Meet - Computer Graphics T

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Indrajit Banerjee is presenting

2 Scan Converting Circles

Indrajit Banerjee
2020ITB009 DIPA...
2020ITB046 AADA...
2020ITB102 GURU...
2020ITB066 GOLI_...
2020ITB064 VISHA...
2020ITB036 KODA...
2020ITB054 MON...
2020ITB073 AKAN...
2020ITB094 CHER...
2020ITB058 ADITY...
2020ITB089 ABHIS...
2020ITB055 DEBO...
2020ITB091 A.PRA...
2020ITB070 VART...
2020ITB041 ADES...
26 others
You

10:02 AM | Computer Graphics Theory

44

3 Scan Converting Circles

- SRGP does not offer a circle primitive
- Circular ellipse arc has an 8-ways symmetry
- $x^2 + y^2 = R^2$
- Circle can be translated to origin
- Draw one quarter by incrementing unit steps in x from 0 to R. Solve for +y in each step. Then exploit symmetry.
- As x approaches R the gap in value computed becomes large.
- Inefficient because of square and root calculation
- Another inefficient method is to compute (RcosΘ, RsinΘ) with Θ from 0^0 to 90^0

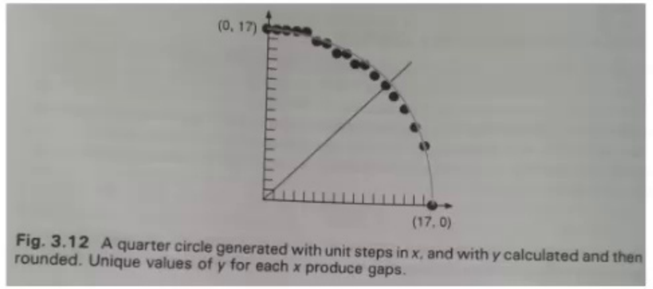

Fig. 3.12 A quarter circle generated with unit steps in x, and with y calculated and then rounded. Unique values of y for each x produce gaps.

1. Eight way symmetry
2. Midpoint circle algorithm
   1. Second Order difference

2 Midpoint circle algorithm

$d_{old} = F(x_p+1, y_p -½)$
$= (x_p+1)^2 + (y_p -½)^2 + R^2$

If $d_{old} < 0$

E $d_{new} = F(x_p+2, y_p -½)$
$= (x_p+2)^2 + (y_p -½)^2 + R^2$
$= d_{old} + (2x_p + 3).\ \Delta_E = (2x_p + 3)$

If $d_{old} >= 0$

SE $d_{new} = F(x_p+2, y_p - 3/2)$
$= (x_p+2)^2 + (y_p - 3/2)^2 + R^2$
$= d_{old} + (2x_p - 2y_p + 5).\ \Delta_{SE} = 2x_p - 2y_p + 5$

- Δ_E and Δ_{SE} Vary at each step unlike the linear case.
- (x_p, y_p) is called the point of evaluation
- Chose the pixel based on the sign of variable d in the previous iteration
- Update the decision variable d with the Δ that corresponds to the choice of pixel.
- Starting point is (0, R).
- The next mid-point is (1, R- ½)
- $F(1, R- ½) = 1 + (R^2 + - R + ¼) - R^2 = 5/4 - R$

```
void MidpointCircle (int radius, int value)
/* Assumes center of circle is at origin */
{
    int x = 0;
    int y = radius;
    double d = 5.0 / 4.0 - radius;
    CirclePoints (x, y, value);

    while (y > x) {
        if (d < 0)          /* Select E */
            d += 2.0 * x + 3.0;
        else {              /* Select SE */
            d += 2.0 * (x - y) + 5.0;
            y--;
        }
        x++;
        CirclePoints (x, y, value);
    } /* while */
} /* MidpointCircle */
```

Fig. 3.15 The midpoint circle scan-conversion algorithm.

