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Riemann Integral In Minicraft Village Area Calculation With Geogebra

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Abstract

This study aims to model and estimate the area of a village in the game Minecraft through a Riemann-sum representation. The research employs a descriptive mathematical modeling approach focusing on a specific village area within the game environment. Spatial data were obtained by collecting the coordinates of boundary blocks, which were then mapped into a Cartesian coordinate system. The modeling and visualization process was carried out using GeoGebra to produce a two-dimensional representation of the analyzed region. The area calculation was performed through the summation of rectangular elements over partitioned intervals. Mathematically, for each fixed value of (y), the horizontal interval length is represented by (L(y)), while the area contribution at each partition is expressed as $A_i = L(y_i)\Delta y$, *with (* $\Delta y = 1$ *) representing the unit height of one block layer. The total area of the region is then approximated using the Riemann-sum formulation* $A = \sum_{i=1}^{n} L(y_i)\Delta y$. *For each fixed value of (y), overlapping or adjacent (x)-intervals were first merged, and the interval lengths were multiplied by unit height to obtain the area contribution at each level. The resulting model produced an estimated village area of 232 square units ((m^2) equivalent). This study demonstrates how spatial data from block-based digital environments can be transformed into coordinate-based mathematical representations and analyzed systematically using mathematical modeling techniques. The findings also illustrate that discrete spatial structures in digital games can be interpreted through the concept of Riemann sums for area approximation. However, this study does not examine instructional effectiveness or student learning outcomes; therefore, any educational implications should be interpreted cautiously.*
Keywords: *Minecraft, GeoGebra, Mathematical modeling, Area approximation, Riemann sums.*

1. Introduction

The use of digital technology in mathematics education has been widely explored to support the visualization and representation of abstract mathematical concepts (Erlinawati, 2018; Maskar & Dewi, 2020). In calculus learning, one of the major conceptual difficulties is that students are often able to perform integral calculations procedurally but experience difficulty in understanding integrals conceptually as representations of accumulation and area (Andiani et al., 2025; Nuraeni et al., 2024). This issue indicates a theoretical tension between symbolic manipulation and conceptual interpretation in integral learning. Although the definite integral is formally defined as the limit of summations over partitioned intervals, learners frequently struggle to connect this formal definition with geometric interpretations involving area accumulation. Therefore, visual and contextual representations are needed to bridge procedural understanding and conceptual meaning in calculus.

One technological tool frequently used to support mathematical visualization is GeoGebra, a dynamic mathematics software integrating algebraic and graphical representations. Previous studies have shown that GeoGebra can assist learners in visualizing functions, curves, bounded regions, and mathematical relationships more interactively (Fahruunnisa et al., 2024; Ratuanik et al., 2025). GeoGebra has also been applied to topics such as area and volume representation to improve conceptual explanation of mathematical processes (Irvan, 2024; Zabala-Vargas et al., 2022). However, most previous studies primarily focus on visualization of continuous mathematical objects and instructional implementation in classroom settings. Limited attention has been given to how coordinate-based spatial data from digital environments can be transformed into discrete mathematical representations for area approximation. As a result, the potential of GeoGebra as a tool for modeling spatial data from nontraditional digital contexts remains insufficiently explored.

Visual representation is particularly important in learning integral-related concepts because integrals involve accumulation processes that are difficult to interpret through symbolic expressions alone. Representations based on partitions, intervals, and area accumulation can help connect abstract calculus concepts with observable geometric structures. In this context, digital spatial environments may provide meaningful representations for illustrating how areas can be approximated through the accumulation of discrete units.

One example of such an environment is Minecraft, a construction-based digital game in which objects and regions are formed using discrete blocks positioned on coordinate grids. Unlike conventional educational media, Minecraft provides naturally structured spatial data in the form of coordinate-based block arrangements. Consequently, regions within the game can be represented mathematically as collections of discrete coordinate intervals. This characteristic makes Minecraft relevant not merely as a game-based context, but as a digital spatial environment suitable for coordinate-based mathematical modeling. The accumulation of block units in Minecraft is conceptually related to the idea of partition accumulation in Riemann sums, where area is approximated through the summation of rectangular elements over finite intervals.

Although GeoGebra has been widely utilized in mathematics learning, studies explicitly combining coordinate-based spatial modeling from digital game environments with area approximation approaches remain limited. Previous research generally emphasizes visualization of predefined mathematical functions, whereas the use of naturally occurring spatial data from block-based digital environments for mathematical modeling has not been widely discussed. In particular, there remains limited discussion regarding how discrete spatial structures can be systematically transformed into coordinate-based mathematical representations analogous to Riemann-sum formulations.

