in regulating the electrolytes and also the levels of fluid in the human body. Estrogen rushes during the fertile phase of the cycle and this estrogen causes Sodium Chloride crystals to form in the shape of fern leaves in both saliva and cervical mucus. It is the crystallization of Sodium Chloride (NaCl) that produces the ferning appearance in saliva.[4] The fern pattern indicates ovulation is about to occur or has already set in.

While studying different parts of ovulation such as the chemical and biochemical aspects, it can be reviewed that saliva is one of the best non-invasively acquired sample. As the pattern in the saliva resembles that of a fern plant or a feather, the term ferning is used. [5] These patterns are absent during the infertile phase of the cycles. As ovulation starts to set in, there are transitional pattern of ferns that appear sparsely. But denser and thicker fern patterns are captured as ovulation is about to start and during. The Estrogen hormone levels correspond to the saliva patterns and the fertility stage itself. As ovulation is nearing, Estrogen levels increase and cause a rise in the levels of sodium present in the body. The increasing salinity in the saliva during the ovulatory phases is a result of the changes in the chemical composition and this can be noticed while the saliva samples are allowed to dry. As nearing the ovulation, the crystallization patterns or ferning pattern are formed as a result of the higher levels of salt content in the dried saliva sample. The same patterns are detected in both saliva and cervical mucus samples. But as mentioned above, saliva is preferable.

Below is a sample of fern pattern observed in the saliva sample:

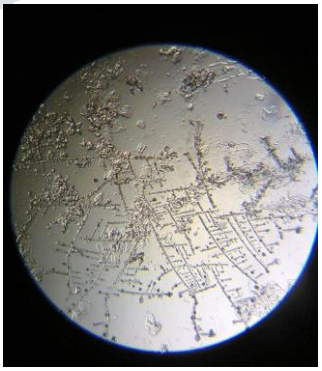


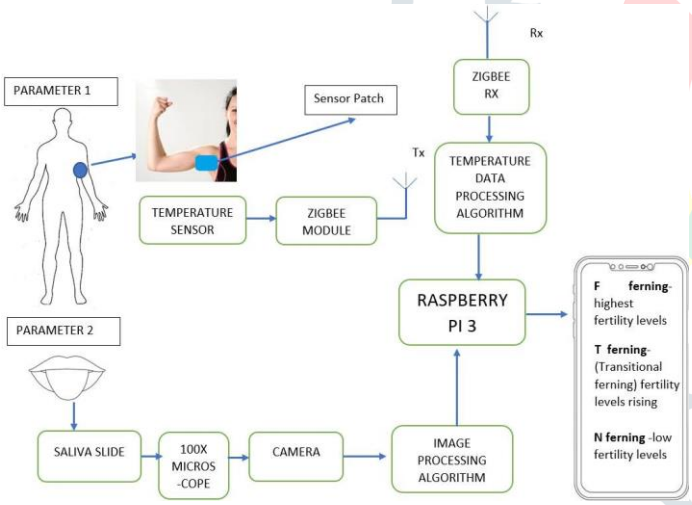
Figure: One of the samples collected during the experiment to check for fern patterns. The stage here is a fertile stage.

D. PATTERN RECOGNITION

Pattern recognition refers to recognition of patterns using various algorithms. In Pattern recognition, the knowledgepreviously gained and some mathematical data taken from the patterns is used for data classification. It is the process of classifying the data into different classes based on the important features of the image. There are two different types of classification : supervised and unsupervised classification.

Open CV with python- We use Open CV using Python for Image Processing. The python version used is 2.7 and open CV is 4.0.0. Open CV has many programming functions mainly used in computer vision. It is a free to use open source license. Presently, Open CV can be performed at different platforms like Linux, OS X, Windows, Android, i OS and many other. Open CV can be used for different programming languages like C++, Java, embedded C,etc. Python is a all-purpose programming language. It enables one to express one's ideas in a reduced and short length of code with proper understand-ability. It is slower compared to other languages like C or C++ and it can be easily extended with the same. Open CV has certain packages like NumPy which makes numerical option easier. The syntax is MATLAB style **[4].**

III. PROPOSED METHODOLOGY



The procedure mainly involves two aspects:

- Diagnosis using body fluids.
- Diagnosis using core body temperature

Diagnosis using body fluids:

Diagnosis using body fluids can include cervical mucus or saliva. The latter is preferred because it is easier and can be done by the patient herself. In this procedure, the patient introduces a small amount of the salivary extract on a slide which is focused under a microscope that is connected to a left to dry for 10-15 minutes so that the pattern in the slide is clear. An image of the extract is obtained and processed to find the density of the fern which indicates the output in three different stages:

- F - Used to indicate the presence of full fern patterns with very less crystals. This occurs right during the ovulation period when fertility level is highest.
- T - Used to indicate Transitional fern level. This shows fertility level in between full fern level patterns and no ferning patterns. This suggests that ovulation is nearing and the chances of getting pregnant are on the rise.
- N - Used to indicate N fern level which shows all crystal structures and hence indicate low fertility levels.

