

Monkey Pixels Tutorial

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1. Introduction

1.1. About this tutorial

This text is an explanation of the source code of the game Monkey Pixels. Monkey Pixels is a new version of my 2002 game Pixelwars, which was written in Blitz Basic. I decided to rewrite it in Monkey so it can be played in the browser. I also had the idea of writing a small tutorial for it, and explaining the structure and workings of a game is easier if that game is not too complex. At the end of this introduction you can read where the game and the source code can be found. The biggest part of this tutorial consists a reproduction of the source code itself, with explanation added. The explanation has a blue background so you can see it is not part of the source code.

1.2. The Monkey language

Monkey Pixels is programmed in the Monkey language. Monkey allows you to write a game in one language and then translate it to something that can be played on different devices, such as webbrowsers using Flash or HTML5 and a variety of mobile phones. To keep it simple I only considered the Flash and HTML5 targets.

Monkey is a language in the Blitz Basic series of languages that are inspired by BASIC, a classic programming language. Being the latest addition to that series, it is in fact more similar to more modern languages such as Java. It supports functions and a number of helpful datastructures, and allows for object-oriented programming through the use of classes. In addition it contains functionality to deal with input, graphics and sound, very important for game programming!

1.3. Monkey Pixels gameplay

In the game, the player controls a green pixel that has to avoid being touched by red pixels for as long as possible. Moving the green pixel is done using the arrow keys on the keyboard. The number of seconds the player manages to stay alive is the score. Red pixels can change into a special blinking pixel; if the player runs into a blinking pixel, a number of red pixels will be deleted to create a bit more room to move in.

1.4. Websites

The Monkey Pixels game and source code described in this tutorial can be found here:

<http://www.foppygames.nl>

The Monkey language can be tried and purchased from:

<http://monkeycoder.co.nz>

2. File structure

2.1. Contents of the project folder

It is probably common practice to store the code and other files for a game you're working on in a project folder. Inside my MonkeyPixels project folder, I created a main source code file called `monkeypixels.monkey`. All Monkey source code files should have the `.monkey` extension. Next, Monkey expects to find a data folder that has the same name as the main source code file, only ending in `.data`. When you tell Monkey to load external graphics or sound effects into the game, this is where it will look for those files. So in my case there's a folder called `monkeypixels.data`. Another folder, but this time created automatically by Monkey, has a name ending in `.build`, in my case `monkeypixels.build`, and will contain the game ready to be run. Finally, you can of course add your own folders. I added a folder called 'includes', containing separate source code files.

All in all my project folder contains the following:

- | | |
|-------------------------------------|---|
| 1) <code>monkeypixels.monkey</code> | main source code file |
| 2) <code>monkeypixels.data</code> | folder for data such as graphics and sound files |
| 3) <code>monkeypixels.build</code> | folder added by Monkey when you 'build' the game |
| 4) <code>includes</code> | folder added by me for separate source code files |

2.2. The build folder

While working on your game's source code you can instruct Monkey to 'build' an executable program out of it. The result will be placed in the `projectname.build` folder. The build folder will not exist up to that point. For every target you ask Monkey to build your game for (Flash, HTML5, Android, ...) Monkey will create a separate folder inside the build folder. In the case of Flash and HTML5, the contents of that folder should be placed on your webspace for people to play your game. For example, for Flash it will contain a SWF file that is the actual game and an HTML file that displays the SWF.

2.3. Clearing out the build folder after a language version change

An interesting point about the build folder is that when you install a new version of the Monkey language it is a good idea (if not a requirement) to delete the contents of the build folder of the game you are working on. This way, Monkey will create a fresh version of your game when building, based on the new language version, instead of adding to what was already there. If you do not clean out the build folder after upgrading (or, in fact, downgrading) the language, you may get funny error messages when building.

3. Typical Monkey main program

3.1. Minimal example

The main program for Monkey Pixels is in file `monkeypixels.monkey`. Before describing this particular file in the next chapter, I will first describe what a Monkey program could look like when it contains only the skeleton of a game. (This example has no explanation inbetween the lines of code, instead I will explain the actual Monkey Pixels code in following sections.)

```
' file: mygame.monkey

Strict

Import mojo

' other imports (for example, your own source code files in includes folder)
' ...

Class Game Extends App
  Const UPDATE_RATE:Int = 60

  ' other constants, globals, fields (for example, fields for score and hi-score)
  ' ...

  Method OnCreate:Int()
    SetUpdateRate UPDATE_RATE
    ' load graphics, sound, initialize globals and fields
    ' ...
    Return(0)
  End

  Method OnUpdate:Int()
    ' do game logic (for example, move player and enemies)
    ' ...
    Return(0)
  End

  Method OnRender:Int()
    ' do game rendering (for example, draw background, player and enemies)
    ' ...
    Return(0)
  End

  ' other functions or methods
  ' ...
End

Function Main:Int()
  New Game
  Return(0)
End
```

The main parts of the file are:

1) A class 'Game' that extends the 'App' class. This is a definition of a new class Game, which is based upon the existing App class. This means it can do everything the App class can do (which is probably a lot), but it can also do everything you add to the definition of Game, for example, create enemies, draw a game background, keep track of the game's hi-score. Extending classes is described further on, as it is also used in Monkey Pixels' classes.

2) A function Main() that creates an instance of Game using the New command. Based on the definition of class Game, an object is created in the computer's memory. This means an actual

Game object is now up and running. When programmed correctly it will start displaying the game on your screen.

3.2. Three required methods in class Game

The Game class should have three standard methods:

- 1) OnCreate()
- 2) OnUpdate()
- 3) OnRender()

OnCreate() is called when an instance of Game is first created. Code to initialize your game should be put in this method. It will not be called again for the time your game runs. One command that you'd place here is a call to SetUpdateRate. It defines how often per second your game's OnUpdate() method will be called. This basically controls the speed at which your game runs. If you set it to 60, any code placed in OnUpdate() will be run 60 times per second.

