JURNAL INFORMATIKA
PROXIES

Vol.10, No.1, July, 2026

Design of an Embedded-Based Automatic Fish Feeding System Based on Fish Stress Level Using JSN-SR04T Sensor

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https://doi.org/10.18280/ proxies. v10i1.14953

Received: 2026-01-27
Revised: 2026-07-20
Accepted: 2026-07-20
Available online: 2026-07-23

Keywords:
Automatic Fish Feeding System, Fish Stress Level, JSN-SR04T Sensor, Simple Moving Average, and Standard Deviation

ABSTRACT

Keeping fish as a pet is one of the many hobbies that everyone can do anywhere. Keeping fish itself can be challenging for some people because every owner may face some difficulties when they need to feed the fishes, therefore an Automatic Fish Feeding System can be one way to solve the problem. The difference of this study from others study or system is the system itself, because to activate the system it used the stress level of the fish and water turbidity as the main parameter. The system will measure the movements of the fish as a pointer in measuring fish stress levels using JSN-SR04T sensor, and to determine the usual or normal amount of movement as a basis for stating that the fish is not under stress is using Simple Moving Average and Standard Deviation method, which when the system find an anomaly (unusual amounts of movements) it can be say that the fish is under stress. The result of this study is to determine when the fishes are under stress, and at the same time make an automatic fish feeding system based on that to help owners to maintain the health and life quality of the fish.

1. INTRODUCTION

For some people keeping a pet can be part of relaxation after having busy daily activities, or as a means to accompany a person when during loneliness, for example of the pet is fish. According to Applebaum et al. [1], state that pets were considered as an attractive alternative to fulfill social needs, especially after the COVID-19 pandemic. New pet owners may have underestimated the tasks that required to take care for a pet, or could have unrealistic expectations for the health and well-being benefits [1]. For some people to do all of the tasks need so much effort, because people don't have enough time to do all of the tasks (too busy), or people are lazy, and there are more factors that make people don't or hard to maintain it. In addition, there is a problem that originates from the fish itself, when fish experience stressed their appetite decreases, and when the owner give the food, the fish will not eat it, and cause the water to become dirty more quickly. Thus, this study aims to developed an automatic fish feeding system based on the stress level of the fish via fish's movements and the turbidity of the water as main parameters to activate the system. This study addresses three key challenges, which are how to formulate the stress level of the fish? how to implement it on the embedded system? also how to design the automated fish feeding system? Scopes focuses solely on monitoring fish behavioral (stress) via sensor measurements, excluding multi-fish scaling, real-time dashboards, sleep-stress difference, and water wave interference.

2. LITERATURE STUDY

According to Sung et al.; Afzaal and Burhan Ul Haq [2, 3] state that Internet of Things (IoT) can help on real-time monitoring, and can help on automate control system or equipment of the aquarium. So, the owner of the fishes can relax if they can't keep the fishes when busy, because the system can automate to give the fish food, or change the temperature, or change the water, and else. According to Hardyanto et al. [4] described that a fish owner need a smart aquarium system that can accommodate completely automated, so the study focused on the fish needed especially on light brightness and fish feed , include other thing such as water content measurement. Based on Rewatkar et al. [5] described that it is difficult to check the conditions of an aquarium manually, so the study focused on making a system which monitor and control all of the aquarium using electronics and can transmitting real time status to user (owner) smartphone. From those articles, smart aquarium is a system that can help on fish owners to keep and maintain the fish to live when the owners can't do it manually, because all of the operations that need to do already being perform completely automated.

In this smart aquarium, the main parameter that being used to build automated fish feeding is the stress level of fish. According Parra et al. [6] if fishes are stress their feeding consumption will be falls and the performance decrease. According Stachowiak and Hemmerling [7] state that fish and other aquatic animals are sensitive towards even small substances, such as ammonium compounds, and because of that it is important to regularly change the water in aquarium. It can be said that if the fishes stress they will not eat their food (their feeding consumption falls), and it will only become something that makes the water dirty faster, due to that if the automated fish feeding only use time based it is not accurately can help maintain the fish life. According to According to Chowdhury and Saikia [8] changes in temperature, oxygen, and salinity can cause the fish become stress, irons that contain in the water can cause the fish become stress. It can say that sudden changes of environment can make the fish become stress, like sudden change of the environment of living, sudden change of weather or temperature, and more. When fish experience stress, their movements will decrease until not moving at all for some time, or increasing rapidly in one time (unnatural movement), and their appetite decreased too. According to Sung et al. and Angani et al. and Ratnasari et al. [2], [9], [10] state that there are some sensors that can help to monitoring the fish life in the aquarium, such as water temperature, water level, water quality , pH level, Dissolved Oxygen (DO), light intensity, and more. This project will used some data from the sensors, such as water temperature, water turbidity level, and light intensity to monitoring and help maintain the fish environment, so the fish can live for a long time. JSN-SR04T sensor will be used to help monitor the stress level of the fish The sensor will be monitored the fish for 24 hours, and the data will be collected real time.