Diagnosis using core body temperature:

The temperature of the female body is constant within a range throughout. However, it varies from person to person. There is a dip in the temperature during the ovulation period. This dip helps indicate the fertility period. The patch with the temperature sensor is placed under the armpit of the patient which is connected to the micro-controller which has a timer that controls the number of times and the intervals at which the temperature of the patient is picked up. This happens in regular delays which is controlled by the code. The data is then plotted on a graph which gives the overall plot of the female's fertility period. This plot is again analyzed and compared with the result of the salivary fern test following which an output is obtained if that particular day is her fertile period or infertile period.

Raspberry Pi 3 Model B: Raspberry Pi 3 Model B is a size of a credit-card.. This methodology uses the third generation Raspberry Pi which is a small sized single board computer can be used for many applications and has a powerful processor, that is faster than the first-generation Raspberry Pi. In this paper we use Raspberry Pi 3 Model B as it adds wireless LAN & Bluetooth connectivity making it the ideal solution for powerful connected designs in our experiment. Saliva samples are taken from the ZigBee and undergoes an image processing algorithm. This in turn is fed to the RPi to process the image and obtain results such as **F** for highest fertility, **T** for transitional fertility, **N** for lowest fertility

Raspberry Pi Camera Module:

Raspberry Pi Camera Module is a custom designed add-on for Raspberry Pi. A small socket is allotted on the board surface for the camera. In this paper, the camera is used to capture the saliva patterns obtained from the slide.

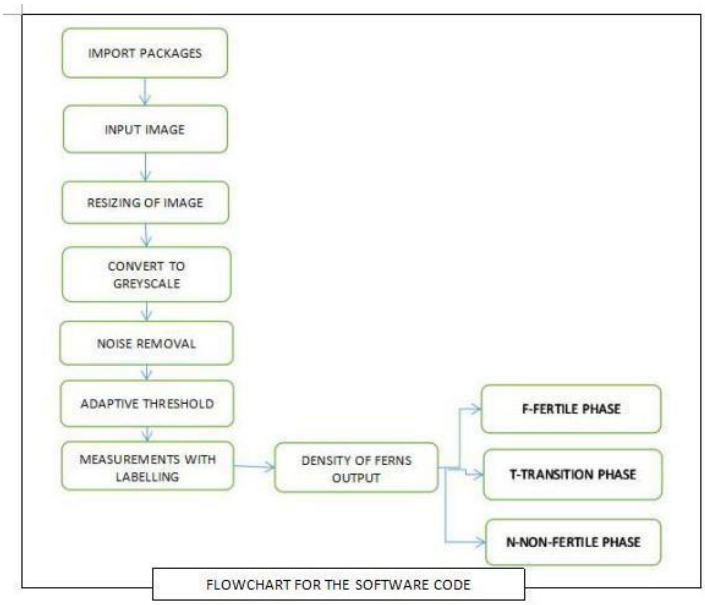
Interfacing DS18B20 and Zigbee:

- A temperature sensor, DS18B20 is used in the measurement of temperature from the female's body
- Zigbee is a novel communication device used for the transfer of data between the computers, controllers, systems, basically anything with a serial port.
- The main purpose of using a ZigBee is to transmit the data over certain distances
- This interface transmits the temperature from LM35 which is recorded from the female's underarm to Zigbee Transmitter

Interfacing Zigbee and Raspberry Pi 3 Model B:

- Raspberry Pi 3 Model B which is of a credit-card size can be plugged into a computer monitor, and used as a standard keyboard and mouse
- Raspberry Pi 3 Model B is used because of its property of a wireless LAN that makes an ideal solution for designs
- Two ZigBee modules are used that act as transmitter and receiver. And ZigBee receiver obtains the temperature from the transmitter.
- This in turn is fed to the RPi to process the image and result is obtained.

Algorithm for Image Processing



FLOWCHART FOR THE SOFTWARE CODE

IV. OBSERVATION

The saliva samples collected by the subjects are processed using image processing algorithms and the density of the fern patterns is obtained. Based on this output the various phases of ovulation are determined. The values gathered by the temperature sensor is periodic and is first transmitted wirelessly through the Zigbee module and is plotted to detect the dip during the day of ovulation.

V. CONCLUSION

This paper involves a new technique of determining the ovulation phase in females using a non-invasive, efficient procedure. The proposed method being non-invasive and accurate to 95% provides a better solution for an everlasting problem. This helps in eradicating various health hazards and in family planning.

VI. REFERENCES

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