OnUpdate(), as explained above, is called a set number of times per second after your game has initialized. It is the heart of the game. Here you would put all code to make your game objects move, but also code to go from the title screen to the action part of your game, and from there to the game over screen, and back to the title screen again. (If your game uses a structure like that.) In practice you would not put literally all the code here, but instead place calls to methods and functions that are described in other source code files. (Otherwise this one OnUpdate() method would get so big it would be difficult to manage.)

OnRender() is like OnUpdate() in that it gets called many times per second. Where OnUpdate() updates the game state (moving things around), OnRender() displays the game state on the screen (drawing things at their new location).

If you want to draw an image, a command that draws that image should be added to OnRender(). It could be a direct call to a drawing command in the Monkey language, such as DrawImage(), or it could be a call to a method of an object that in turn makes a call to DrawImage(). For example, in Monkey Pixels, the class TPixel contains a function called renderAll() that draws all pixels.

If you draw something, it appears on top of things that were drawn before. Therefore in OnRender() you would typically first draw the game background, and then draw the game objects, so that they appear on top of the background.

4. Monkey Pixels main program

4.1. Naming conventions

In my programming I use some conventions for naming variables and other parts of the program. Some of these are also used by other people, other conventions are a bit more personal, that's why it is probably a good idea to mention them before showing more of my code:

Constants are written in all upper case:	EXAMPLE_CONSTANT
Variables and functions use camel case:	exampleLocalVariable, exampleFunction()
Globals get a 'g' prefix:	gExampleGlobal
Fields get an 'f' prefix:	fExampleField
Parameters get a 'p' prefix:	pExampleParameter
Class names get a T:	TExampleClass
Images get an extra 'gfx' prefix:	gGfxExampleGlobalImage
Sounds get an extra 'snd' prefix:	gSndExampleGlobalSound

This way of writing constants and the use of camel case is fairly universal. The prefixes for globals, fields and parameters are more personal. I like to be able to see instantly whether I am talking about a global variable, a class field, a function parameter, or (if there are no prefixes) a local variable. It also makes it easier to use similar names without using the same name twice. For instance, in a class method setName(pName:String) I could say fName = pName and it would be instantly clear that I am assigning the parameter value to the class field. Without prefixes it would of course also be possible, and I would then have to do Self.name = name, which is not bad, but I still prefer to use my prefixes.

4.2. Description of monkeypixels.monkey

This is the main program file for Monkey Pixels. In its basic structure it is similar to the minimalistic main program presented in the previous chapter, but this time code has been added inside the structure that turns this into a particular game with its own rules and game objects.

```
' Monkey Pixels, Foppygames 2011
' monkeypixels.monkey
```

```
Strict
```

```
Strict tells Monkey that in checking the syntax of this program it should use its strictest set of rules. Typically this means your code will look better and fewer mistakes will be made.
```

```
Import mojo
```

```
Import includes.constants
Import includes.deltatimer
Import includes.pixel
Import includes.player
Import includes.enemy
```

```
In order to use code that is in other files, the files need to be 'imported' using the Import command. First 'mojo' is imported, a part of Monkey that allows us to use graphics, sounds and input devices. Then, source code files that I made myself, containing the constants and the class definitions for the game, are imported. Putting everything in one file is also possible but I prefer to use separate files. Note that even though the source code files have the extension .monkey, this extension is not used when importing the file.
```

Class Game Extends App

```
Field fGfxTitleScreen:Image  
Field fGfxGameOverScreen:Image  
Field fGfxDigits:Image
```

A couple of fields for our Game class that will hold images. The class Image is a part of the mojo module, imported earlier. This would not work if mojo was not imported. (In fact, extending the Game class from the App class would fail too, since App is also part of mojo. Extending classes is discussed in more detail later, in the description of other classes.) I put an f at the front of every field name. This way you can see right away that something is a field. Different programmers sometimes use different variable naming rules, I got used to this.

```
Field fPlayer:TPixel  
Field fState:Int  
Field fNextEnemy:Int  
Field fNextPoint:Int  
Field fScore:Int  
Field fHiScore:Int
```

Some more fields. fPlayer is an instance of the TPixel class, the definition of which was imported at the top of the file. Then there are a few int variables, basically numbers that help in running the game. fState is the variable that holds the current game state. The use of 'states' or a 'state machine' to control game flow is described in more detail below this code example.

Method OnCreate: Int()

OnCreate() is called once automatically at the start of the game. It is used to set up the game by loading any graphics and sound, setting the update rate (the speed the game will run at) and setting the first game state to be the title screen. It also initializes the class TDeltaTimer, which is a class that makes sure that every object moves at the intended speed, even if the game is slowed down because the computer is having a hard time. (This will be explained later.)

```
loadGraphics()  
SetUpdateRate UPDATE_RATE
```

Note that UPDATE_RATE is a constant declared in file constants.monkey, imported at the top of the file. Its value is 60. I could have used the value 60 here directly, but using constants helps to make the code readable. It also means that if I use the update rate constant at multiple places in the code, I can change it later just by changing the value assigned to the constant.

```
switchToState(STATE_TITLE)  
TDeltaTimer.init()  
fHiScore = 0
```

```
Return(0)
```

End

Method OnUpdate: Int()

OnUpdate() is called automatically at the rate set in OnCreate(). In the case of Monkey Pixels, this is 60 times per second. In this method you are expected to update the game logic. If the game is currently being played, this means objects are moved around, new objects are created, old ones removed, etc. If the current state is the title screen or the game over screen, updating the logic means checking if the player has pressed space bar and then changing the state if he or she has.

```
TDeltaTimer.update()
```

The class that keeps track of the game's speed needs to be updated too, so it knows how fast the game is running. We have not declared a variable for an instance of the class; instead, functions from the class definition are called upon directly. The class is a 'static' class, which is explained later.

```
Select fState
```

This is a Select statement that tells Monkey what should be done for different values of fState.

```
Case STATE_TITLE  
  ' space bar was pressed  
  If (KeyHit(KEY_SPACE)) Then  
    switchToState(STATE_GAME)  
  End If
```

If the space bar is pressed while the game is in the title screen state, the state is changed to the game-play state. Note that KEY SPACE is a constant that represents the space bar. This constant, as well as constants for all other keys on the keyboard, is a part of the mojo module. The function KeyHit() is also defined in the mojo module. KeyHit() actually returns the number of times the requested key was hit since the last call to OnUpdate(). The statement "If (KeyHit(KEY SPACE))" will be True for any number of keyhits that is greater than 0, because in programming (or at least in many programming languages), 0 corresponds to False when tested, and every number that is not zero corresponds to True.

