Cold Storage Temperature Monitoring with Trilinear Interpolation

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Abstract: The Internet of Things (IoT) is widely applied in agriculture and industry. This article proposes a 3-dimensional temperature monitoring model for cold storage, enhancing the ability to observe and detect abnormal temperature changes within the storage. Using real-time temperature acquisition and applying trilinear interpolation techniques, this model determines temperatures at all locations in the storage. It accepts temperature values and sensor locations, appropriately segmenting the cold storage space to apply trilinear interpolation and determine the temperature value at every location in the storage. The model was tested based on different number of sensors and different sensor locations. Based on that, we provide an optimal solution for the number of sensors needed for cold storage.

Keywords: *Iot, cold storage, temperature, trilinear interpolation, monitor.*

Tiêu đề: **Giám sát nhiệt độ kho lạnh bằng phương pháp nội suy ba chiều**

Tóm tắt: Internet vạn vật (IoT) được ứng dụng rộng rãi trong nông nghiệp và công nghiệp. Bài báo này đề xuất một mô hình giám sát nhiệt độ ba chiều cho kho lạnh, tăng cường khả năng quan sát và phát hiện những thay đổi nhiệt độ bất thường trong kho. Sử dụng việc thu thập nhiệt độ theo thời gian thực và áp dụng các kỹ thuật nội suy tam tuyến, mô hình này xác định nhiệt độ tại tất cả các vị trí trong kho. Nó chấp nhận các giá trị nhiệt độ và vị trí cảm biến, phân đoạn không gian kho lạnh một cách thích hợp để áp dụng nội suy ba tuyến tính và xác định giá trị nhiệt độ tại mọi vị trí trong kho. Mô hình đã được thử nghiệm dựa trên số lượng cảm biến khác nhau và các vị trí cảm biến khác nhau. Dựa trên đó, chúng tôi cung cấp một giải pháp tối ưu cho số lượng cảm biến cần thiết cho kho lạnh.

Từ khóa: *Iot, cold storage, temperature, trilinear interpolation, monitor.*

I. INTRODUCTION

IoT applications are widely applied in agriculture and industry [1]. This article focuses on improving IoT usage in cold storage temperature management. Specifically, using temperature sensors in cold storage allows managers to monitor real-time temperature changes, providing timely solutions to ensure product quality is maintained optimally.

However, applying temperature sensors in cold storage has limitations. These include managing the number of sensors, sensor installation locations, and accuracy when analyzing data. One significant challenge is determining the optimal number of sensors to ensure effective monitoring while minimizing costs. Sensor installation locations significantly impact monitoring efficacy, and the accuracy of temperature data is a concern when sensors cannot cover all required locations.

To address these issues, we propose a model that calculates all temperature values within the cold storage and displays a 3-dimensional (3D) simulation of these values on a web platform, called Cold Storage Temperature Simulation with Trilinear Interpolation. The goal is to support visual monitoring and plan appropriate sensor installations for maximum efficiency and cost savings. The model calculates temperature values at all locations within the cold storage using trilinear interpolation, even in areas without sensors. It relies on three factors: storage size for sensor location estimation, sensor placement for determining storage division before temperature calculation, and real-time temperature values from sensors installed within the storage.

The content of this paper is arranged into six main parts. The first section is the introduction, which provides a general presentation of the contents of the study. The second section is the related work that presents previous studies in the same field. The third section is the proposed model that provides a detailed description of the research problem-solving method. The fourth section is the experiment that provides detailed test scenarios based on the proposed model. The fifth section is the conclusion, which summarizes the problems the study has solved and future development directions. The final section is the references that provide annotate the documents used for reference in the study.

II. RELATED WORK

1. Trilinear Interpolation

Trilinear interpolation is a 3D extension of linear and bilinear interpolation. It estimates values within a cube by performing linear interpolation along each axis based on the values at the cube's eight corners.