Based on this gap, this study focuses on modeling and estimating the area of a village in the game Minecraft using a coordinate-based mathematical representation through a Riemann-sum perspective. The region is represented as a collection of intervals at each fixed (y)-value, while the area is approximated through the accumulation of rectangular units over partitioned intervals. The approach does not involve formal integral processes or limit evaluation; rather, it reflects the fundamental idea of area accumulation underlying Riemann sums. The scientific contribution of this study lies in demonstrating how spatial data from a block-based digital environment can be systematically transformed into coordinate-based mathematical representations and analyzed through a discrete area approximation approach. Furthermore, this study positions Minecraft not simply as a contextual learning medium, but as a structured digital environment capable of supporting mathematical modeling of spatial data. However, this study is limited to a single modeled region and does not evaluate instructional effectiveness or student learning outcomes.

2. Method

This study employs a descriptive case study approach to analyze a specific village area in the game Minecraft. The research does not involve instructional implementation or student participation; instead, it focuses on mathematical modeling of spatial data obtained from a digital environment.

Spatial data were collected directly from the game by identifying boundary blocks of the village area. The coordinates of these boundary points were recorded using the in-game coordinate display (debug/F3 menu). Each boundary point represents a unit corresponding to a block position in the game. The collected data consist of a finite set of coordinate pairs (x,y), which define the outline of the village area.

The recorded coordinates were then mapped into a Cartesian coordinate system to enable mathematical analysis. For visualization purposes, the coordinate data were entered into GeoGebra as a list of points and used to construct a two-dimensional representation of the region. GeoGebra was used primarily as a visualization tool to verify the shape and continuity of the boundary.

The area of the region was calculated using a summation approach based on horizontal intervals. For each fixed value of y, the corresponding intervals of x-values were identified and merged if overlapping or adjacent. The length of each interval represents the horizontal extent of the region at that level. The total area was obtained by summing the products of interval lengths and unit height, forming a step-function representation of the region.

From a mathematical perspective, this procedure corresponds to a Riemann-sum formulation, in which the area is obtained through the accumulation of rectangular elements over partitioned intervals. The data are derived from a block-based spatial structure, resulting in a finite representation that remains consistent with the fundamental idea of the Riemann integral as the limit of such summations.

Overall, this study is limited to a single case and a single measurement result. Therefore, it does not involve statistical analysis or generalization, but rather provides an example of applying mathematical modeling to spatial data derived from a digital environment..

3. Results and Discussion

3.1 Data Representation and Visualization

The spatial data obtained from the Minecraft environment consist of coordinate points representing the boundary of the village area. Each point corresponds to a discrete block position, resulting in a finite coordinate-based representation of the region. To ensure consistency and reproducibility, the coordinate data were organized into structured (x,y) pairs. Prior to analysis, duplicated entries, inconsistent notation, and incorrect coordinate signs were corrected to maintain the integrity of the dataset.

The coordinate data were subsequently mapped into a Cartesian coordinate system using GeoGebra to construct a two-dimensional representation of the village boundary. This visualization was used to verify that the mapped points formed a closed region suitable for area approximation. GeoGebra functioned solely as a visualization tool, while the mathematical analysis and area calculations were performed independently through interval-based summation.

Mathematically, for each fixed value of (y), the corresponding horizontal interval length can be represented as:

$$L_i = x_{\max} - x_{\min} + 1$$

where (L_i) denotes the horizontal length of the interval at a particular partition level. The additional unit is included because Minecraft blocks are discrete units in which both endpoints belong to the interval.

The area contribution for each partition is then calculated using:

$$A_i = L_i \Delta y$$

where ($\Delta y = 1$) represents the unit height of one block layer.

The total area of the village region is subsequently estimated through the summation of all partition areas:

$$A = \sum_{i=1}^{n} L_i \Delta y$$

This formulation represents a discrete area approximation approach conceptually related to Riemann sums, in which the area is obtained through the accumulation of finite rectangular elements over partitioned intervals. Accordingly, the Minecraft village boundary can be represented mathematically as a coordinate-based partition model suitable for structured area analysis.

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Figures illustrating the mapping results and coordinate plotting are included to support verification of the mathematical modeling process and to demonstrate the relationship between visual representation and interval-based area approximation..