Midpoint circle algorithm
Second Order Difference

- We noted that Δ functions were linear and we computed them directly.
- Any polynomial can be computed incrementally as we did with line and circle.
- We calculate the first and second order partial difference.
  - Evaluate function directly at two adjacent points
  - Calculate the difference (which for a polynomial is always a polynomial of lower degree)
  - Apply the difference in each iteration

Midpoint circle algorithm Second Order Difference

- $\Delta_{E_{old}}(x_p, y_p) = 2x_p+3$
- $\Delta_{E_{new}}(x_p+1\ y_p)$
  $= 2(x_p+1)+ 3$
  $\Delta_{E_{new}} - \Delta_{E_{old}} = 2$
- $\Delta_{SE_{old}}(x_p, y_p) = 2x_p - 2x_p+5$
- $\Delta_{SE_{new}}(x_p+1, y_p)$
  $= 2(x_p+1)- 2y_p+5$
  $\Delta_{SE_{new}} - \Delta_{SE_{old}} = 2$
- If we choose SE in current iteration point moves from (x_p, y_p) to (x_p+1, y_p-1)
- $\Delta_{E_{new}}(x_p+1, y_p-1)$
  $= 2(x_p+1)+ 3.$
  $\Delta_{E_{new}} - \Delta_{E_{old}} = 2$

$\Delta_{SE_{new}}(x_p+1, y_p-1)$
$= 2(x_p+1)- 2(y_p-1)+5$
$\Delta_{SE_{new}} - \Delta_{SE_{old}} = 4$

```
void MidpointCircle (int radius, int value)
/* This procedure uses second-order partial differences to compute increments */
/* in the decision variable. Assumes center of circle is at origin */
{
   int x = 0;
   int y = radius;
   int d = 1 - radius;
   int deltaE = 3;
   int deltaSE = -2 * radius + 5;
   CirclePoints (x, y, value);

   while (y > x) {
      if (d < 0) {              /* Select E`*/
         d += deltaE;
         deltaE += 2;
         deltaSE += 2;
      } else {
         d += deltaSE;          /* Select SE */
         deltaE += 2;
         deltaSE += 4;
         y--;
      }
      x++;
      CirclePoints (x, y, value);
   } /* while */
} /* MidpointCircle */
```

Fig. 3.18 Midpoint circle scan-conversion algorithm using second-order differences.

Midpoint circle algorithm
Second Order Difference

- We noted that Δ functions were linear and we computed them directly.
- Any polynomial can be computed incrementally as we did with line and circle.
- We calculate the first and second order partial difference.
  - Evaluate function directly at two adjacent points
  - Calculate the difference (which for a polynomial is always a polynomial of lower degree)
  - Apply the difference in each iteration

2 Midpoint circle algorithm

$d_{old} = F(x_p+1, y_p - ½)$
$= (x_p+1)^2 + (y_p - ½)^2 + R^2$

If $d_{old} < 0$

E $d_{new} = F(x_p+2, y_p - ½)$
$= (x_p+2)^2 + (y_p - ½)^2 + R^2$
$= d_{old} + (2x_p + 3)$. $\Delta_E = (2x_p + 3)$

If $d_{old} >= 0$

SE $d_{new} = F(x_p+2, y_p - 3/2)$
$= (x_p+2)^2 + (y_p - 3/2)^2 + R^2$
$= d_{old} + (2x_p - 2y_p + 5)$. $\Delta_{SE} = 2x_p - 2y_p + 5$