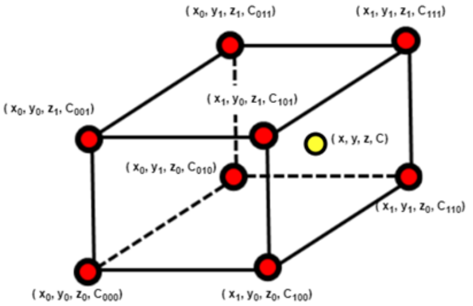

Figure 1. The 3-dimensional space used for interpolation

The Trilinear interpolation function gives results at any point (x, y, z) according to formula (1):

$$5\,{}^{1}G\text{-}\,H\text{-}\,I^{o} = O_0 \text{ ¸ } O_1G \text{ ¸ } O_2H \text{ ¸ } O_3I \text{ ¸ } O_4GH \text{ ¸ } O_5GI \text{ ¸ } O_6HI \text{ ¸ } O_7GHI \qquad (1)$$

The values at the vertices are usually known, so we need to compute the coefficients $\{O_0, O_1, O_2, ..., O_7\}$. These coefficients are then used in the interpolation function's linear equation.

$$\begin{bmatrix} 1 & G_0 & H_0 & I_0 & G_0H_0 & G_0I_0 & H_0I_0 & G_0H_0I_0 \\ 1 & G_1 & H_0 & I_0 & G_1H_0 & G_1I_0 & H_1I_0 & G_1H_0I_0 \\ 1 & G_0 & H_1 & I_0 & G_0H_1 & G_0I_1 & H_0I_1 & G_0H_1I_0 \\ 1 & G_1 & H_1 & I_0 & G_1H_1 & G_1I_1 & H_1I_1 & G_1H_1I_0 \\ 1 & G_0 & H_0 & I_1 & G_0H_0 & G_0I_0 & H_0I_0 & G_0H_0I_1 \\ 1 & G_1 & H_0 & I_1 & G_1H_0 & G_1I_0 & H_1I_0 & G_1H_0I_1 \\ 1 & G_0 & H_1 & I_1 & G_0H_1 & G_0I_1 & H_0I_1 & G_0H_1I_1 \\ 1 & G_1 & H_1 & I_1 & G_1H_1 & G_1I_1 & H_1I_1 & G_1H_1I_1 \end{bmatrix} \begin{bmatrix} O_0 \\ O_1 \\ O_2 \\ O_3 \\ O_4 \\ O_5 \\ O_6 \\ O_7 \end{bmatrix} = \begin{bmatrix} 2_{000} \\ 2_{100} \\ 2_{010} \\ 2_{110} \\ 2_{001} \\ 2_{101} \\ 2_{011} \\ 2_{111} \end{bmatrix} \qquad (2)$$

Solving equation (2) we get the correlation coefficients {a₁, a₂, . . . , a₇} as in formula (3):

$$O_0 = \frac{2_{000}G_1H_1I_1 \text{ ¸ } 2_{001}G_1H_1I_0 \text{ ¸ } 2_{010}G_1H_0I_1 \quad 2_{011}G_1H_0I_0}{{}^{1}G_0 \quad G_1{}^{o1}H_0 \quad H_1{}^{o1}I_0 \quad I_1{}^{o}} \text{ ¸ } \frac{2_{100}G_0H_1I_1 \quad 2_{101}G_0H_1I_0 \quad 2_{110}G_0H_0I_1 \text{ ¸ } 2_{111}G_0H_0I_0}{{}^{1}G_0 \quad G_1{}^{o1}H_0 \quad H_1{}^{o1}I_0 \quad I_1{}^{o}}$$

$$O_1 = \frac{2_{000}H_1I_1 \quad 2_{001}H_1I_0 \quad 2_{010}H_0I_1 \text{ ¸ } 2_{011}H_0I_0}{{}^{1}G_0 \quad G_1{}^{o1}H_0 \quad H_1{}^{o1}I_0 \quad I_1{}^{o}} \; \frac{2_{100}H_1I_1 \text{ ¸ } 2_{101}H_1I_0 \text{ ¸ } 2_{110}H_0I_1 \quad 2_{111}H_0I_0}{{}^{1}G_0 \quad G_1{}^{o1}H_0 \quad H_1{}^{o1}I_0 \quad I_1{}^{o}}$$

