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P1 4 From Nauvis to Earth: How Physical is Pollution in Factorio?

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Abstract

The pollution system in the video-game Factorio is investigated to determine if it can be described as a physical diffusion process. The game's chunk-based spreading rule is compared with a finite-difference approximation to the two-dimensional diffusion equation, giving an effective diffusion coefficient of $19.2\,\mathrm{m^2\,s^{-1}}$. The results agrees closely with the predictions of the continuum diffusion equation. However, the game's pollution system is a simplified representation of atmospheric transport.

Introduction

Factorio is a factory-building simulation game in which industrial machines generate pollution that spreads across the map and interacts with the surrounding environment. Pollution is calculated on a grid of 32×32 tile chunks, with polluted chunks transferring a fraction of their pollution to neighbouring chunks once a threshold value is reached [1, 2]. The pollution system therefore provides a simple discrete model for transport across a two-dimensional grid.

This spreading behaviour resembles diffusion, where particles move from regions of high concentration to regions of lower concentration. In the continuum limit, this behaviour is described by the diffusion equation [4]. This paper investigates whether the pollution-spreading algorithm used in Factorio can be interpreted as a finite-difference approximation to two-dimensional diffusion, and uses the published game values to estimate an effective diffusion coefficient for the model.

Pollution Model

Diffusion describes the transport of a quantity from regions of high concentration to regions of lower concentration. The flux $\mathbf{J}$ of a diffusing quantity is given by Fick's first law [4],

$$\mathbf{J} = -D\nabla C, \tag{1}$$

where C is the concentration and D is the diffusion coefficient. Combining Eq. (1) with conservation of the diffusing quantity gives the diffusion equation,

$$\frac{\partial C}{\partial t} = D\nabla^2 C. \tag{2}$$

Factorio does not treat pollution as a continuous field. Instead, pollution is calculated on 32×32 tile chunks and, once the pollution within a chunk exceeds 15 units, 2% is transferred to each of the four neighbouring chunks every 64 ticks [1, 2]. For comparison with ordinary diffusion, we assume uniform spreading across a two-dimensional grid and neglect pollution sources

and absorption.

$$C_{i,j}^{n+1} = C_{i,j}^{n} + \alpha(C_{i+1,j}^{n} + C_{i-1,j}^{n} + C_{i,j+1}^{n} + C_{i,j-1}^{n} - 4C_{i,j}^{n}), \tag{3}$$

where $\alpha = 0.02$. This has the same form as an explicit finite-difference approximation to the two-dimensional diffusion equation [5], for which

$$\alpha = \frac{D\Delta t}{(\Delta x)^2}. \tag{4}$$

A chunk is 32 tiles across and one tile may be treated as approximately 1 m in the game scale [2]. Taking $\Delta x = 32\,\mathrm{m}$ and using 60 ticks per second [3] gives $\Delta t = 64/60\,\mathrm{s}$. Rearranging Eq. (4) therefore gives

$$D = \frac{\alpha(\Delta x)^2}{\Delta t} \simeq 19.2\,\mathrm{m^2\,s^{-1}}. \tag{5}$$

This value represents an effective diffusion coefficient for the game model rather than the molecular diffusivity of a real atmospheric pollutant. The threshold at 15 pollution also means that Eq. (3) is only an exact description of the spreading rule when the relevant neighbouring chunks are themselves able to spread pollution.

Results and Discussion

For normal diffusion in two dimensions, the mean-square displacement is given by [4]

$$\langle r^2 \rangle = 4Dt. \tag{6}$$

Using the effective diffusion coefficient from Eq. (5) gives $\langle r^2 \rangle = 76.8t$. Figure 1 compares this continuum prediction with the discrete Factorio model obtained by iterating Eq. (3). The close agreement shows that, away from the pollution threshold, the chunk-based spreading rule behaves like a finite-difference approximation to ordinary diffusion.

The value $D = 19.2\,\mathrm{m^2\,s^{-1}}$ is much larger than molecular diffusion coefficients for gases in air, which are typically of order $10^{-5}\,\mathrm{m^2\,s^{-1}}$ [9]. It should therefore be interpreted as an effective transport coefficient rather than a true molecular diffusivity.

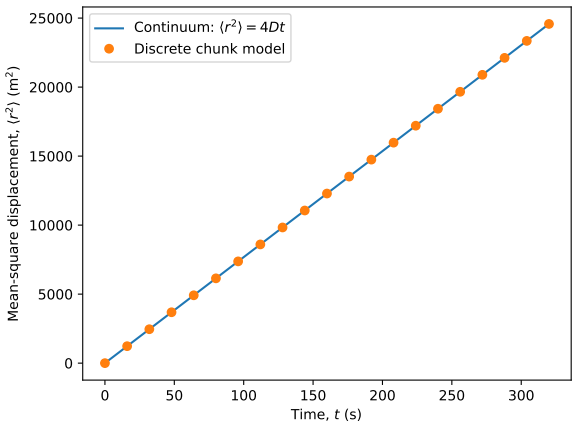

Figure 1: Mean-square displacement of pollution for the discrete Factorio model compared with the continuum diffusion prediction.

Real atmospheric pollution is also affected by wind, turbulent mixing and removal processes [6, 8]. Factorio includes sources from machines and absorption by terrain and trees, but does not include wind-driven convection [1]. Its 15-unit spreading threshold also causes the model to leave ordinary diffusion near the edge of a pollution cloud.

Conclusion

The pollution system in Factorio can be interpreted as a discrete approximation to two-dimensional diffusion. Using the published game parameters gives an effective diffusion coefficient of $D = 19.2\,\mathrm{m^2\,s^{-1}}$, and the resulting mean-square displacement agrees closely with the continuum prediction $\langle r^2 \rangle = 4Dt$.

This agreement shows that the chunk-based spreading rule behaves like ordinary diffusion when the pollution level is well above the spreading threshold. However, the large value of D, together with the absence of wind-driven transport and the inclusion of threshold and absorption effects, means that the model should be treated as a simplified representation of atmospheric pollution rather than a realistic physical description.

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