Table 1. Data coordinates of village boundary points

No	Dot X	Dot Y
1	-1291, -1292, -1293, -1294, -1295, -1296, -1297, -1298, -1299, -1300, -1301.	67
2	-1302, -1303, -1304, -1305, -1306, -1307, -1308, -1309, -1310, -1311, -1312.	66
⋮	⋮	⋮
12	-1318, -1319, -1320, -1321, -1322, -1323, -1324, -1325, -1326, -1327, -1328, -1329, -1330, -1331, -1332, -1334, -1335, -1336, -1337, -1338, -1339, -1340, -1341, -1342, -1343, -1344, -1345.	69

For readability purposes, the coordinate data in Table 1 are presented in grouped form rather than as individual coordinate pairs. Each value represents a discrete (x)-coordinate corresponding to a specific (y)-level. A complete structured list of coordinate pairs ((x, y)) can be reconstructed from this dataset.

Figure 1. Original spatial layout of the Minecraft village used as the source of coordinate-based boundary data

Figure 1 presents the original village environment in Minecraft used as the source of spatial data in this study. The village layout consists of discrete block structures arranged on a coordinate grid, allowing the boundary of the region to be represented mathematically as coordinate-based spatial data for area approximation analysis.

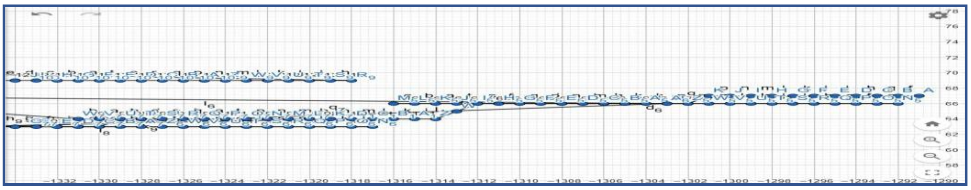

Figure 2. Coordinate-based visualization of the Minecraft village boundary constructed in GeoGebra

Figure 2 presents the coordinate-based representation of the Minecraft village boundary mapped onto the Cartesian coordinate system using GeoGebra. The visualization illustrates the continuity of the boundary structure and verifies that the mapped coordinate points form a connected region suitable for interval-based area approximation. This figure serves as the primary mathematical representation of the spatial data used in the analysis.

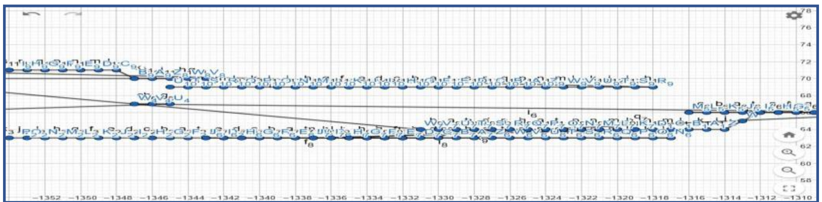

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Figure 3. Coordinate-based visualization of the Minecraft village boundary constructed in GeoGebra

Figure 3 presents the overall coordinate-based representation of the Minecraft village boundary mapped onto the Cartesian coordinate system using GeoGebra. The visualization illustrates the continuity of the village boundary and verifies that the mapped coordinate points form a connected region suitable for mathematical modeling and area approximation analysis.

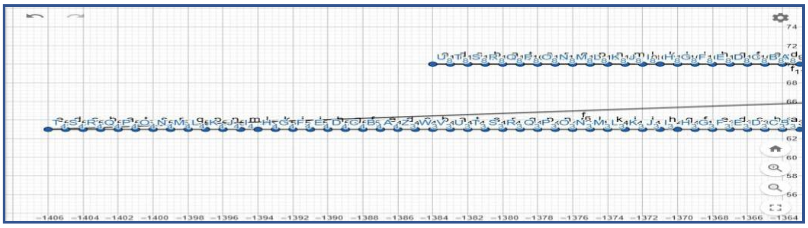

Figure 4. Visualization of horizontal coordinate intervals used for discrete area approximation of the Minecraft village boundary in GeoGebra

Figure 4 shows the visualization of horizontal coordinate intervals representing the Minecraft village boundary in the Cartesian coordinate system. The coordinate data were mapped using GeoGebra to illustrate the arrangement and continuity of discrete block intervals at specific (y)-levels. This visualization is important for verifying the correctness of interval partitioning, identifying adjacent or overlapping coordinate ranges, and supporting the discrete area approximation process through interval-based summation. Furthermore, the figure demonstrates how the spatial structure of the Minecraft environment can be transformed into a coordinate-based mathematical representation suitable for structured area analysis.