$$O_2 = \frac{2_{000}G_1I_1 \quad 2_{001}G_1I_0 \quad 2_{010}G_1I_1 \text{ ¸ } 2_{011}G_1I_0}{{}^{1}G_0 \quad G_1{}^{o1}H_0 \quad H_1{}^{o1}I_0 \quad I_1{}^{o}} \text{ ¸ } \frac{2_{100}G_0I_1 \text{ ¸ } 2_{101}G_0I_0 \text{ ¸ } 2_{110}G_0I_1 \quad 2_{111}G_0I_0}{{}^{1}G_0 \quad G_1{}^{o1}H_0 \quad H_1{}^{o1}I_0 \quad I_1{}^{o}}$$

$$O_3 = \frac{2_{000}G_1H_1 \quad 2_{001}G_1H_1 \quad 2_{010}G_1H_0 \text{ ¸ } 2_{011}G_1H_0}{{}^{1}G_0 \quad G_1{}^{o1}H_0 \quad H_1{}^{o1}I_0 \quad I_1{}^{o}} \text{ ¸ } \frac{2_{100}G_0H_1 \text{ ¸ } 2_{101}G_0H_1 \text{ ¸ } 2_{110}G_0H_0 \quad 2_{111}G_0I_0}{{}^{1}G_0 \quad G_1{}^{o1}H_0 \quad H_1{}^{o1}I_0 \quad I_1{}^{o}} \qquad (3)$$

$$O_4 = \frac{2_{000}I_1 \text{ ¸ } 2_{001}I_0 \text{ ¸ } 2_{010}I_1 \quad 2_{011}I_1}{{}^{1}G_0 \quad G_1{}^{o1}H_0 \quad H_1{}^{o1}I_0 \quad I_1{}^{o}} \text{ ¸ } \frac{2_{100}I_1 \quad 2_{101}I_0 \quad 2_{110}I_1 \text{ ¸ } 2_{111}I_0}{{}^{1}G_0 \quad G_1{}^{o1}H_0 \quad H_1{}^{o1}I_0 \quad I_1{}^{o}}$$

$$O_5 = \frac{2_{000}H_1 \text{ ¸ } 2_{001}H_1 \text{ ¸ } 2_{010}H_0 \quad 2_{011}H_0}{{}^{1}G_0 \quad G_1{}^{o1}H_0 \quad H_1{}^{o1}I_0 \quad I_1{}^{o}} \text{ ¸ } \frac{2_{100}H_1 \quad 2_{101}H_1 \quad 2_{110}H_0 \text{ ¸ } 2_{111}H_0}{{}^{1}G_0 \quad G_1{}^{o1}H_0 \quad H_1{}^{o1}I_0 \quad I_1{}^{o}}$$

$$O_6 = \frac{2_{000}G_1 \text{ ¸ } 2_{001}G_1 \text{ ¸ } 2_{010}H_1 \quad 2_{011}G_1}{{}^{1}G_0 \quad G_1{}^{o1}H_0 \quad H_1{}^{o1}I_0 \quad I_1{}^{o}} \text{ ¸ } \frac{2_{100}G_0 \quad 2_{101}G_0 \quad 2_{110}G_0 \text{ ¸ } 2_{111}G_0}{{}^{1}G_0 \quad G_1{}^{o1}H_0 \quad H_1{}^{o1}I_0 \quad I_1{}^{o}}$$

$$O_7 = \frac{2_{000} \quad 2_{001} \quad 2_{010} \text{ ¸ } 2_{011} \quad 2_{100} \text{ ¸ } 2_{101} \text{ ¸ } 2_{110} \quad 2_{111}}{{}^{1}G_0 \quad G_1{}^{o1}H_0 \quad H_1{}^{o1}I_0 \quad I_1{}^{o}}$$

In short, applying formulas (1), (2), (3), we can calculate the entire set of coefficients {a₁, a₂, . . . , a₇} as shown above to determine any value inside the space of the given rectangular box.

2. IoT-Based Cold Storage Monitoring and Controlling Systems

Patel et al. [2] introduced a comprehensive Smart Cold Storage and Inventory Monitoring System that leverages IoT technology to significantly improve the efficiency and reliability of cold storage management. Their system integrates real-time monitoring capabilities with early warning alerts, providing complete end-to-end visibility throughout the entire product value chain. This integration allows for precise control of temperature and inventory levels, which is crucial for maintaining the quality and safety of stored goods. However, the system's high complexity and substantial implementation costs may present barriers, particularly for smaller operations with limited budgets. Furthermore, the system's dependence on continuous internet connectivity could be a critical vulnerability in regions experiencing unstable network access, potentially impacting the reliability of the monitoring and control functions.