3. RESEARCH METHODOLOGY

For this project there will be 4 sensors that will be used. The sensors that used are water temperature sensor, turbidity sensor, light sensor, and JSN-SR04T sensor. Water temperature sensor (DS18B20) used to measure the water temperature level, because fish require a suitable water temperature to survive. Turbidity sensor (KS0414 Keyestudio Turbidity Sensor V1.0) used to measure the level of the turbidity inside the water, because the turbidity level inside the water affects the life quality of the fish, and the data will also be used as a main parameter of the automatic fish feeding. Other sensors that used in this project is Light sensor (Light-Dependent Resistor/ LDR) used to measure the brightness level from the sunlight, because brightness can affect the life quality of the fish. The JSN-SR04T sensor is a sensor that measure distance using ultrasonic based (sound waves), and from the distance it can show the position of the fish, if the distance that obtained by the sensor is different from the usual score, it can say that the fish is moving and pass the sensor.

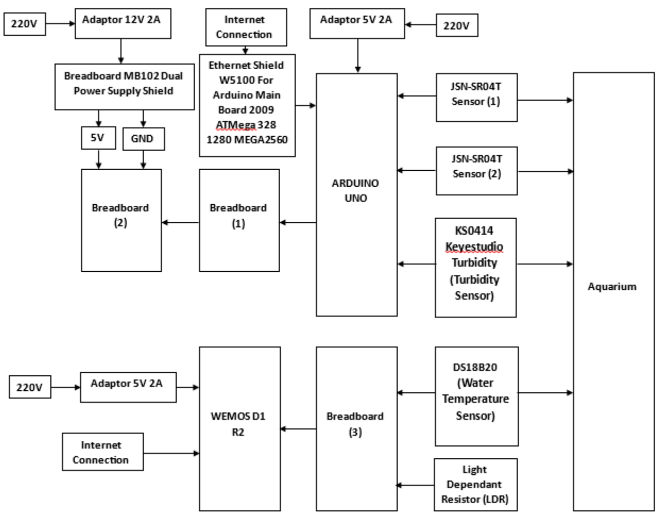


Figure 3. 1 System Block Diagram (IoT) in an Aquarium

JSN-SR04T sensor used to indicate the fish's stress level, by monitor the fish movement. If the fish movement is unusual, like faster movement or not moving at all for some time, it can be said that the fish is stress. If the sensor obtained a same score, but different from the usual score for some time, it can say that the fish is not moving at all, but it's stop right in the front of the sensor. From the movement that obtained, it became the main parameter if the automatic fish feeding will give the food or not, if the fish stress, the automatic fish feeding will not give the food vice versa. This project will used ARDUINO UNO and WEMOS D1 R2 as the microcontroller, and the amount that will be used are 2 microcontrollers (1 for each of the different microcontroller). The automatic fish feeding system will be made from cardboard as the food tank, and servo motor will be used as the automatic open-closed the automatic fish feeding. For the fish itself, this project will use *Osphronemus Goramy* fish or known as Gourami Fish.

$$SMA = \frac{A1 + A2 + .. + An}{n} \quad (1)$$

Simple Moving Average is one of several type of Moving Average Method. This method will be used to determine the usual or normal movement of the fish each day. This method calculates by finding trends from determine time period, where A is the number of the fish movements each day, and n is the number of the determine time period. The value of the SMA (average) will be determined from the formula, for example if the time period is 12 hours, the data that will be used is from Hour 1 – Hour 12 (A1 + .. + A12) and divided by the time period which is 12, subsequently to view the trend for the next hour, the calculation became An+1. Another formula that will be used on this study is Standard Deviation that used to determined when the fish is under stress condition. In this project case, it will determine when the fish's movements can be called or identified as fish is under stress condition.

