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The Pac-Man Dossier

by Jamey Pittman [Design]

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Chapter 3: Maze Logic 101

We need to take a look at how ghosts are able to move through the maze in pursuit of a goal. All pathfinding logic described in this chapter is shared by the four ghosts - it is important to understand what they have in common before we get into what makes them different.

Before we proceed, let's see how the game tracks the location of Pac-Man and the four ghosts (herein referred to as *actors* for brevity's sake). The visible game screen should be thought of as a regular grid of tiles, each eight pixels square.

The actual pixel dimensions of the screen are 224 x 288, so dividing each value by eight yields a grid that is 28 x 36 tiles in size.

Each tile is either in legal space or dead space. In the picture above, legal space is shown as the gray-colored tiles; all other tiles are considered dead space.

Actors only travel between the tiles in legal space. Each dot sits in the center of a tile, meaning they are exactly eight pixels (one tile) apart-this is useful for estimating distances during gameplay:

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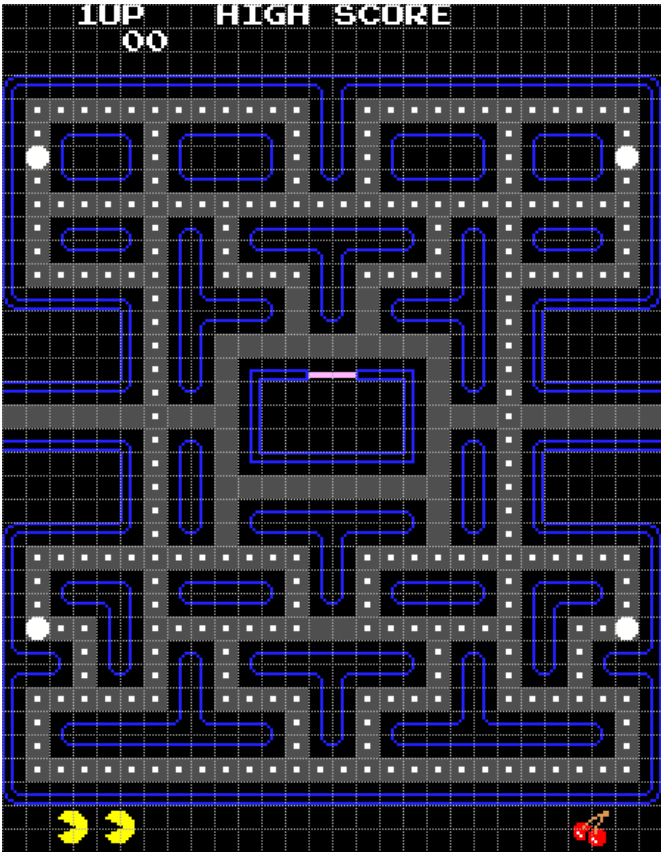
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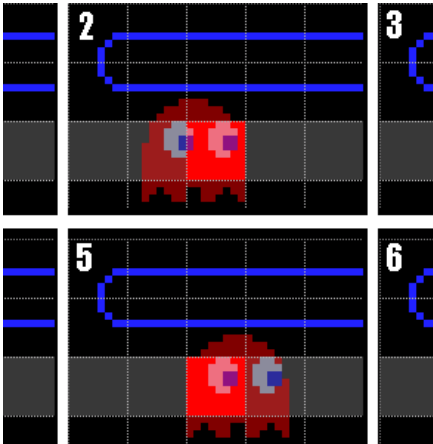
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What Tile Am I In?

As the actors move through the maze, the game keeps track of the tile each one occupies. An actor is only associated with a single tile at a time, although its graphic will overlap into the surrounding tiles. The location of the actor's center point is what determines the tile it occupies at any given time. As the actors can move at pixel-level precision, they are often not centered directly on top of the tile they are in. Consider the following example:



