Safe Slide

New Mexico Supercomputing Challenge
Final Report
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Team 33
Down To Earth School

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Executive Summary:

Many children are burned at playgrounds throughout the United States every year. Often, burns occur to children under the age of 10 due to sensitive skin. Because of these incidents, I wanted to develop a model that could predict surface temperature that could be used to provide safer playground materials.

My project uses a number of variables, including; ambient air temperature, convection, reflectivity, and emissivity. Ambient air temperature is the temperature of the air surrounding the material. Convection is the amount of air flow that has access to the material. Reflectivity is the material's ability to reflect heat, Emissivity is the material's ability to retain heat.

I also considered how color may affect the temperature of the given material. Lighter colors such as white, tend to reflect light instead of capturing it. Darker colors like black however tend to trap the light and turn it into heat energy, making the surface area hotter. Therefore, a lighter materials temperature would be less than darker colored materials would be.   The reflectivity of an object is the inverse of its ability to absorb radiant heat. Reflectivity is easy to see, shiny metals are highly reflective. Another factor that affects temperature is emissivity. Emissivity is not easy to see, you can feel the heat of it, if you move near. Emissivity is also a surface property; materials with a high reflectivity have a low emissivity. This is why shiny metals get hot in the sun; while it is reflecting most of the heat away it can only emit heat slowly so it gets really hot. Based on these factors, the model predicts the surface temperature of the material.

Statement of problem:

Many children all over the U.S get burns, many serious, every year. My project "Safe Slide" is about the effects heat can have on slides based on the material and density and burns hot slides can cause children. In Knoxville Tennessee a child got 2nd and 3rd degree burns on her knees from a slide that was measured at 140 degrees Fahrenheit. Later that year another child had burns on her feet from the slide at a water park. In Des Moines Iowa an 18 month old got 2nd degree burns on the hands, knees, and stomach from a 160 degree slide. At a fall festival in California a 3 year old got burned on a 100 degree inflatable slide. These are problems that could possibly be avoided with the right research and precautions.

Different burn degrees occur at different temperatures. 1st degree burns begin to take place at 115 degrees after 45 minutes. 2nd degree burns start at 130 after 30 seconds, and 3rd degree at 140 after 5 seconds. To give and example of how intense burns can be, skin ignites at 480 degrees. (All temperatures are in Fahrenheit.)

Through research and modeling, I hope I can find a safer alternative and as a result, reduce the number of children that get burned. I have selected two different materials, steel and plastic. I will be modeling how heat affects these materials and find which is safer for playgrounds so children can avoid getting burned. In the model I have one square representing the material, there are different sliders attached to the material that change emissivity, reflectivity, thermal convection, and ambient air temperature. The background changes color based on the ambient air temperature. There is an equation set up in the model that works out and predicts the temperature.

Method used to solve problem:

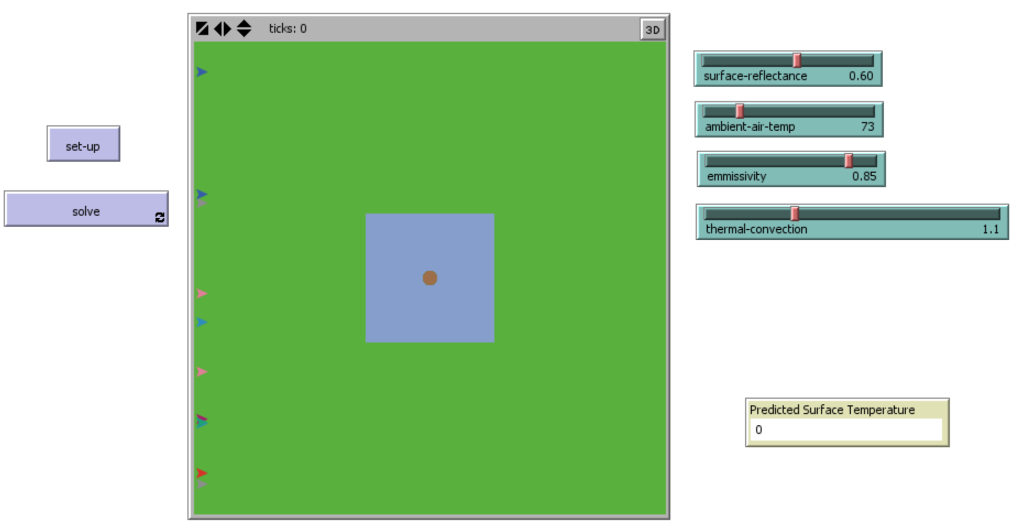
The method I used in my model is based on an equation:

Heat = D8*C8 (1-E8)-(F8-G8)/ (1/ (J8*C8))-H8*I8*C8*(F8+460) ^4-460^4))
C = Surface area
D = Derived Solar Radiation
E = Surface Reflection
F = the Predicted Surface Temperature
G = the Ambient Air Temperature
H = Emissivity
I = Sigma
J = Thermal Convection.