$$\sigma = \sqrt{\frac{\sum(x_i - \mu)^2}{N}} \tag{2}$$

$$r = \frac{m \sum(xy) - (\sum x)(\sum y)}{\sqrt{[m \sum x^2 - (\sum x)^2]\,[m \sum y^2 - (\sum y)^2]}} \tag{3}$$

$$z = \frac{(x - \mu)}{\sigma} \tag{4}$$

Pearson Correlation Coefficient will be used to determine the correlation between variables in the system, such as Fish's movements and turbidity, Fish's movements and water temperature, Fish's movements and light intensity. From this correlation, it can determine whether those 3 variables can influence the fish's movements. Z-Score formula will be used to crosschecking the data in the population (identify outliers) that was checked using the standard deviation formula above. After the Z-score values has been cross-checked with the data in the population, then it can be seen which data are outliers or anomalies from the data population.

4. IMPLEMENTATION AND RESULTS

4.1 Implementation

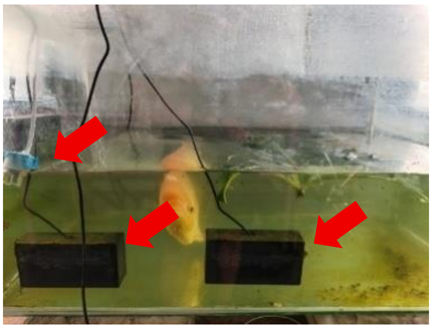
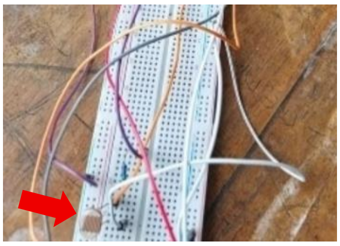


Figure 4. 1 JSN-SR04T Sensors Inside Project Box & Turbidity installation on aquarium

The amount of JSN-SR04T that was used is 2 units, and both units are mounted in the aquarium using project boxes and sealant glue, and this sensor is connect to Arduino Uno. The value from this sensor will be used as one of the parameters to open/ closing the automatic fish feeding system. The amount of the turbidity sensor that used in this project is 1 unit, which the module was glued to a project box and mounted in the aquarium, and this sensor is connect to Arduino Uno. This sensor also used to check if the water turbidity inside the aquarium will affect the fish or not, and also the value from this sensor will be used as one of the parameters to open/ closing the automatic fish feeding system.

(a) Water Temperature



(b) Light Dependent Resistor (LDR)

Figure 4. 2 Support Sensors

The amount of the water temperature sensor that was used is 1 unit, and this sensor is connect to Wemos D1 R2 microcontroller. This sensor also used to check if the water temperature inside the aquarium will affect the fish or not. In this project, the amount of LDR sensor that was used is 1 unit, and this sensor is connect to Wemos D1 R2 microcontroller. This sensor also used to check if the brightness of the light around the aquarium will affect the fish or not.

Figure 4. 3 Automatic Fish Feeding Using Servo Motor

Servo Motor in this project used to open – close the fish's food box, so the system and all of the data that used as the parameter, was used to control this servo motor. The system that checks the parameters to open/ closing the servo motor will run every 12 hours. Therefore, this section that called automatic fish feeding system.

4.2 Results

After the trial period that was conducted for 4 days, the amount of data that was collected from every 5 minutes is around 993 rows of data about amount of fish's movements, turbidity, water temperature, and light intensity. The average value of the fish's movements is around 74,62 times, with the median value of the data is 70 times. There are several lines of data that the sensor collected with a value of 0 because there may be a problem with the sensor (damaged/ broken cables), or the aquarium is undergoing unavoidable maintenance, which interferes with the sensor's performance. As results there are 66 lines of data from the amount of fish's movements and turbidity that have a value of 0, and 73 lines of data from the water temperature and light intensity.