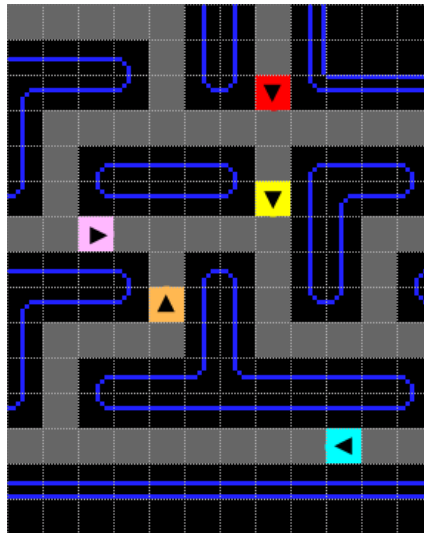
(click image for full size)

The transparent red ghost is moving left-to-right across a row of tiles in legal space. In frame one, its occupied tile (shown in bright red) is near the left side of the picture. It does not matter that some of the ghost's graphic is not in the tile-what matters is that the ghost's center point *is* in the tile.

By frame two, it has moved far enough for its center point to be in the adjacent tile to the right and its occupied tile is updated accordingly. The ghost continues to be associated with the same tile until frame six where its center point has now crossed over into the next one.

The underlying concept of tiles is essential for understanding the ghosts' pathfinding logic as it only cares about the tile an actor occupies-not its per-pixel location within that tile. To the logic routines, the five actors look very much like the picture below.

Each actor is defined by the tile it presently occupies along with its current direction of travel. Distances between actors are also measured in tiles (the pink ghost is five tiles away from Pac-Man horizontally and one tile away vertically, for example).



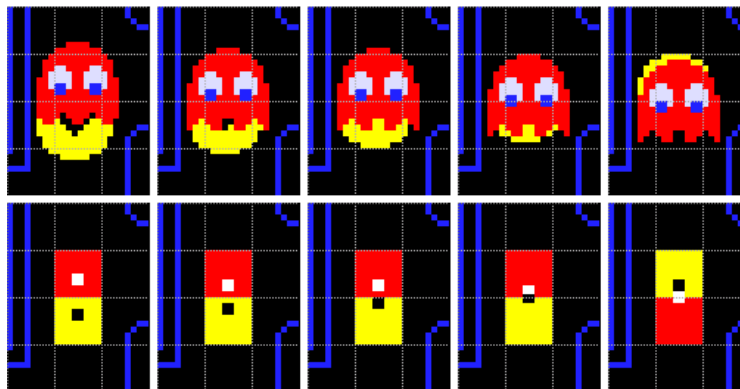
Just Passing Through

It wasn't too long after the release of *Pac-Man* when word began to spread of players occasionally passing straight through a ghost unharmed, seemingly at random. This rumor turned out to be completely true as most die-hard *Pac-Man* players can attest.

If you play the game long enough, you will eventually see Pac-Man run into one of the ghosts and come out unscathed on the other side—it doesn't happen very often so enjoy it when it does! Some players have even gone so far as to incorporate this mysterious pass-through oddity into their patterns.

The root cause of this elusive peculiarity lies in the way the game detects collisions between Pac-Man and the four ghosts. Any time Pac-Man occupies the same tile as a ghost, he is considered to have collided with that ghost and a life is lost.

It is irrelevant whether the ghost moved into Pac-Man's tile or Pac-Man into the ghost's—the result is the same either way. This logic proves sufficient for handling collisions more than 99% of the time during gameplay, but does not account for one very special case:



The above picture illustrates the conditions necessary to produce this curious behavior. There are five consecutive frames showing Blinky and Pac-Man passing through each other. Below each frame is the same scene represented by the tiles they currently occupy and the per-pixel location of their center points. Pac-Man and Blinky are at just the right position and speed relative to one another to cause them to swap tiles with each other simultaneously.

In other words, Pac-Man's center point moves upwards into Blinky's tile in the same $1/60^{\text{th}}$ of a second that Blinky's center point moves downwards into Pac-Man's tile, resulting in them moving past each other without colliding. Note that Pac-Man's origin point is centered on the top edge of his tile in frame four; this is still considered to be inside the bottom tile, but moving up one more pixel will push him over the edge into the next one.