- Δ_E and Δ_{SE} Vary at each step unlike the linear case.
- (x_p, y_p) is called the point of evaluation
- Chose the pixel based on the sign of variable d in the previous iteration
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```
void MidpointCircle (int radius, int value)
/* Assumes center of circle is at origin */
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    while (y > x) {
        if (d < 0)          /* Select E */
            d += 2.0 * x + 3.0;
        else {              /* Select SE */
            d += 2.0 * (x - y) + 5.0;
            y--;
        }
        x++;
        CirclePoints (x, y, value);
    } /* while */
} /* MidpointCircle */
```

Fig. 3.15 The midpoint circle scan-conversion algorithm.

1. Eight way symmetry

- For any given point (x,y) we can trivially draw 7 other points as in diagram.
- If we draw a 45^0 segment we can draw a circle
- Also avoid the boundary condition where x = y= R √2. This one to be drawn only 4 times.

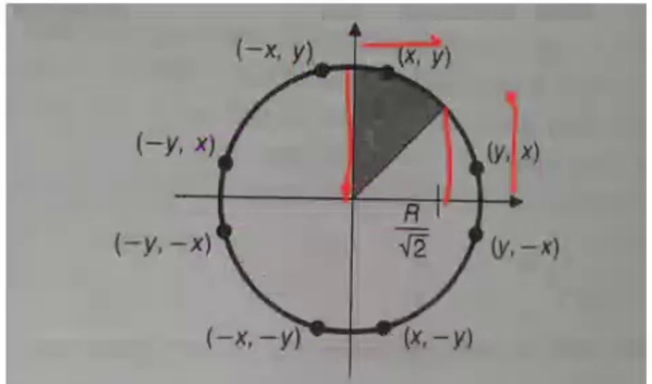

Fig. 3.13 Eight symmetrical points on a circle.

```
Void CirclePoints(int x, int y, int value)
{
    WritePixel( x,  y,value);
    WritePixel( y,  x,value);
    WritePixel( y, -x,value);
    WritePixel( x, -y,value);
    WritePixel(-x, -y,value);
    WritePixel(-y, -x,value);
    WritePixel(-y,  x,value);
    WritePixel(-x,  y,value);
    /* CirclePoints */
```

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- Circle can be translated to origin
- Draw one quarter by incrementing unit steps in x from 0 to R. Solve for +y in each step. Then exploit symmetry.
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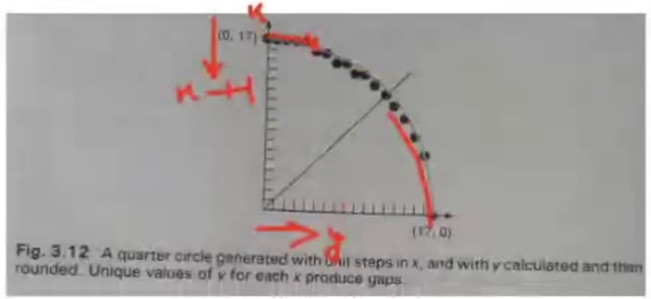

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2. Midpoint circle algorithm
   1. Second Order difference

2 Midpoint circle algorithm

- Bresenham: More efficient that 8-way symmetry. Go all the way round the circle.
- Mid-point algorithm: integer centre and radius.
- Second Octant: Consider 45^0 between x=0 to x=y=R/√2.
- Evaluate mid-point between pixels and find which is closer to the circle.

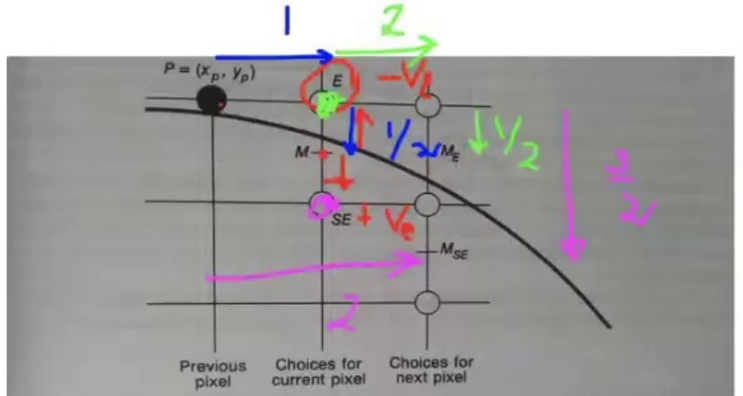

Fig. 3.14 The pixel grid for the midpoint circle algorithm showing *M* and the pixels *E* and *SE* to choose between.

If pixel P is at (x_p, y_p) has been choosen previously select between E and SE.
$F(x,y) = X^2 + y^2 - R^2$ is 0 on the circle +ve outside and –ve inside. If mid-point outside select SE else E

2 Midpoint circle algorithm

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If $d_{old} >= 0$

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{
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    while (y > x) {
        if (d < 0)          /* Select E */
            d += 2.0 * x + 3.0;
        else {              /* Select SE */
            d += 2.0 * (x - y) + 5.0;
            y--;
        }
        x++;
        CirclePoints (x, y, value);
    } /* while */
} /* MidpointCircle */
```