In contrast, Chen et al. [3] focused on developing an IoT-Based Low-Cost Cold Storage Atmosphere Monitoring and Controlling System, aiming to offer a more affordable solution while still providing essential monitoring and control functions. Their system utilizes a combination of temperature and humidity sensors, a microcontroller, and a mobile application to deliver real-time updates and allow for manual adjustments in cold storage environments. This approach is designed to be cost-effective, making it accessible for facilities with budget constraints, and helps in maintaining optimal storage conditions for perishable goods. However, this low-cost model may impact the system's overall durability and accuracy, as the sensors used may not be as robust or precise over time compared to more expensive alternatives. Additionally, the system's limited scalability could pose challenges for larger storage facilities that require more extensive monitoring capabilities.

III. PROPOSED MODEL

This section proposes the "Cold Storage Temperature Monitoring with Trilinear Interpolation" model (CSTM) for calculating and monitoring temperature parameters in cold storage using storage size, sensor locations, and real-time sensor temperature data. To compare with the research [2], our proposed model uses interpolation to determine temperatures at locations without sensors, thereby reducing the number of sensors needed and lowering costs, while still providing necessary warnings. In addition, our research improves upon the research [3] by demonstrating efficient sensor placement, optimizing the number of sensors needed, and ensuring cost savings without compromising accuracy.

1. CSTM Overview

In this study, we conduct two main stages:

Firstly, based on sensor numbers, we divide the cold storage space, ensuring compliance with trilinear interpolation techniques and using all sensor values inside the storage. This stage outputs divided spaces within the storage.

Secondly, once the storage space is divided, we perform trilinear interpolation to calculate temperature values at virtual sensors, using real and virtual sensor values to interpolate temperatures within all divided spaces. Finally, we aggregate these values to form a comprehensive temperature picture of the entire storage.

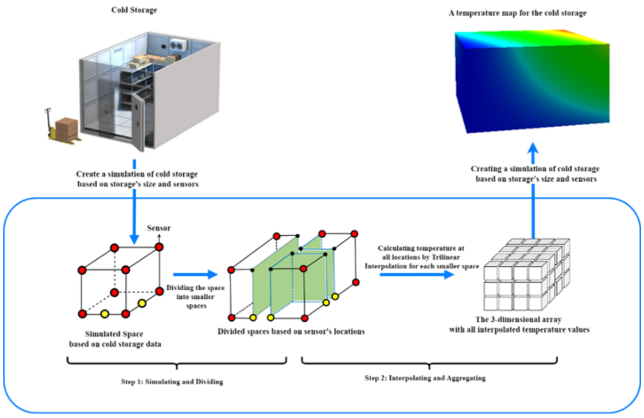

Figure 2. Overview of CSTM

Finally, we change the location and number of sensors to create different experiments. From there, the difference can be evaluated, and improvement methods can be drawn to help optimize the use of sensors.

2. Simulating and Dividing

In this phase, we determine the number of sensors in the cold storage, which is the most critical factor in dividing the cold storage space. Fig.3 is the flowchart of the algorithm used for dividing and saving all storage spaces.

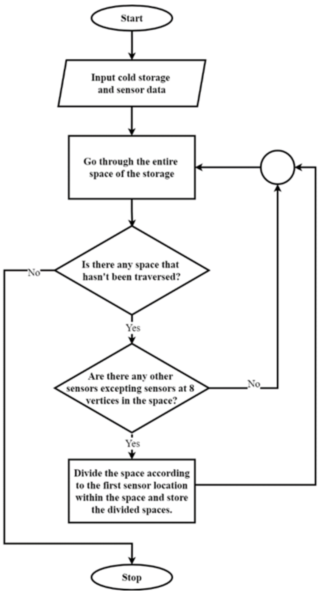

Figure 3. The algorithm divides spaces of the storage

Based on the number of sensors, we divide into 3 cases that need to be handled as follows:

Case 1: There are only eight sensors at eight corners of the cold storage, corresponding to the requirements of the trilinear interpolation technique. In this case, we propose to skip the space division step because the cold storage space already meets the technical conditions and real-time interpolation can be performed anytime the sensors update the price new treatment.