Figures 1-4 present the visualization of the village boundary obtained from GeoGebra. These figures are included to verify the correctness of coordinate mapping and to ensure that the region forms a closed shape. GeoGebra is used solely for visualization, while the area calculation is carried out through a structured summation process.

From a mathematical perspective, the area of the region is approximated through the accumulation of rectangular elements over partitioned intervals. For each fixed value of (y), the horizontal extent of the region is represented by an interval length (L(y)), corresponding to the number of coordinate units occupying that partition level. Accordingly, the region can be represented using a discrete piecewise formulation:

$$f(y) = L(y)$$

where (L(y)) denotes the horizontal interval length associated with a particular value of (y). Since the coordinate data are derived from discrete block structures, the function takes constant values over specific partition levels, producing a stepwise representation of the region.

The area contribution at each partition level is then expressed as:

$$A_i = L(y_i)\Delta y$$

with (\Delta y = 1) representing the height of one block layer. Consequently, the total area of the village region is obtained through the summation:

$$A = \sum_{i=1}^{n} L(y_i)\Delta y$$

This formulation is conceptually related to Riemann sums, in which area is approximated through the accumulation of finite rectangular elements over partitioned intervals. Thus, the area of the region is determined by summing the rectangular partitions represented on the Cartesian plane..

Mathematically, the total area can be expressed as:

$$\text{Total area} = \sum(\text{wide} \times \text{tall})$$

This approach is suitable for representing data in the form of a piecewise function or step function, where the function value remains constant over certain intervals.

Based on the obtained coordinate data, it can be observed that for each specific value of y, there is a range of x values that form the boundary of the village area. In other words, the relationship between the variables can be represented in the form of:

$$y = f(x)$$

Where the value of y is constant over certain intervals of x. This representation shows that the shape of the village area is more accurately modeled as a step function.

The next step is to combine all overlapping or adjacent x intervals at the same y value. After these intervals are combined, the length of each interval is calculated to obtain the width of the area at a specific y value. The area is then obtained by multiplying the length of the interval by the unit height on the y-axis.

This approach allows the calculation of area to be carried out systematically and structurally, in accordance with the characteristics of discrete data derived from the blocks that make up the village area in the game. Thus, this method provides a clear illustration of the application of the integral concept as the summation of area in the context of coordinate-based discrete data.

Example Calculation of Village Area

The area calculation is performed by analyzing the horizontal coordinate intervals at each fixed value of (y). For every partition level, adjacent or overlapping intervals are first merged to form continuous coordinate ranges. The horizontal length of each interval is then calculated using:

$$L_i = x_{\max} - x_{\min} + 1$$

where (L(y)) represents the interval length at a specific partition level. Since the Minecraft environment consists of discrete blocks, both interval endpoints are included in the calculation.

a. For $y = 67$
   Intervals: ([-1301, -1291]), ([-1347, -1345])
   Lengths:
   (= (-1291 - (-1301) + 1) = 11)
   (= (-1345 - (-1347) + 1) = 3)
   Total length = (11 + 3 = 14)
b. For $y = 66$
   Merged interval: ([-1316, -1292])
   Length:
   (= (-1292 - (-1316) + 1) = 25)
c. For $y = 65$
   Single point: (-1313)
   Length = 1

Calculation of Total Village Area

Based on the interval calculations obtained from all partition levels, the total area estimation is y:
$104 + 18 + 1 + 22 + 14 + 28 + 27 + 18 = 232$
Accordingly, the resulting coordinate-based model produces an estimated village area of: $232\ m^2$.

From a mathematical perspective, this result demonstrates how discrete spatial data derived from block-based structures can be transformed into partition-based coordinate intervals and analyzed

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through a structured accumulation process conceptually related to Riemann sums. The interval accumulation procedure reflects the idea of approximating area through finite rectangular partitions rather than through formal continuous integration.

Verification of Results

To support the consistency of the calculated result, the estimated area may be compared with a grid-based counting procedure within the Minecraft environment, where each block contained inside the village boundary is enumerated manually or using in-game tools. Such a comparison can provide a basic consistency check for the interval-based approximation model.

However, this study does not implement an independent validation procedure. Therefore, the calculated result should be interpreted as a coordinate-based area approximation derived from discrete spatial partitioning.