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Midpoint circle algorithm
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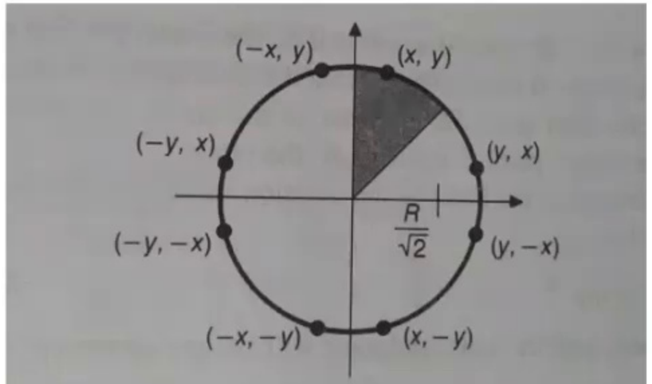

Fig. 3.13 Eight symmetrical points on a circle.

```
Void CirclePoints(int x, int y, int value)
{
        WritePixel( x,  y,value);
        WritePixel( y,  x,value);
        WritePixel( y, -x,value);
        WritePixel( x, -y,value);
        WritePixel(-x, -y,value);
        WritePixel(-y, -x,value);
        WritePixel(-y,  x,value);
        WritePixel(-x,  y,value);
        /* CirclePoints */
```

Midpoint circle algorithm Second Order Difference

- $\Delta_{Eold}(x_p, y_p) = 2x_p+3$
- $\Delta_{Enew}(x_p+1\ y_p)$
  $= 2(x_p+1)+ 3$
  $\Delta_{Enew} - \Delta_{Eold} = 2$
- $\Delta_{SEold}(x_p, y_p) = 2x_p - 2x_p+5$
- $\Delta_{SEnew}(x_p+1, y_p)$
  $= 2(x_p+1)- 2y_p+5$
  $\Delta_{SEnew} - \Delta_{SEold} = 2$
- If we choose SE in current iteration point moves from (x_p, y_p) to (x_p+1, y_p-1)
- $\Delta_{Enew}(x_p+1, y_p-1)$
  $= 2(x_p+1)+ 3.$
  $\Delta_{Enew} - \Delta_{Eold} = 2$

$\Delta_{SEnew}(x_p+1, y_p-1)$
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$\Delta_{SEnew} - \Delta_{SEold} = 4$

```
void MidpointCircle (int radius, int value)
/* This procedure uses second-order partial differences to compute increments */
/* in the decision variable. Assumes center of circle is at origin */
{
   int x = 0;
   int y = radius;
   int d = 1 - radius;
   int deltaE = 3;
   int deltaSE = -2 * radius + 5;
   CirclePoints (x, y, value);

   while (y > x) {
      if (d < 0) {              /* Select E */
         d += deltaE;
         deltaE += 2;
         deltaSE += 2;
      } else {
         d += deltaSE;          /* Select SE */
         deltaE += 2;
         deltaSE += 4;
         y--;
      }
      x++;
      CirclePoints (x, y, value);
   } /* while */
} /* MidpointCircle */
```

Fig. 3.18 Midpoint circle scan-conversion algorithm using second-order differences.

Meet - Computer Graphics T

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Indrajit Banerjee is presenting

4 Scan Converting Ellipses

Indrajit Banerjee

2020ITB009 DIPA...