This equation was formulated by Dr. Sparrow, and simplified by Robert Thibadeau.

This equation works by solving the other quantities by adding to the surface area until the Heat is at or near 0.

In my model there is a square in the middle that represents the material. The circles exiting the square represent emissivity being emitted from the material. The stars represent the amount of reflectivity, and the arrows moving across the screen represent thermal convection (wind.) Different sliders change the amount of convection, emissivity, and reflectivity. When the temperature gets hot enough to cause burns, then the square will turn red.



Verifying and Validating:

I used my model to get a range of temperatures that certain materials (i.e. plastic and metal) can get. I first imputed the variables of emissivity, reflectivity, ambient air temperature, and thermal convection to get my answers. Once I had the minimum and maximum temperatures I went around the parks in my town and measured the slides with an infrared temperature laser.

Park	Surface Temp	Air Temp	Material	Sun	Shade	Open	Closed	Color	Predicted surface temp
Penny									
	137	77	plastic	yes	no	yes	no	green	117
	91	77	plastic	yes	no	no	yes	green	117
	70.5	77	plastic	no	yes	yes	no	green	117
Virginia St.									
	120.5	69	plastic	yes	no	yes	no	green	112
	68.5	69	plastic	no	yes	yes	no	green	112
Pucket									
	48	70	metal	no	yes	yes	no	red/blue	82 (w/ sun prediction)
Tyrone									
	94.5	85	metal	yes	no	yes	no	NA	92
	89.5	85	metal	yes	no	yes	no	NA	92
	85.5	85	metal	yes	no	yes	no	NA	92
Spring St									
	85.5	85	plastic	yes	no	yes	no	yellow	122
Nobel									
	85	85	plastic	yes	no	yes	no	yellow	122

Results and Conclusion:

Some of our model's predictions were close to the measured temperature. However some were off by many degrees, I believe this may be the result of factors I had not considered, such as shade. Later on in the challenge I hope to apply these factors and get more correct results. The information this model can provide may help the future of building playground equipment. I hope that it will be used to supply safer playground equipment for children.

Significant achievement:

My significant achievements were finding what material is safer for children and playgrounds, finding how hot the materials really can get, and supplying valid information on slides and burns. Hopefully this information will be used to prevent future injuries.

Acknowledgements:

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Appendix: Program Code

```
globals [
  derived-solar-radiation
  material
  surface-area
  sigma
  surface-temp
  heating
]
breed [materialss materials]
breed [reflects reflect]
breed [emmis emmi]
breed [winds wind]
to set-up
  clear-all
  reset-ticks
  set-default-shape reflects "star"
  set-default-shape emmis "circle"
  set surface-area 100
  set derived-solar-radiation 205
  set sigma 0.000000001712
  set surface-temp 0
  create-reflects surface-reflectance * 10
  create-emmis emmissivity * 10
  ask patches
  [ if (ambient-air-temp >= 60) and( ambient-air-temp <= 70)
    [ set pcolor blue]]
  ask patches
  [ if (ambient-air-temp > 70) and( ambient-air-temp <= 80)
    [ set pcolor green]]
  ask patches
  [ if (ambient-air-temp > 80) and( ambient-air-temp <= 90)
    [ set pcolor yellow]]
  ask patches
  [ if (ambient-air-temp > 90) and( ambient-air-temp <= 100)
    [ set pcolor orange]]
  ask patches
  [ if (ambient-air-temp > 100) and( ambient-air-temp <= 110)
    [ set pcolor red]]
  ask patches
  [ if (ambient-air-temp > 110) and( ambient-air-temp <= 120)
    [ set pcolor white]]
    ask patches
 [if (pxcor >= -4 and pxcor <= 4 and pycor >= -4 and pycor <= 4)
   [set pcolor 107]]
```

```
create-winds thermal-convection * 10
[setxy -16 random-ycor]
    ask winds
    [set heading 90 ]
end
to solve
  set heating derived-solar-radiation * surface-area * (1 - surface-reflectance)-(surface-
temp - ambient-air-temp)/(1 / (thermal-convection * surface-area)) - emmissivity * sigma
* surface-area * ((surface-temp + 460) ^ 4 -  44774560000)
    if (heating < 2)
       [
         if surface-temp >= 115
         [ask patches
           [if pcolor = 107
           [set pcolor red]]]stop]
   if (heating > 2)
   [ set surface-temp surface-temp + .01]
   show-reflectivity
   show-emissivity
   show-thermal-convection
end
to show-reflectivity
    ask reflects
    [
      set color white
    if pcolor = 107
    [ fd  .5
      set color yellow
      rt random 40
      lt random 40
      set color white
      ]
    set color yellow
   if pcolor != 107
   [set xcor random -4
     set ycor random 4]
    ]
end
to show-emissivity
         ask emmis
    [ fd  .5
      rt random 40
      lt random 40]
end
to show-thermal-convection
  ask winds [
```

```
    pen-down
    set color grey
    rt random 2
    lt random 2
   fd .5
  ]
end
```