From the tables below, based on the data that was collected using JSN-SR04T sensors and Simple Moving Average method for 4 days, the average values of the fish's movements in 12 hours are about 42 times – 106 times. For the average fish's movements every 12 hours is 76,03 times or if the value is rounded, the result of the average fish's movement in a day is 76 times. The minimum of the fish's movement in a day is 42 times, and the maximum is 106 times. To determine how much movements from the fish to categorized as stress, this study used standard deviation formula that compared the data from several time periods and obtained the following results:

Table 4. 1 12 Hours Intervals Results

Date	Times	Fish's Movements	Turbidity	Water Temperature	Light Intensity	Status	Z-Score
23/12/2025	00:00-11:59	42,84848485	37,22106061	22,31015152	431,8636364	Tidak Normal	-1,374097055
23/12/2025	12:00-23:59	52,54929577	34,86866197	25,20225352	485,2887324	Normal	-0,972391075
24/12/2025	00:00-11:59	55,32638889	25,52722222	24,416875	566,1944444	Normal	-0,857392966
24/12/2025	12:00-23:59	78,04225352	45,02929577	25,80577465	515,8873239	Normal	0,083260216
25/12/2025	00:00-11:59	69,99300699	14,35972028	21,2334965	413,4405594	Normal	-0,250055265
25/12/2025	12:00-23:59	113,9225352	34,49422535	24,86711268	490,5633803	Tidak Normal	1,569045665
26/12/2025	00:00-11:59	106,7708333	20,4075	25,32173611	569,1180556	Tidak Normal	1,272897082
26/12/2025	12:00-23:59	88,8	17,6	21,276	819,2	Normal	0,528733396

Table 4. 2 Standard Deviation Results

Fish’s Movements Mean	76,03159982
Fish’s Movements Median	74,01763026
Max Normal Fish’s Movements	100,1806327
Min Normal Fish’s Movements	51,88256692
Fish’s Movements Standard Deviation	24,1490329

From this data, the value that used as a parameter to considered the fish is in the normal condition (not in the stress condition) is 24,15 (from the figure of Standard Deviation Every 12 Hours). If the new value of the fish movement’s that was collected has a gap around 24,15 values with the previous fish movement’s value it can be considered that the fish is in the state of stressed out. From the figure above, the Z-Score that was shown is around -1,37 until 1,57, and for the status/ interpretation of the Z-Score that was used is around -1 until 1 (or it can be say as 68% of the data population) to identify as normal, that’s why if the Z-Score value is under -1,00 and above 1,00 are identify as abnormal movements. From the data, it shown that if the fish’s movements are under 51,88 and above 100,18, it can be said if the fish is stressed, and it is these values that serve as the benchmark for determining abnormal movements.

From the data that collected every 5 minutes, and using the results of the Standard Deviation, it shown that there are 500 lines data that shows the fish is not under stress (normal movements), and 493 lines data that shows the fish is under stress (abnormal movements). The reason to choose the value from the standard deviation every 12 hours because the system will activate its automatic system every 12 hours in sequence with the Simple Moving Average algorithm that calculate the data every 12 period of times. Furthermore, the data obtained at 12 hours intervals was selected because it had more data variation and produced more reliable results (not too small or too large). In addition, if the fish are not fed for 30 days, it caused health problems, that’s why in this study, even though the fish is stressed, the system continued feed the fish within a maximum limit of 15 days without feeding, which assuming that the fish were still in good condition.

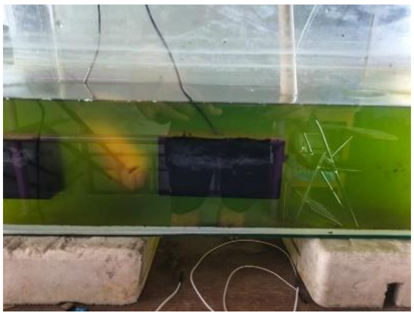


Figure 4. 4 Water Turbidity Condition

During the testing, it was found that the value of 62 is indicates a very turbid water where the fish can hardly see clearly. When it times to give the foods, the fish can’t even see clearly where is the foods. That’s the reason, the value of 62, was used as the other parameter besides the fish’s movements to activated the automatic feeding system.