2020ITB046 AADA...

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2020ITB094 CHER...

2020ITB058 ADITY...

2020ITB089 ABHIS...

2020ITB055 DEBO...

2020ITB029 JATIN...

2020ITB075 TAMO...

R510819001 JISHU_SHIT has raised a hand

Open queue

10:15 AM | Computer Graphics Theory

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4 Scan Converting Ellipses

1. Standard ellipse centered at (0,0) is

   $b^2x^2 + a^2y^2 - a^2b^2 = 0$

2. Draw for Quad 1 and apply symmetry.
3. Divide Quad in 2 by -1 slope point.
4. The perpendicular to tangent will have slope = 1

grad F(x,y) = $\delta F/\delta x\, i + \delta F/\delta y\, j$

$= 2\, b^2x\, i + 2\, a^2y\, j$

5. $b^2x = a^2y$ and at the next mid-point $b^2(x_p+1) >= a^2(y_p - ½)$

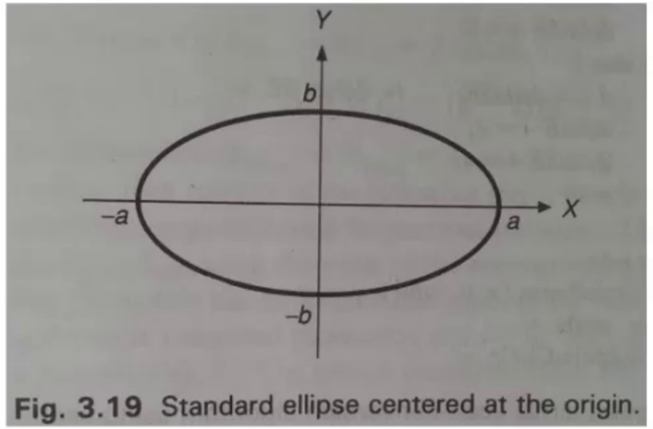

Fig. 3.19 Standard ellipse centered at the origin.

4 Scan Converting Ellipses

1. In Region 1 the y component is larger.
2. In region 1 you selct between E and SE
3. In region 2 select between S and SE

$d_{old}=F(x_p+1, y_p-½) = b^2(x_p+1)^2 + a^2(y_p-½)^2 - a^2b^2$

$d_{new}=F(x_p+2, y_p-½) = b^2(x_p+2)^2 + a^2(y_p-½)^2 - a^2b^2$ To move E

$d_{new}= d_{old} + b^2(2x_p+3)$

$\Delta_E = b^2(2x_p+3)$

$d_{new}=F(x_p+2, y_p-3/2) = b^2(x_p+2)^2 + a^2(y_p-3/2)^2 - a^2b^2$ To move SE

$d_{new}= d_{old} + b^2(2x_p+3) + a^2(-2y_p+2)$

$\Delta_{SE} = b^2(2x_p+3) + a^2(-2y_p+2)$

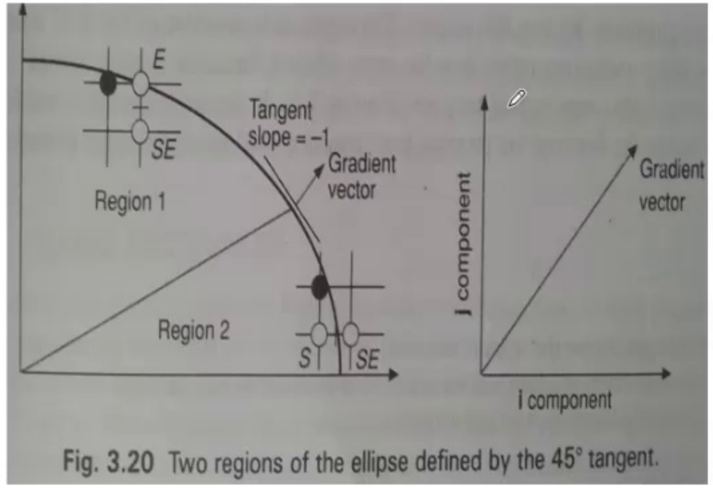

Fig. 3.20 Two regions of the ellipse defined by the 45° tangent.