Case 2: There are nine sensors inside the cold storage, including eight sensors at the eight roots (vertices of a space or the storage) of the storage and one outside of those locations. In this case, we propose a solution reference table based on the location of that ninth sensor (x, y, z) as follows:

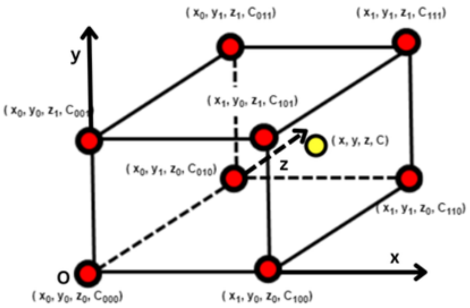

Figure 4. Eight sensors at eight vertices of the storage

Table I
DIVIDING SPACE BASED ON AN ADDED SENSOR LOCATION – THE 9TH SENSOR'S LOCATION

Situation	Ox axis	Oy axis	Oz axis	Number of separated spaces
Inside	G_0 Ÿ G Ÿ G_1	H_0 Ÿ H Ÿ H_1	I_0 Ÿ I Ÿ I_1	8
On face	$G_0 = G$ jj $G = G_1$	H_0 Ÿ H Ÿ H_1	I_0 Ÿ I Ÿ I_1	4
	G_0 Ÿ G Ÿ G_1	$H_0 = H$ jj $H = H_1$	I_0 Ÿ I Ÿ I_1	
	G_0 Ÿ G Ÿ G_1	H_0 Ÿ H Ÿ H_1	$I_0 = I$ jj $I = I_1$	
On edge	G_0 Ÿ G Ÿ G_1	$H_0 = H$ jj $H = H_1$	$I_0 = I$ jj $I = I_1$	2
	$G_0 = G$ jj $G = G_1$	H_0 Ÿ H Ÿ H_1	$I_0 = I$ jj $I = I_1$	
	$G_0 = G$ jj $G = G_1$	$H_0 = H$ jj $H = H_1$	I_0 Ÿ I Ÿ I_1	

In there:

x_0 (x_1): is the smallest (largest) x value on the Ox axis.
y_0 (x_1): is the smallest (largest) y value on the Oy axis.
z_0 (x_1): is the smallest (largest) z value on the Oz axis.

Each situation is reproduced graphically as follows:

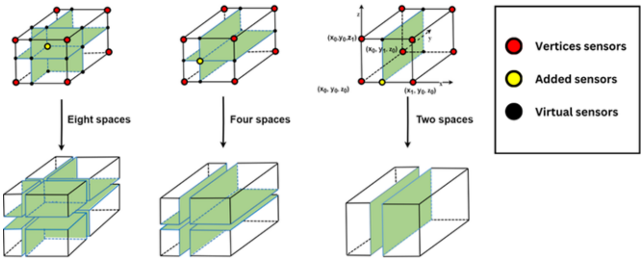

Figure 5. The results of divided spaces based on sensor locations

During the division process, roots with no sensors will be marked as virtual sensors. Their temperatures will be updated in the interpolation step using the eight original sensors of the cold storage. The virtual sensor will have the same role as the sensor at eight roots.

Case 3: More than nine sensors were added to the cold storage space. In this case, we propose that for each new sensor (other than the original eight sensors) added, the space containing that new sensor will be redistributed according to the convention of the 9-sensor case in cold storage. This makes us immediately think of recursive techniques in programming, and its stopping condition is when a space only has eight sensors left at eight roots.

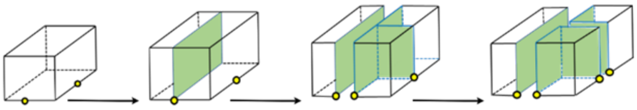

Figure 6. Dividing space process based on additional sensor locations

3. Interpolating and Aggregating

Applying the interpolation technique to the problem of calculating temperature inside cold storage, we can set some prerequisites as follows:

Cold storage's spaces must be rectangular.