Table 4. 3 Pearson Correlation Coefficient Results

Time Periods	***r* towards Fish's Movements**		
	Turbidity	**Water Temperature**	**Ligh Intensity**
Every 1 Hours	0,38	0,02	0,33
Every 2 Hours	0,46	0,05	0,36
Every 4 Hours	0,068	0,055	0,043
Every 6 Hours	0,07	0,41	0,14
Every 12 Hours	-0,21	0,23	0,33
For 4 Days	-0,97	0,16	0,47

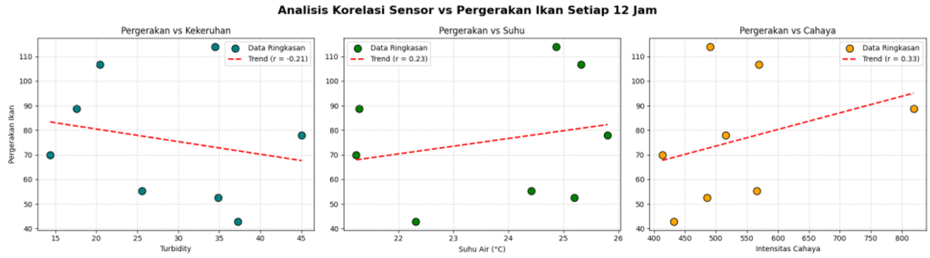


Figure 4. 5 Normal Condition Pearson Correlation Coefficient Every 12 Hours Results

From this data, there are 3 correlation test that was calculated, which are Correlation between fish's movements & turbidity, fish's movements & water temperature, and fish's movements & light intensity. In this study, the Pearson Correlation Coefficient result that was used is the correlation at 12 hours intervals because the system will activate its automatic system every 12 hours in sequence with the Simple Moving Average algorithm that calculate the data every 12 period of times, and the data obtained at 12 hours intervals was selected because it had more data variation and produced more reliable results (not too small or too large). The results from the 12 hours correlations are -0,21 (fish's movements & turbidity), +0,23 (fish's movements & water temperature), and +0,33 (fish's movements & light intensity). The meaning of -0,21 is weak negative correlation which is when the water becomes more turbid, the less or even there are no movements from the fish. The meaning + 0,23 is weak positive correlation which is when the water becomes warmer, the fish will become more active. The meaning +0,33 is moderate strong correlation which is when the light around the aquarium becomes brighter, the fish will become more active.

Figure 4. 6 Abnormal Condition Pearson Correlation Coefficient Every 12 Hours Results

To determine whether the turbidity of the water, the temperature, and the light intensity are the factors that cause stress on the fish, and in this study, those parameters were calculated the correlation from the abnormal condition from the 12 Hours results data. The result is -0,55 (fish's movements & turbidity) which is strong negative correlation, +0,97 (fish's movements & water temperature) which is strong positive correlation, and +0,77 (fish's movements & light intensity) which is strong positive correlation. The meaning of these results is that the fish will become more active when the water temperature is warmer and the light intensity is bright, which is inverse to the results for turbidity, where the fish will become inactive as the water becomes more turbid. Based on all of the results above, it was found that the fish will become more inactive when the water becomes more turbid, because there is some dirt around the fish gills that making it difficult to breath that force the fish to conserve oxygen, and the reduced visibility on the water makes the fish feel threatened, causing it becomes stressed. If the water temperature is colder, it causes the decreased of the fish's metabolism, and make the fish lethargic, causing a decrease in appetite and weakened immune system. If the light intensity is darker, can cause the fish become stress because due to the inability to find foods and detect the environment (feeling the insecurity).

4.3 Obstacles

a. Sensors damaged, defective, or can't be used

Throughout the duration of this project, there are some sensors that damaged during the first testing or in the implementation in the aquarium, due to incorrect installation, or damage caused by water splashing from the fish, for the example that damaged because of the water is the turbidity sensor. Some sensors are defective from the beginning, and some can't be used in this project because it cannot do the expectation tasks.

b. Internet connection

During the implementation period, the Arduino Uno microcontroller, can't get any internet connection, even though already tried some methods, such as sending the data to Wemos D1 R2 microcontroller first and then send the data to the web-server platform, or using a signal catcher, the result is still nil (data can't be send to the platform).

4.4 Solutions

a. Change other sensors or buy a new one

The solution to the problem of the damaged, defective, or unused sensors is to change the type of the sensor or buy new sensor units. Even it takes some times to wait the sensors delivered, but it is better than rather erase some sensors in this project.

b. Using Ethernet cable

The solution to the problem of internet connection that can't connected to Arduino Uno microcontroller is used ethernet cable that has a stable connection rather than use wireless connection.