Case STATE GAME

```
TPixel.updateAll()  
TPixel.removeInactive()
```

In the game-play state, we call upon functions in the TPixel class that update all TPixel objects and remove inactive TPixel objects. These functions are described later when TPixel is described.

```
' time to add point to score  
If (Millisecs() >= fNextPoint) Then  
    fScore += 1  
    fNextPoint = Millisecs() + 1000  
End If
```

Millisecs() is a Monkey function that returns the number of milliseconds that have passed since the game started. In a way it can be used as the current time. If a certain point in time (stored earlier in fNextPoint) is reached, the score is increased by one point. Then the point in time to be reached is increased by 1000, so it will take 1000 milliseconds (1 second) for this to happen again. The effect is you get 1 point each second. In this case I could also have defined a constant to store the number 1000, but for some reason I did not, perhaps because 1 second will always be 1000 milliseconds and I knew I wanted to have the score reflect the number of seconds survived. (Excuses, excuses...)

```
' time to add enemy  
If (Millisecs() >= fNextEnemy) Then  
    New TEnemy()  
    fNextEnemy = Millisecs() + Int(Rnd(ENEMY MIN INTERVAL,  
ENEMY MAX INTERVAL))  
End If
```

Just like above, another point in time (fNextEnemy) can be reached, in which case a new enemy is introduced, an instance of TEnemy. Then this point in time is also increased, but this time with a random number of milliseconds. The increment is randomly picked between two constants. Lowering these constants would make the game harder, as the period until the next enemy will be shorter and thus more enemies appear.

```
' special was hit  
If (TPixel.gSpecialHit) Then  
    TPixel.deactivateEveryNthEnemy(fPlayer)  
    TPixel.deactivateEnemiesAroundPlayer(fPlayer)  
    TPixel.gSpecialHit = False  
End If
```

Part of class TPixel is a global variable that stores whether the player ran into a 'special' pixel. If so, functions from TPixel are used to deactivate enemy pixels. Finally, the variable storing the hit is reset to False so that a new hit event can be registered in the future. I put a g in front of global variable names in order to set them apart from fields. Global variables are typically used in classes for values that are not particular to a single instance of the class, but rather to the class as a whole.

```
' player was hit  
If (TPixel.gPlayerHit) Then  
    switchToState(STATE END)  
' escape key was pressed  
Else If (KeyHit(KEY_ESCAPE)) Then  
    switchToState(STATE TITLE)  
End If
```


Another global in TPixel tells us if the player was hit (by a non-special pixel). If so, it's game over as the game state is changed to the game over state (STATE_END). Note that constants are used to denote game states. I could have used direct values such as 0, 1, and 2 but that would make the code quite unreadable for (most) humans. If the player was not hit, but instead the player pressed the escape key, we end the game by returning to the title screen state. I used an 'else' here because I don't want these two things to happen at the same time. It would be a big coincidence but if the player died AND escape was pressed, the game would be instructed to move to one state, and then to another, in the same update step, which could lead to unforeseen effects. It's better to make sure that as an effect of one update step, at most one state change can happen. It's also best to make that state change the last thing you do within the update step. For example, it would be unwise to start by changing the state to the title screen state, and THEN try to move all game objects around! They might not even exist anymore, after the state change.

```

Case STATE_END
  ' space bar was pressed
  If (KeyHit(KEY_SPACE)) Then
    switchToState(STATE_TITLE)
  End If

```

If the space bar is pressed while the game is in the game-over state, the state is changed to the title screen state.

```
End Select
```

```
Return(0)
```

```
End
```

```
Method OnRender:Int()
```

OnRender() is called automatically after every call to OnUpdate(). It is the place to put commands for drawing your game so that the effects made in OnUpdate() (such as creating and moving objects) become visible.

```
SetAlpha(1)
SetColor(255,255,255)
```

SetAlpha() is used to set transparency for following drawing actions, 0 meaning fully transparent and 1 being not transparent at all. SetColor() determines the color used in following drawing actions. Some drawing that is done from objects in my game change these values, so now they are reset again.

```

If (fState = STATE_TITLE) Then
  DrawImage(fGfxTitleScreen,0,0)
Else
  Cls(0,0,0)
End If

```

If we are on the title screen, draw the title screen image. Else, just clear the screen and make it black.

```

' display hi-score and current score
drawDigits(String(fScore),SCREEN_WIDTH-8,SCREEN_HEIGHT-25,True)
drawDigits(String(fHiScore),8,SCREEN_HEIGHT-25)

```

DrawDigits() is a method that is defined below. It uses an image containing the digits (0-9) to draw a number to the screen. We could use a Monkey command for displaying text, but those are usually a bit slow and better used during debugging only. Using an image also allows us to create our own font. (Although in this case I am re-using a font I created for an older game called Flyout and which was also used in my game Ranger...)

```

If (fState = STATE_GAME) Then
  TPixel.renderAll()
End If

```

If we are in the game play state, draw the pixels! This calls a function in class TPixels that will in turn take care of drawing all individual TPixel objects, as explained below in the description of class TPixel.

```

If (fState = STATE_END) Then
  TPixel.renderAll()

  SetAlpha(1)
  SetColor(255,255,255)
  DrawImage(fGfxGameOverScreen,0,0)
End If