3.2 Discussion

The findings of this study demonstrate that discrete spatial data derived from a block-based digital environment can be transformed into a coordinate-based mathematical representation suitable for structured area approximation. From a mathematical perspective, the interval accumulation process applied in this study reflects the fundamental idea underlying Riemann sums, namely that an area can be approximated through the summation of finite rectangular partitions over subdivided intervals. Although this study does not involve formal limit evaluation or continuous integration, the resulting model illustrates how the conceptual principle of area accumulation can be represented using discrete coordinate structures.

The interval-based formulation also shows that spatial structures in Minecraft can be interpreted mathematically as partitioned coordinate regions. For each fixed value of (y), the horizontal interval length (L(y)) represents the local spatial extent of the village boundary. The summation process:

$$A = \sum_{i=1}^{n} L(y_i)\Delta y$$

Demonstrates how discrete coordinate intervals contribute incrementally to the total area approximation. In this sense, the mathematical model emphasizes the relationship between geometric partitioning and area accumulation, which conceptually corresponds to the interpretation of Riemann sums in calculus.

Compared with previous studies that primarily use GeoGebra to visualize continuous functions, curves, or definite integrals (Fahruunnisa et al., 2024; Ratuanik et al., 2025), this study differs in both data source and modeling orientation. Earlier studies generally focus on symbolic representations of predefined mathematical functions in instructional settings, whereas the present study utilizes naturally occurring spatial data obtained from a virtual block-based environment. GeoGebra in this study functions as a coordinate visualization tool rather than a computational integration system. Consequently, the contribution of this study lies not in symbolic calculus procedures, but in demonstrating how discrete spatial environments can be systematically modeled using coordinate-based partition analysis.

The results also suggest that digital game environments may provide alternative contexts for representing abstract mathematical ideas related to area accumulation and partition structures. The discrete arrangement of Minecraft blocks naturally produces finite coordinate intervals, making the environment suitable for illustrating how area approximation can emerge from rectangular accumulation processes. This characteristic provides a conceptual bridge between spatial visualization and mathematical representation, particularly for interpreting partition-based area models.

Scientifically, this study contributes by extending the application of coordinate-based mathematical modeling to nontraditional spatial datasets derived from digital environments. Unlike studies that treat Minecraft primarily as a contextual or game-based learning medium, this research positions Minecraft as a structured source of spatial data that can be analyzed mathematically through interval partitioning and discrete area approximation. Thus, the study contributes to the broader discussion of how virtual spatial environments may support mathematical modeling approaches involving coordinate representation and accumulation-based analysis.

Nevertheless, several limitations should be acknowledged. The analysis is limited to a single modeled village region and does not include comparative datasets, statistical evaluation, or computational validation methods. In addition, the study does not investigate instructional effectiveness, student understanding, or learning outcomes. Therefore, the findings should be interpreted primarily as a mathematical modeling demonstration rather than evidence of educational impact. Further studies may extend this approach by applying the model to larger spatial datasets, implementing computational verification procedures, or examining its potential role in mathematics learning contexts..

3.3 Limitations

This study has several limitations. First, the analysis is based on a single dataset from one village, which limits the generalizability of the findings. Second, the coordinate data require careful preprocessing to ensure consistency and to avoid errors such as duplication or incorrect notation. Third, the absence of an independent validation method may affect the reliability of the calculated results. Finally, the study does not include experimental or educational evaluation, and therefore cannot support claims regarding learning effectiveness.

4. Conclusion

This study models and calculates the area of a village in the game Minecraft through the perspective of the Riemann integral based on coordinate data. The region is represented as a collection of intervals at each fixed (y)-value, and the total area is obtained through the summation of rectangular elements corresponding to the discrete Riemann-sum model

$$A = \sum_{i=1}^{n} L(y_i)\Delta y$$

Based on the calculations performed, the total area of the analyzed village is 232 m². This result demonstrates that spatial data derived from a block-based digital environment can be systematically represented and analyzed using a mathematical modeling approach consistent with the concept of the Riemann integral.

The findings imply that block-based digital environments such as Minecraft can serve as alternative sources of coordinate-based spatial data for mathematical modeling and area approximation analysis. In addition, the study shows that discrete spatial structures in virtual environments can provide meaningful representations for illustrating accumulation processes related to Riemann sums and integral concepts. Therefore, this approach has the potential to support the development of contextual and visualization-based mathematical representations in calculus and coordinate geometry learning.

However, this study is limited to a single case and does not include validation through alternative methods or comparisons. In addition, the study does not examine educational implementation or learning outcomes. Therefore, further research is needed to verify the accuracy of the method, apply the model to larger spatial datasets, and explore its potential applications in broader mathematical and educational contexts.

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