Eight sensors must be installed at the corners of the storage or the space, which correlates with the available values in the example above.

From there, we can calculate all the values inside the cold storage based on a set of coefficients deduced from the temperature values of 8 sensors at eight corners. In particular, temperature values will be calculated in real-time as soon as the sensors update the values.

In addition, we also built an algorithm to support the use of trilinear interpolation in cases where there were more than eight original sensors as the Fig. 7.

This means we can add other sensors to the cold storage at any location and use them for calculations without violating the conditions of the trilinear interpolation technique.

During this phase, we execute two main jobs and these jobs are executed periodically in real time to ensure accuracy in temperature monitoring of cold storage.

First, we perform trilinear interpolation based on 8 sensors of the cold storage. From there, we determined the temperature values at the virtual sensors that were previously determined in the previous stage.

Second, based on the values at the 8 vertices of each space, it has been divided to perform the trilinear interpolation technique of all temperature values in that space. Finally, we aggregate all the divided spaces to form a temperature picture of the entire cold storage.

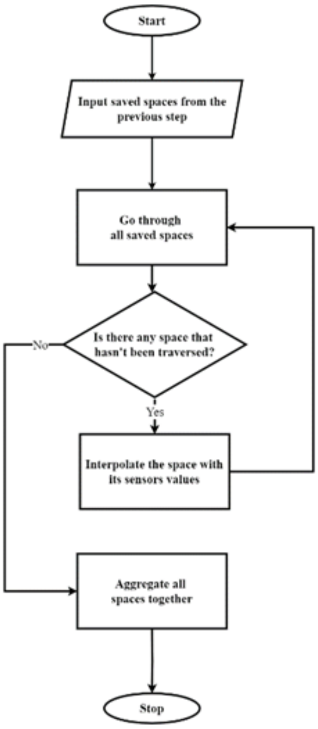

Figure 7. The algorithm interpolates and aggregates spaces of the storage

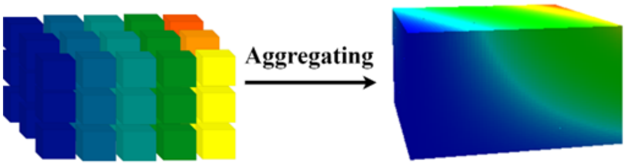

Figure 8. The aggregated space

As a result, all real-time cold storage temperature values have been completely calculated.

4. Evaluating the proposed model

Using a cold storage size (length, width, height), position (x, y, z in the Oxyz coordinate axis) and current temperature (^{o}C) at all sensors in that cold storage as the input, the proposed model gives the main result, which is an array denoted as (4):

$$) = f^{1}G\text{-}H\text{-}I\text{-}\ _{GHI}{}^{o}j0\quad G\ddot{Y}0\text{-}0\quad H\ddot{Y}1\text{-}0\quad I\ddot{Y}2g \qquad (4)$$

In there, each array will have N = a * b * c elements, where a = cold storage length + 1, b = cold storage width + 1, c = cold storage height + 1 because we consider coordinates from position 0 to the end of a certain length.

From there, we change sensor locations and the number of sensors for our experiments differently. Then, we measure their difference by the average deviation. This is necessary to help optimize the cost and the accuracy of results by finding which locations sensors can be placed and the number of sensors as an improvement method. For the 3D array result of each experiment, we call them T_i (i = 1, 2, ..., n where n is the number of experiments). To do that, we follow a series of steps below:

We calculate the absolute deviation between any two of the above those arrays according to the following formula (5):

$$_{89} = j)_{8}\quad)_{9}j = f4_{:}\text{-}:\ 2\ »1;\ \#¼g \qquad (5)$$

In there: $_{89}$ is a 3D array that stores the absolute deviation of each pair of values in the two arrays. Based on that, the absolute deviation between spaces of i and j is $_{89}$.