```

If we are in the game-over state, we ALSO draw all pixels. In addition we then draw a game-over image. This looks better than just drawing the game-over image, as now the player can still see the end result of the game, even though he or she can't move around anymore.

```
Return(0)
```

```
End
```

```
Method drawDigits:Void(pNumber:String,pX:Int,pY:Int,pRightAligned:Bool=False)
```

A method for drawing a number using separate image frames. Monkey's DrawImage() command allows you to draw a frame out of an image that contains several frames (images next to each other, each of the same width). In this case the image contain the digits 0 to 9 from left to right. The method uses DrawImage() to draw one of those frames for each digit in the number pNumber we provided.

```
If (pRightAligned) Then
```

```
    pX -= pNumber.Length()*17
```

```
End If
```

```
For Local i:Int=0 To pNumber.Length()-1
```

```
    DrawImage(fGfxDigits,pX+i*17,pY,pNumber[i]-48)
```

```
Next
```

```
End Method
```

```
Method switchToState:Void(pState:Int)
```

This method is called to change the current game state. In addition to just changing the value in fState (for which alone you would not need a separate method) it does everything needed to initialize the new state (and to shut down the old state, if necessary). For each state there is a 'Case' in the Select statement below.

```
Select (pState)
```

```
    Case STATE_TITLE
```

When switching to the title screen: store the new hi-score if it is indeed better than the current hi-score.

```
    ' new hi-score was reached
```

```
    If (fScore > fHiScore) Then
```

```
        fHiScore = fScore
```

```
    End If
```

```
    Case STATE_GAME
```

When switching to the game play state: set a new base value (seed) for random numbers, initialize the TPixel class (it will remove all current TPixel objects), create the player, set the first time-points for a new enemy and the next score point, and finally set the score to 0.

```
        Seed = Millisecs()
```

```
        TPixel.init()
```

```
        fPlayer = New TPlayer()
```

```
        fNextEnemy = Millisecs() + 1000
```

```
        fNextPoint = Millisecs() + 1000
```

```
        fScore = 0
```

```
    Case STATE_END
```

When switching to the game over state, we don't need to do anything extra, but I still put a Case here, to make it complete.

```
End Select
```

```
fState = pState
```

Here the new state value is actually stored in fState. This is done at the end. If necessary the code above could still use the state value in fState before it was changed, to refer to the old state. It was not necessary here but you can imagine saying something like "if the old state is the title screen, play a song for leaving the title screen".

```
End Method
```

```
Method loadGraphics:Void()
```

A method for loading the images used in this game into the fields of the Game class. Monkey knows that images loaded with LoadImage() will be in the projectname.data folder in the project folder, so here we just specify the file name, not the path to the file. The projectname.data folder is where you need to put all such data. This also goes for sound effects and music (such as .wav and .mp3 files), but Monkey Pixels does not use any sound effects.

```
fGfxTitleScreen = LoadImage("titlescreen.png")
```

```
fGfxGameOverScreen = LoadImage("gameoverscreen.png")
fGfxDigits = LoadImage("digits.png",10)
```

I use 'Gfx' in variable names to indicate that these variables point to graphics (objects of type Image, to be precise). The f in front is still to indicate that this is a field, and not a global variable or parameter. Global variables in my games get a g prefix, parameters get a p.

```
End Method
End

Function Main:Int()
    New Game
    Return(0)
End
```

4.3. Using states to control program flow

In OnUpdate() the game logic is run. Here it is decided what happens on the screen. In the case of Monkey Pixels, I cannot just say "OK, move the pixels" because it could be that the player hasn't even started playing yet and is still on the title screen. We have to describe what happens when the program is in one of its different states. This is taken quite literally here, as I have added a variable fState that holds the current state. The possible states are:

- 1) STATE_TITLE
- 2) STATE_GAME
- 3) STATE_END

I have added a method called switchToState() that is used to make the program switch from one state to another, changing the value in fState and initializing objects or settings when needed in a new state.

In OnUpdate() we perform different actions based on what the current state is. Sometimes an action means we change state. For example, if the current state is STATE_TITLE and we press the space bar, we change the state to STATE_GAME. If the state is STATE_GAME and the player was hit, we change the state to STATE_END. In that state, if the space bar is pressed, the state is changed to STATE_TITLE and a new game can begin.

In addition to OnUpdate(), OnRender() also uses the current state. Based on the current state, different things are drawn to the screen. So to sum it up, the state system controls both the program flow and the visible game screen.

4.4. Using states to control individual game objects

Here states are used to control the flow of the entire program. You could use this system to control individual game objects, too. Imagine an aircraft being controlled by the player. It could be in different states, such as STATE_GROUNDED, STATE_FLYING. This is not always the best solution. For example, you could also describe those states implicitly through the current height of the aircraft, perhaps in combination with other variables that together could be said to describe the craft's state. If the height is 0, the craft is grounded. You do not necessarily need an extra state variable to store that information. You need to consider in every case if an explicit state variable is helpful. In the case of Monkey Pixels I have not defined states for the pixel creatures, since they're not very complicated and do not have many different states to begin with.

5. TDeltaTimer class

5.1. Delta timing

I want my game to run at 60 frames per second. However, it could be that for some reason it is slowed down. The player could have lots of other programs running, for example. Some players could even run a special program to slow my game down and get a better hi-score! Either way the result would be slow moving game objects. One way to counter this is to speed up the game objects as much as the game slows down, by making them move in bigger steps. This way the objects would again move at the desired speed.

'Delta Timing' is a method that does this. If the game runs ten times as slow as intended, game objects should move in steps that are ten times as big. This factor should not only be applied to the movement of game objects, but also to other things such as counters that count until something happens. (Note: if you use MilliSecs() to see if a certain time has elapsed, this does not need Delta Timing to be applied to it, because it is based on actual time. Even if the game slows down, a second is still a second, and that is what MilliSecs() measures.)