4.5 Discussion

4.5.1 Implementation Time

This project has been running for about 2-3 months, and during the implementation period, there are some tasks that need to be done. The first task is to gather all the necessary supplies, not just the sensors, but the aquarium and other support items too. After all of the necessities have been prepared, the next task is to find the right location for the aquarium so that it is easily accessible. The next task that must to be done before implement the system in the aquarium is the sensors need to be check or tested first, because there is a possibility that the sensors is damaged or defective. After that, all of the sensors and other support items must be assembled first, then attached to the aquarium, and finally tidied up the rest. After all sensors attached in the aquarium, the next step is to testing the system again to find if there any problems in the field or not. If the system can run smoothly without any problem, next the system must be connected to an internet connection so it can transfer the data that were collected from the sensors to a web-server platform. Finally, the last thing to do is to monitor the system and its sensors to ensure they continue to function normally.

4.5.2 Result Analysis

The results that described in the Chapter 4 above may have occurred due to some factors. For examples the fish's movements affected by the fish itself and water wave. If the fish doesn't want to move, or when the water wave is big, it can affect the sensor reading because the sensor will read if there a movement from the fish when the current range that obtained from the sensor is different with the previous range data. For the turbidity sensor, the result can be affected by moss and fish's waste, because these two factors can cause the water become more turbid. The temperature of the water is affected by the temperature of the room (surrounding) temperature and sunlight. If the room temperature is high then the water temperature can slightly become higher than the usual, and vice versa, and if the water inside the aquarium is exposed to direct sunlight can make the temperature slightly become higher. Light intensity is affected by the light that surround the aquarium, regardless of whether it is sunlight or light from the lamps. From the results of abnormal correlation coefficient it was found that in some condition, the fish will become stressed (the movements are high) when the turbidity is high because the fish is uncomfortable with particles/ dirt that touched the bodies/ gills, causing them to panic and move excessively in search of clear water condition, and also the higher movements indicate that the fish are cleaning debris from the gills. This project has several limitations such as the amount of the object that was used (the fish) is 1, the system does not use any machine learning model, and the system can't find the difference whether the fish is sleeping or stressed out.

CONCLUSIONS

This research was designed to understanding fish's behavior which is stress especially on a gourami fish, and utilizing this knowledge to create an automatic fish feeding system. This system used some sensors to collected the data that support the system, and for the main sensor, this project used JSN-SR04T sensor. Based on the results of implementation in the field, several conclusions were obtained, such as This research used Standard Deviation and Z-Score formula to determine and formulate the stress level of the fish. To implement stress level of the fish into the Embedded System, this research used standard deviation that identified when the fish is stressed, as one of the parameters to open-closed the servo motor. To design the system, this project used some microcontrollers, sensors, and internet connection which are discussed in Chapter 4. There are several recommendations that can be made by anyone who wishes to use this research as their own study, which are as follows The system can be integrated with a Machine Learning model for using a camera to monitor the fish, The study can be improved not only using 1 specific fish as the research object, The system can be improved by making an interface that show the system and fish condition status by real rime, and Future research focus can be changed not by how to implement fish's stress level to automatic fish feeding system, but how to tell the difference between fish that is stressed out or fish that is sleeping, or how water waves affect sensor readings on JSN-SR04T.

ACKNOWLEDGMENT

First and foremost, I would like to express my deepest gratitude to God Almighty for His blessings, guidance, and strength throughout the completion of this thesis. Without His grace, none of this can be done.

I would like to thank you towards my parents and all of my family members for their unconditional loves, prayers, and constant supports. Your encouragement has been my motivation to move forward during difficult times.

My heartfelt thanks go to my supervisor and lecturers at Faculty of Computer Science, Soegijapranata Catholic University throughout formulating topic, and writing this document, because your guidance through mentorship has helped me grow both academically and personality.

Lastly, I would like to thank my friends, fellow students, and everyone that has contributed directly and indirectly to the completion of this thesis because everyone supports through discussions, encouragements, and shared laughter was made this journey that has been part of my university experience more enjoyable.

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NOMENCLATURE

Latin symbols

A	Average in period
n	Number of time periods
N	Size of the population
r	Pearson Correlation Coefficient
m	Amount of data
x	Raw data value of variable x
x_i	Each value from the population
z	Z-Score

Greek symbols

μ	Population average (mean)
σ	Standard Deviation

Operators/ Mathematical Notation

$\sum x$	Sum of all x values
$\sum y$	Sum of all y values
$\sum x^2$	Sum of each x value squared
$\sum y^2$	Sum of each y value squared