Pac-Man and Blinky have now swapped tiles with each other in frame five, and Pac-Man can go on his merry way because he never "collided" (i.e., shared the same tile) with Blinky at all! Click on the YouTube video below to see an example of the pass-through bug (it happens 40 seconds after playback begins):

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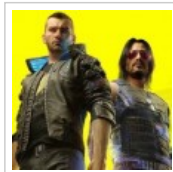
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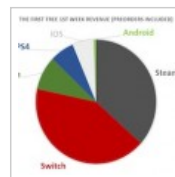
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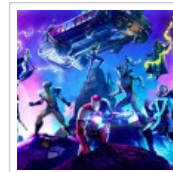
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Comments

Jake Romigh

23 Feb 2009 at 9:26 am PST



This was a most informative and entertaining read. I'm not sure everyone will agree with me here, but I think these articles have promise. They show the development history, design principals, execution, cultural reaction, and legacy of a game. If the rest of your "Dossiers" are as indepth and quality as this one, I'll be sure to read them.

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Mike Saunders

23 Feb 2009 at 1:59 pm PST



This was an amazing article! I really enjoyed reading it due to the clear descriptions and the great diagrams visually depicting the algorithms/etc. Of course, I'm an arcade junkie from the 80's so the fact that the article focused on one of those games was just icing on the cake.

Please, please do more of these types of in-depth technical analysis articles! I'll read every one.

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Roberto Alfonso

23 Feb 2009 at 4:02 pm PST

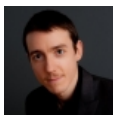


Indeed, this is one of the most insightful articles I have ever read. I knew about the chase/scatter modes from an early interview, but didn't know the gameplay was so deep!

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Joshua Dallman

24 Feb 2009 at 12:43 am PST



This is a simply fantastic article and I would love to see more well researched, in-depth game design and theory articles such as these here. There's a lot to sink your teeth into in this article, it isn't just armchair speculation about theory and market trends. Very well done, well researched, and an appreciated read and reference. I hope this type of article can also show newer game developers how much subtle coding behind the curtain occurs to create a well polished and deep gameplay, even if seemingly on the surface it is a "simple game" especially by graphical standards alone. I would also be remiss to not point out the recent "Pac Man Zero G" outlined on your sister site:

http://www.indiegames.com/blog/2009/02/freeware_game_pick_pacman_phys.html

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Tom Newman

24 Feb 2009 at 7:05 am PST



The best article on Pac-Man I have ever read. Answered many questions I've had since the 80's.

This proves that you can deliver a deep gameplay experience without lots of CPU, without high end graphics, and with minimal player control (up, down, left, right, no buttons). People will still be playing Pac-Man 50 years from now.

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Christopher Enderle

24 Feb 2009 at 1:33 pm PST



The game's depth is astounding, I'll never look at Pac-Man the same way again. Such in depth analysis as this makes me wish we could see the game's actual GDD, if such official documents exist. I'd imagine they do with the continual remakes that come out, but perhaps that's the same reason they still hold on to those.

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John Leffingwell

24 Feb 2009 at 3:38 pm PST



Absolutely great article. The superlatives do not exist for how I feel about the author's coverage of this subject matter. I didn't know of the author until now, but I've been a follower of Don Hodges work for a while, and I do this sort of thing myself from time to time. I hope we can see similarly gritty technical articles about classic games in the future. The only thing that could possibly improve this article is if Gamasutra could use some of its clout to get in contact with the original designers for additional insight and background information. I'd love to see something about the work of Vid Kidz. Robotron: 2084 has some nifty bugs, and some of the later technology Jarvis et al. developed was radically ahead of its time. See Halcyon Days.

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Tom Newman

25 Feb 2009 at 7:03 am PST

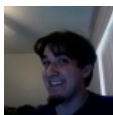


I would love to see a dossier on Joust. Left, right, and a flap button - the rest of the gameplay built in to the physics of the game itself.

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Matthew Oztalay

27 Feb 2009 at 11:16 pm PST



Very well written, very informative. An excellent window into the level of depth and detail required to design a game.

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Shawn Yates

2 Mar 2009 at 3:04 pm PST



Excellent article. I'm such a sucker for the algorithm diagrams I cannot express how grateful I am. This really helps peel back the layers of complexity of a game that at first glance might seem "simple".

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