In order to know by what factor the speed of game objects should be adjusted, Delta Timing computes for every frame how long that frame took, and compares this to how long it should have taken ideally. If it took 10 times as long, the resulting Delta Time factor is 10. Applying this to game object speeds means they will move ten times as fast to make up for the slowdown.

5.2. Description of deltatimer.monkey

File deltatimer.monkey contains the definition of class TDeltaTimer. I decided to create a separate class to handle the delta timing. This way I can easily copy it into another project later. It is not a class that will be used to create many instances of; you typically only need a single Delta Timer. Therefore I have implemented this as a 'static class'. The idea of static classes is explained further after the code explanation.

```
' Monkey Pixels, Foppygames 2011
' deltatimer.monkey
```

```
Import mojo
```

```
Import constants
```

```
Class TDeltaTimer
```

```
Global gDeltaTime:Int
```

```
Global gDeltaFactor:Float
```

These globals are used to store the last time we called the TDeltaTimer.update() function, and the resulting delta time factor. This last value is the one the rest of the program will be interested in. As you can see, there are no fields, and no methods in this class. It only has globals and functions. This means it is not meant to be used to create objects from. There will be no 'New TDeltaTimer()' anywhere in the program. In fact, there is not even a method New(). Instead, functions are called upon directly as in 'TDeltaTimer.update()'. This is called a 'static class' and it's a nice way of combining variables and functions that work together in a certain context.

```
Function init:Void()
    gDeltaTime = MilliSecs()
End Function
```

```
Function update:Void()
```

The update function of TDeltaTime is called every frame from the main program. It will compute the delta time factor that other parts of the program will use to change the speed at which objects move, for example.

```
Local time:Int = Millisecs()  
First, the current time is noted.
```

```
gDeltaFactor = (time - gDeltaTime) / (1000.0/UPDATE RATE)
```

Then, the difference with the previous time is computed: `time - gDeltaTime` is the number of milliseconds between the previous call to update and this call to update, so it's the time from one frame to the next. This is divided by the number of milliseconds there SHOULD have been between two frames. As an example, if the time difference is 100 ms, and the target time difference is 10 ms, `gDeltaFactor` would be $100 / 10 = 10$. This means that game objects movement will be multiplied by 10 to make the game objects move at the intended speed.

```
gDeltaTime = time  
End Function
```

```
End
```

5.3. Static classes

A static class is a class that is not meant to be instantiated as an object. It has no `New()` method. Instead it only contains globals and functions. The functions and globals can be called upon directly from outside of the class by putting the class name in front of them: `TMyStaticClass.myFunction()`. If the static class is made known (imported) where it is needed, this provides a nice way of using the same set of globals and functions across your program. An example of this is `TDeltaTime` above. The delta timing functionality is typically needed in many parts of the game. Importing `TDeltaTime` in those parts allows me to get the current delta time factor as `TDeltaTime.gDeltaTime`, the global variable in the `TDeltaTime` class.

6. Constants

6.1. Description of constants.monkey

For this game I have collected the constants in one file called constants.monkey. Another approach (perhaps more logical) would be to put constants in the class that uses them. For instance, the state identifier constants, such as STATE_TITLE, could be put in the Game class, that being the only class that uses them. On the other hand, some constants are used throughout the whole program and in those cases it's better to define them once in a shared file.

```
' Monkey Pixels, Foppygames 2011
' constants.monkey

Const SCREEN_WIDTH:Int           = 640
Const SCREEN_HEIGHT:Int          = 480
Const UPDATE_RATE:Int            = 60

Const STATE_TITLE:Int            = 0
Const STATE_GAME:Int             = 1
Const STATE_END:Int              = 2
These values are used to identify the different states the game can be in. The values 0, 1 and 2 are in fact not very important, it could also have been 324, 765 and 654, as long as they are unique, but it's of course easier to just start counting at 0.

Const PIXEL_WIDTH:Int            = 4
Const PIXEL_HEIGHT:Int           = 4
These are the width and height of the TPixel objects on screen. In the original Pixel Wars I think they were actual pixels (1*1) but Monkey Pixels is displayed in a 640*480 window (not full screen) so we need bigger pixels to make it playable.

Const PLAYER_SPEED:Float         = 1.0
Const ENEMY_SPEED:Float          = 0.8

Const LAUNCH_RADIUS:Int          = 14
Const HIT_RADIUS:Int             = 2
Launch radius is the radius of the circle around the player in which new (enemy) pixels will be introduced. Hit radius is used to decide if the player hits another pixel; closer than hit radius means it's a hit.

Const SPECIAL_CHANCE:Int         = 2
Const SPECIAL_REMOVE_EVERY_NTH:Int = 8
Const SPECIAL_REMOVE_RADIUS:Int  = 60
Every time an enemy pixel is introduced, it has a SPECIAL_CHANCE out of 100 of becoming special. A special pixel blinks and can be used by the player to create room. When the player runs into a special pixel, every SPECIAL_REMOVE_EVERY_NTH enemy pixel is removed and all enemy pixel in a SPECIAL_REMOVE_RADIUS around the player is removed.

Const ENEMY_MIN_INTERVAL:Int     = 150
Const ENEMY_MAX_INTERVAL:Int     = 700
Const ENEMY_ALPHA_CHANGE:Float   = 1.0/(UPDATE_RATE*2)
The interval constants are the minimum and maximum number of milliseconds between introducing one enemy and introducing the next. The ENEMY_ALPHA_CHANGE value is about how quickly an enemy becomes non-transparent. The alpha value used in the enemies ranges from 0 to 1, 0 being fully transparent. Every frame, the above constant value is added. The step size is 1 divided by the number of frames in two seconds. With this step size it will take two seconds to go from 0 to 1.
```

7. TPixel class

7.1. Base class

TPixel is the class behind the pixel objects in the game. However, TPixel itself is a base class. It is used as a basis for two other classes that represent the player and the enemies on screen. This means we will not be using instances of TPixel itself, but only of the classes that are extended from it.