Then, we perform the sum of all values inside each absolute deviation array, and the result is as a following formula (6):

$$(_{89} = \sum_{:=1}^{\#}\ 4_{:}\text{-}\ 4_{:}\ 2\quad _{89} \qquad (6)$$

Next, we apply the formula (7) to calculate the average deviation for each pair of arrays:

$$_{89} = \frac{(_{89}}{\#} \qquad (7)$$

In there:

$_{89}$ is the average deviation for each pair of arrays.
$(_{89}$ is the sum of the absolute deviations of all elements in an array.
N is the total number of elements in an array (N = a * b * c).

We can evaluate the influence of the number of divided spaces based on the average difference between the resulting arrays. From there, we can find a way to set the sensor to increase or decrease the number of divided spaces to reduce that difference.

IV. EXPERIMENT

1. Install sensors

In this study, we installed a thermal sensor system based on cold storage. According to recommendation of [4] the cold storage should have 12 meters in length, 3 meters in width, and 3 meters in height with a temperature range from 12 C to 8 C as a suitable temperature to maintain frozen products. Besides, we conducted three experiments as follows:

Scenario 1: Install eight sensors at eight corners of the cold storage to capture a particular space and perform interpolation based on that space.

Scenario 2: Install the 9th sensor to check the spatial division according to the output model. Then, interpolation will be performed based on the divided spaces.
Scenario 3: Install the 10th sensor to check the spatial division according to the output model recursively.

Based on the evaluation of the average deviation between the spaces, we evaluated the above 3 scenarios and proposed an optimization direction in sensor installation.

2. Scenario 1: Install eight sensors at eight vertices

We build a sensor network consisting of 8 sensors at eight roots of the cold storage. Based on the division method, the cold storage will be divided into a single space because there are no sensors other than the eight sensors at the eight roots attached.

Below is information about the original eight sensors; the sensor values will change in real-time:

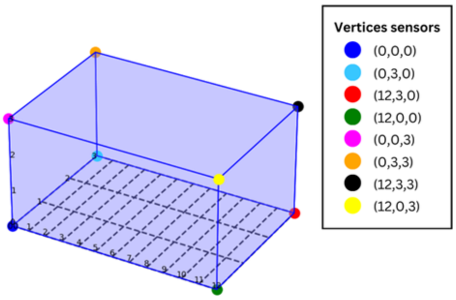

Figure 9. Sensor locations of scenario 1

Below are the resulting parameters after performing trilinear interpolation for the entire cold storage based on the number and changes in temperature values of those sensors.

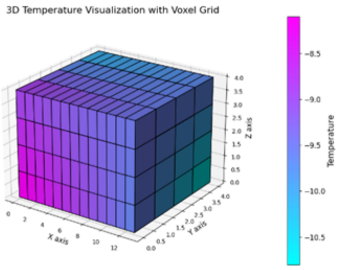

Figure 10. The result of scenario 1

3. Scenario 2: Install nine sensors

We add cold storage on a sensor at any location and check the number of divided spaces. This helps verify the model's ability to divide space according to sensor changes. In this case, we add a sensor at (8, 0, 0). Based on the number and location of sensors, our model splits the space into 2 smaller spaces including:

Table II
DIVIDED SPACES OF SCENARIO 2

Space No	x0	y0	z0	x1	y1	z1
1	0	0	0	8	3	3
2	8	0	0	12	3	3

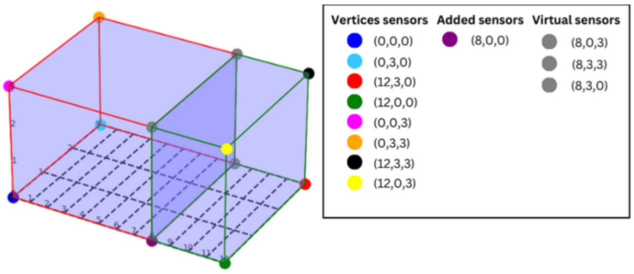

Figure 11. Divided space of scenario 2

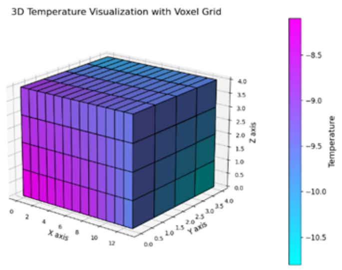

Figure 12. The result of scenario 2

4. Scenario 3: Install ten sensors

We perform additional cold storage on more than one sensor at any location. In this case, we add the 10th sensor at (2, 2, 0). Based on the number and location of sensors, our model splits the space into 5 smaller spaces including:

Table III
DIVIDED SPACES OF SCENARIO 3

Space No	x0	y0	z0	x1	y1	z1
1	0	0	0	2	2	3
2	2	0	0	8	2	3
3	0	2	0	2	3	3
4	2	2	0	8	3	3
5	8	0	0	12	3	3

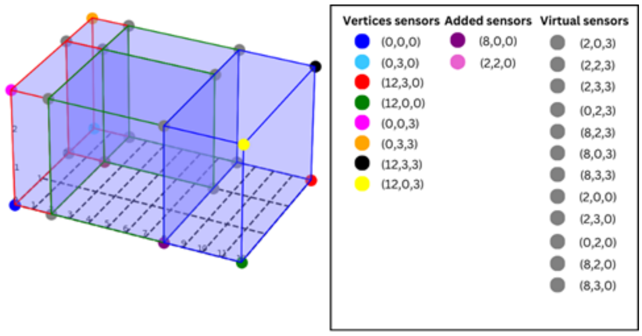

Figure 13. Divided spaces of scenario 3

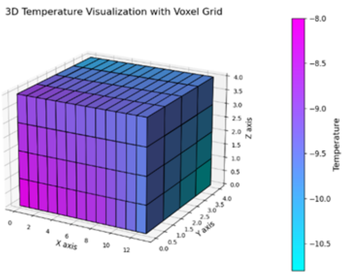

Figure 14. The result of scenario 3

5. Improvement

Based on the above experiments, we realized that the more space is divided, the more virtual sensor values are used to perform interpolation. This can lead to apparent differences between experiments. However, the temperature values at the eight original sensors of each experiment are equal.

To show the difference between experiments, we determine the average deviation of all three experiments as follows:

We call the three 3D arrays that store temperatures in the above three experiments: T1, T2, and T3. Each array has a size of 13x4x4 elements.

We calculate the absolute deviation between any two of the above three arrays. The results:

The absolute deviation between arrays 1 and 2 is $_{12}$
The absolute deviation between arrays 1 and 3 is $_{13}$
The absolute deviation between arrays 2 and 3 is $_{23}$

We perform the sum of all values inside each absolute deviation array, and the result is as follows:

The total absolute deviation between arrays 1 and 2 is $(_{12} = 33{•}60000000000005$
The total absolute deviation between arrays 1 and 3 is $(_{13} = 64{•}26666666666671$
The total absolute deviation between arrays 2 and 3 is $(_{23} = 43{•}26666666666675$

We apply the formula to calculate the average deviation for each pair of arrays (T1, T2), (T1, T3) and (T2, T3). The results:

The average deviation between arrays 1 and 2 is $_{12} = 0{•}1615384615384618$
The average deviation between arrays 1 and 3 is $_{13} = 0{•}30897435897435915$
The average deviation between arrays 2 and 3 is $_{23} = 0{•}2080128205128209$

The above results show that the average deviation reflects the difference in temperature between measurements. The higher the deviation value, the more significant the difference. In this case, the largest deviation between spaces 1 and 3 indicates a significant temperature fluctuation. The deviation between spaces 1 and 2 is the smallest, indicating that the temperature in this area is relatively stable. From there, we can see that the division of space and the use of virtual sensors partly affect the change in temperature after interpolation because the virtual temperature values will be used as a parameter of the trilinear interpolation process. Therefore, we propose an optimal way to install sensors to eliminate virtual sensor values inside the cold storage. We propose a method to reduce virtual sensors in cold storage by strategically placing real sensors to improve temperature interpolation accuracy. This is done by identifying virtual sensor locations created by new sensor installations and replacing them with real sensors.

V. CONCLUSION

This study proposes a model to monitor temperature in the cold storage, clearly showing each temperature position inside the cold storage, even where no temperature sensors are installed. In addition, the study also proposed a solution to optimize the location and number of sensors used through experiments. In the future, this model will be applied in practice to help measure and monitor temperature in cold storages. Furthermore, the model will also be improved to suggest sensor mounting locations to save the number of sensors but achieve the highest efficiency.

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