7.2. Extending classes

Extending classes from a base class is a nice way of reducing the work for the programmer. While writing the game I realized that the player object and the enemy object have some things in common. They both can be active or inactive, they have a current location on the screen, they have a certain width and height, they move in four directions, they should stay on the screen... The only big difference is that one is controlled by the player (using the keyboard) and the other is controlled by the computer.

In such a situation it makes sense to create a base class that contains everything the player and enemy objects share, and then create two extended classes from the base class, one for the player and one for the enemy, in which the things that differ are defined. TPixel below is the base class. TPlayer and TEnemy described later are the extended classes. Now I can talk about objects of type TPixel (for instance, have a function that accepts a TPixel object as a parameter), and it will work with objects of type TPlayer and TEnemy.

7.3. Description of pixel.monkey

```
' Monkey Pixels, Foppygames 2011
' pixel.monkey

Import mojo

Import constants
Import deltatimer

Class TPixel
  Global gList:List<TPixel> = New List<TPixel>
  A global list of objects of type TPixel, as part of the TPixel class itself. The class
  also has functions to maintain this list. Keeping as much as possible within the class
  itself is preferable to keeping track of all TPixel objects from the main program.

  Global gPlayerX:Int
  Global gPlayerY:Int
  Global gPlayerHit:Bool
  Global gSpecialHit:Bool
  It may seem strange to talk about the player here, but storing the location of the
  player pixel in globals inside the TPixel class provides a way of letting the enemy
  pixels know where the player is. This is used to check if any enemy collides with the
  player. If we did not store it in a central location like this, we would have to either
  track which pixel is the player (for instance using a global gPlayer:TPixel, which
  would be a good solution, perhaps even better than the solution I am using here),
  or look through the whole list of pixels everytime to see which one is the player
  (which is a bad solution), or keep separate lists of player objects and enemy
  objects, an idea I don't like as it would go against the concept of player and enemy
  being based on and treated as the same base class. In general it can be said that
  there are several solutions to such "communication" problems.

  Field fX:Float
  Field fY:Float
  Field fW:Int
```

```
Field fH:Int
```

```
Field fActive:Bool
```

When fActive becomes false, this means the object can be removed from the list. Sometimes there are several spots in your code where an object can become inactive (destroyed, killed, etc.). However it is often good to only have one spot where objects are actually removed from the list. This is because if you remove objects in different locations in your code and at different moments during the update cycle, other parts of your code could run into trouble if they still assume an object to exist that has been removed elsewhere. Therefore it is necessary to remember that an object is no longer active by using such a field. Then when the time has come to start removing inactive objects (typically at the start or end of the update cycle), this information is used.

```
Method New(pX:Int,pY:Int)
```

This method creates a new instance of TPixel. The New() method of a class is also known as the constructor. It assigns initial values to the object's fields, some values (x, y) being provided as parameters in the call to New().

```
fX = pX
fY = pY
fW = PIXEL WIDTH
fH = PIXEL HEIGHT
fActive = True
```

```
' add this new object to the global list
gList.AddLast(Self)
```

Here the newly created object is added at the end of the global list of TPixel objects. The keyword Self typically refers to the object for which the method was called. In the case of the New() method it refers to the object being constructed.

```
End
```

```
Function init:Void()
```

This is a function to initialize the TPixel class as a whole. This is not a method that works on one object of type TPixel, but a function that works on the class itself. It clears the global list and resets two global booleans. This init function is called at the start of a game, like this: TPixel.init()

```
gList.Clear()
gPlayerHit = False
gSpecialHit = False
```

```
End Function
```

```
Function updateAll:Void()
```

Another function, this one calls the update method for all TPixel objects in the global list. In the Game class, this is called from OnUpdate(), when the game is in the state STATE_GAME, like this: TPixel.updateAll()

```
For Local pixel:TPixel = Eachin gList
    pixel.update()
```

```
Next
```

```
End Function
```

```
Function renderAll:Void()
```

This function calls the render method for all TPixel objects in the global list. In the Game class, this is called from OnRender(), when the game is in the state STATE_GAME, like this: TPixel.renderAll()

```
For Local pixel:TPixel = Eachin gList
    pixel.render()
```

```
Next
```

```
End Function
```

```
Function removeInactive:Void()
```

A function to remove all inactive objects from the global list.

```
For Local pixel:TPixel = Eachin gList
    If (Not(pixel.fActive)) Then
        gList.Remove(pixel)
```

```
    End If
```

```
Next
```

```
End Function
```

```
Function deactivateEnemiesAroundPlayer:Void(pPlayer:TPixel)
```

A function to remove all enemies that are within a certain distance from the player. The player itself is passed along as a parameter so the function knows which pixel is the player. For the location of the player it actually uses the global values that I talked about at the start of this file description. It

could again be said that perhaps storing a global pointer to the player object (gPlayer:TPixel) is a better solution, as then we would not need the pPlayer parameter in this function, and we would have access to the player location as gPlayer.fx and gPlayer.fy.

```
For Local pixel:TPixel = Eachin gList
  Local dX:Int = gPlayerX - pixel.fx
  Local dY:Int = gPlayerY - pixel.fy
  ' pixel is within radius from player
  If (Sqrt(dX*dX+dY*dY) <= SPECIAL REMOVE RADIUS) Then
```

Here we use Pythagoras' theorem to compute the distance between two objects, using the differences in their x and y components. If the distance is smaller than the constant SPECIAL REMOVE RADIUS, the pixel is removed, but only if it is not the player. The pixel is not removed directly; instead its fActive value is set to false, so it will be removed later.

```
  ' pixel is not player
  If (pixel <> pPlayer) Then
    pixel.fActive = False
  End If
End If
```

```
Next
End Function
```

```
Function deactivateEveryNthEnemy:Void(pPlayer:TPixel)
```

A function to remove every Nth enemy. Again the player itself is passed along as a parameter so the function knows which pixel is the player and therefore not an enemy. The function goes through all TPixel objects in a For...Next loop, while counting from 0. Once count is equal to (or greater than) N, the pixel currently being visited in the list will be removed (if it is not the player). The count is then also reset to zero.

```
Local count:Int = 0
For Local pixel:TPixel = Eachin gList
  count += 1
  ' pixel is next Nth pixel in list
  If (count >= SPECIAL REMOVE EVERY NTH) Then
    ' pixel is not player
    If (pixel <> pPlayer) Then
      pixel.fActive = False
      count = 0
    End If
  End If
End For
```

```
Next
End Function
```

```
Method stayOnScreen:Void()
```

Once we decide that TPixel, as a base class, has a position (x, y) we can also decide that such an object may never be moved from the screen. This can then be added to the base class as a method. When moving the pixel around, we then only need to call stayOnScreen() after moving to make sure the pixel stays on screen. The method checks that x and y do not go beyond the values that represent the screen border: not smaller than 0, and not greater than the width or height of the screen. In doing this it takes the width and height of the object into account. (The x and y values of the TPixel object are used as its upper-left corner in drawing. This means if you do not take the width into account, it could cross the screen border with its right side. The same is true for the height and the bottom side.)

```
  If (fx < 0) Then
    fx = 0
  End If
  If (fx > SCREEN_WIDTH-fw) Then
    fx = SCREEN_WIDTH-fw
  End If
  If (fy < 0) Then
    fy = 0
  End If
  If (fy > SCREEN_HEIGHT-fh) Then
    fy = SCREEN_HEIGHT-fh
  End If
End Method
```

```
End Method
```

```
Method update:Void() Abstract
```

```
Method render:Void() Abstract
```

```
Update() and render() are abstract methods. This means they need to be defined in
classes that are extended from this base class TPixel. Below this code is some more
explanation of abstract methods.
```

End

7.4. Global list of objects inside class

The global `gList` is a list that contains `TPixel` objects. Instead of maintaining a list of `TPixel` objects in the main program, it is now part of `TPixel` itself. `TPixel` contains a set of functions that work on the list of `TPixel` objects, such as functions for drawing all objects and for removing inactive objects from the list.

7.5. Functions inside class

The `TDeltaTimer` class described earlier only had functions, this is why it was called a static class. `TPixel` is not a static class: it has methods. But it also has functions. The functions are not related to any `TPixel` object in particular, but to the class as a whole.

7.6. Abstract methods

There are two methods in `TPixel` that have no body. Instead, the keyword `Abstract` is behind their names. This means that they are not defined in `TPixel`, but classes extended from `TPixel` are required to define them.

`TPixel` is a base class that will never be used to create objects from directly. The fact that it has abstract methods makes it indeed impossible to create an object of type `TPixel`, because definitions are still missing. However, we know that at some stage, we want to be able to update objects extended from the base class, and to render them. That is why the abstract methods are already added. Not defining them in extended classes will result in an error message from Monkey. This is a way of reminding the programmer that although we do not provide a definition just yet, in the future these methods need to be defined.

This makes your code more portable: if you hand this class to another programmer, the fact that the methods are abstract will help that other programmer to make proper use of the class. He or she will be able to see instantly what should be added to any classes extended from the base class.

8. TPlayer class

8.1. Description of player.monkey

In the chapter about file pixel.monkey it was explained that TPixel was a base class, from which other classes could be extended. The TPlayer class is one such extended class, TEnemy being the other. TPlayer is a class that represents the player on screen. Being extended from TPixel it does everything TPixel does, plus what we add in TPlayer. We also need to come up with definitions for the abstract methods in TPixel, update() and render(). If we would not add actual definitions for those methods, TPlayer would itself only be able to function as a base class. But we actually want to create an instance of it, namely the player.

You will see that TPlayer is not a very big class. Most of its functionality has already been taken care of by TPixel on which it is based. What is added is in fact the definitions for update(), the method that deals with moving the pixel around based on keyboard input, and render(), the method that displays the pixel on the screen.

```
' Monkey Pixels, Foppygames 2011
' player.monkey

Import mojo

Import constants
Import deltatimer
Import pixel

Class TPlayer Extends TPixel
    The keyword Extends followed by the name of the base class tells Monkey that this new
    class TPlayer is based on (extended from) the base class TPixel.

    Method New()
        Super.New(SCREEN_WIDTH/2,SCREEN_HEIGHT/2)

        The constructor of a class (the child class) that is extended from a base class
        (the parent class) replaces the constructor of the base class. This is true for
        any method defined in the child class that is also in the parent class: when
        called upon in the context of the child class, the child class version is the
        one that will be used. If you still want to use the method as defined in the
        parent class, you have to add Super in front of the method name. This is done
        here: Super.New() means that as part of the child class constructor, we are
        calling the constructor as defined in the parent class. Here we pass along two
        fixed values that represent the center of the screen. In other words, the
        constructor of TPlayer creates a pixel object at the center of the screen.

    End

    Method update:Void()
        This method is called from the update function in TPixel to move the object. In
        the case of TPlayer, the movement is based on keys hit. The player controls his
        or her pixel using the arrow keys (up, down, left, right). The amount by which
        x and y are changed is multiplied by the current delta time factor. How this
        works is explained in the delta time chapter. It basically adjusts the pixel's
        speed so that in the case of program slowdown the pixel still moves at the
        intended speed.

        ' move player based on keys hit
        If (KeyDown(KEY LEFT)) Then
            fX -= PLAYER_SPEED*TDeltaTimer.gDeltaFactor
        Else If (KeyDown(KEY RIGHT)) Then
            fX += PLAYER_SPEED*TDeltaTimer.gDeltaFactor
        End If
        If (KeyDown(KEY UP)) Then
            fY -= PLAYER_SPEED*TDeltaTimer.gDeltaFactor
        Else If (KeyDown(KEY DOWN)) Then
            fY += PLAYER_SPEED*TDeltaTimer.gDeltaFactor
        End If
```

```
stayOnScreen()
Method stayOnScreen() is part of TPixel. As TPlayer is extended from TPixel, it
can make use of this method. It is called after changing fX and fY to adjust
those values so the pixel stays on screen.

' also store player location in global variables
gPlayerX = fX
gPlayerY = fY
The location of the player is now stored in globals defined in TPixel (and
therefore usable from TPlayer, the child class) so that it may be used by
pixels of type TEnemy (which will be shown in the next chapter to also be a
child class of TPixel).
End Method

Method render:Void()
Method render() is called from the render function of TPixel to draw all pixel
objects. It draws a solid green rectangle at the current location.

SetAlpha(1)
SetColor(0,255,0)
DrawRect(fX,fY,fW,fH)
End Method
End
```

9. TEnemy class

9.1. Description of enemy.monkey

The class defined in enemy.monkey is TEnemy. It is extended from the base class TPixel. Like TPlayer, it defines the render() and update() methods, but this time the result is an object that is controlled by the computer instead of through the keyboard.

```
' Monkey Pixels, Foppygames 2011
' enemy.monkey

Import mojo

Import constants
Import deltatimer
Import pixel

Class TEnemy Extends TPixel
    TEnemy extends TPixel, just like TPlayer did. TEnemy and TPlayer have the same parent
    class.

    Field fAlpha:Float
    Field fSpecial:Bool
    Field fSpecialCountDown:Float

    Method New()
        Super.New(gPlayerX+Rnd(-LAUNCH_RADIUS,LAUNCH_RADIUS),gPlayerY+Rnd(-
        LAUNCH_RADIUS,LAUNCH_RADIUS))
        Like TPlayer, TEnemy also calls the construtor of its parent class. This time
        the location that is passed along is based on the location of the player, as we
        want the enemy pixel to appear close to the player.

        fAlpha = 0
        fSpecial = False

        ' enemy will become special
        If (Int(Rnd(100)) < SPECIAL_CHANCE) Then
            fSpecialCountDown = Rnd(600,1200)
        ' enemy will not become special
        Else
            fSpecialCountDown = 0
        End If
        Some enemies will be 'special'. Here we basically throw a dice to see if this
        enemy will become special. Int(Rnd(100)) gives a random number between 0
        (inclusive) and 100 (exclusive). If the number is smaller than SPECIAL_CHANCE,
        it will become special. As an example, if we were to set SPECIAL_CHANCE to 100,
        the random number would always be smaller than that, resulting in a 100% chance
        of the enemy becoming special. If the enemy is special, its special count down
        is set to a number that is higher than zero. If that count down reaches zero
        (later on) the enemy will truely become special and start blinking.

    End

    Method update:Void()
        The update method of the enemy pixel moves it around at random, but only if it
        is fully visible. If not fully visible, it will continue to increase its fAlpha
        value until the enemy is visible (fAlpha is then 1).

        ' enemy is fully visible
        If (fAlpha = 1) Then
            ' move enemy in random direction
            fX += (Int(Rnd(3))-1)*ENEMY_SPEED*TDeltaTimer.gDeltaFactor
            fY += (Int(Rnd(3))-1)*ENEMY_SPEED*TDeltaTimer.gDeltaFactor
            The x and y values are changed by a value that is either -1, 0 or 1
            times the enemy pixel speed. For the x component, that means it will
            move to the left, stay were it is, or move to the right respectively.
            Int(Rnd(3)) is a random value that is 0, 1 or 2. If we then subtract 1
            from that, we get -1, 0 or 1.
```

```

stayOnScreen()
As in TPlayer, we need to make sure the pixel stays on screen.

Next, we check if this enemy is close to the player. If so this is
registered as a hit in the global variable gPlayerHit. Except if the
enemy is special, in that case it is registered as a special hit in
gSpecialHit. In both cases the enemy is deactivated.
' player is near enemy horizontally
If (Abs(gPlayerX-fX) < HIT_RADIUS) Then
    ' player is near enemy vertically
    If (Abs(gPlayerY-fY) < HIT_RADIUS) Then
        ' enemy is normal
        If (Not(fSpecial)) Then
            gPlayerHit = True
            fActive = False
        ' enemy is special
        Else
            gSpecialHit = True
            fActive = False
        End If
    End If
End If
' enemy is still appearing
Else
    fAlpha += ENEMY_ALPHA_CHANGE*TDeltaTimer.gDeltaFactor
The speed by which an enemy changes from transparent to solid is also
adjusted by the delta time factor.

    If (fAlpha > 1) Then
        fAlpha = 1
    End If
End If

If the enemy is destined to become special (if it is currently counting down),
we continue counting down on its special count down. When that reaches zero,
fSpecial is set to true. This will affect the way the pixel is drawn in its
render() method. It will also change the result of a hit with the player as
seen above.
' enemy is counting down to becoming special
If (fSpecialCountDown > 0) Then
    fSpecialCountDown -= 1.0*TDeltaTimer.gDeltaFactor
    ' countdown has finished
    If (fSpecialCountDown <= 0) Then
        fSpecialCountDown = 0
        fSpecial = True
    End If
End If
End Method

Method render:Void()
The render method of TEnemy draws a red pixel normally, but if the enemy is
special it will pick a random color for the drawing each time, resulting in a
blinking pixel.

SetAlpha(fAlpha)
The enemy's fAlpha value is used for the alpha value in drawing the pixel.

    If (Not(fSpecial)) Then
        SetColor(255,0,0)
    Else
        Local color:Int = Int(Rnd(256))
        SetColor(color,color,color)
    End If
    DrawRect (fX, fY, fW, fH)
End Method
End

```