4 In Region 2 decision variable d_2 is $F(x_p+1/2, y_p-1)$

4 Scan Converting Ellipses

1. Start at (0, b) and the first mid-point will be (1, b- ½) at each mid-point decide if you need to shift region by gradient evaluation.

$F(1, b - 1/2) = b^2 + a^2 (b - 1/2)^2 - a^2b^2 = b^2 + a^2(-b + 1/4)$.

```
void MidpointEllipse (int a, int b, int value)
/* Assumes center of ellipse is at the origin. Note that overflow may occur */
/* for 16-bit integers because of the squares. */
{
   double d2;

   int x = 0;
   int y = b;
   double d1 = b^2 - (a^2 b) + (0.25 a^2);
   EllipsePoints (x, y, value);                    /* The 4-way symmetrical WritePixel */

   /* Test gradient if still in region 1 */
   while ( a^2 (y - 0.5) > b^2 (x + 1) ) {         /* Region 1 */
      if (d1 < 0)                                  /* Select E */
         d1 += b^2 (2x + 3);
      else {                                       /* Select SE */
         d1 += b^2 (2x + 3) + a^2 (-2y + 2);
         y--;
      }
      x++;
      EllipsePoints (x, y, value);
   } /* Region 1 */

   d2 = b^2 (x + 0.5)^2 + a^2 (y - 1)^2 - a^2 b^2;
   while (y > 0) {                                 /* Region 2 */
      if (d2 < 0) {                                /* Select SE */
         d2 += b^2 (2x + 2) + a^2 (-2y + 3);
         x++;
      } else
         d2 += a^2 (-2y + 3);                      /* Select S */
      y--;
      EllipsePoints (x, y, value);
   } /* Region 2 */
} /* MidpointEllipse */
```

Fig. 3.21 Pseudocode for midpoint ellipse scan-conversion algorithm.

4 Scan Converting Ellipses

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2. In region 1 you selct between E and SE
3. In region 2 select between S and SE

$d_{old}=F(x_p+1, y_p-½) = b^2(x_p+1)^2 + a^2(y_p-½)^2 - a^2b^2$

$d_{new}=F(x_p+2, y_p-½) = b^2(x_p+2)^2 + a^2(y_p-½)^2 - a^2b^2$ To move E

$d_{new}= d_{old} + b^2(2x_p+3)$

$\Delta_E = b^2(2x_p+3)$

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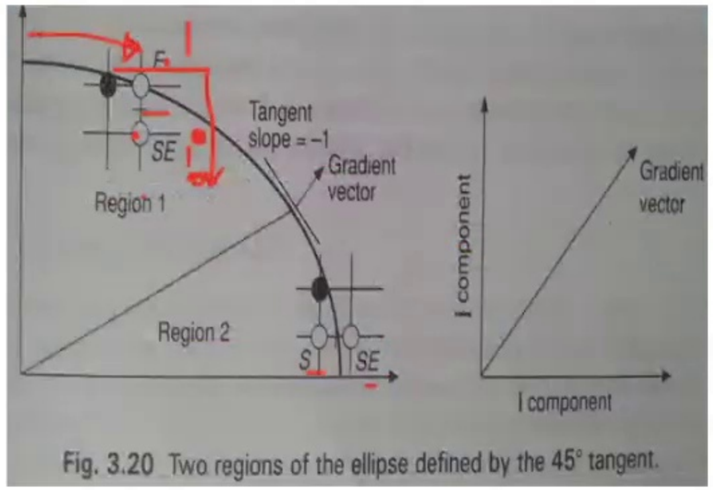
$\Delta_{SE} = b^2(2x_p+3) + a^2(-2y_p+2)$



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4 Scan Converting Ellipses

1. Start at (0, b) and the first mid-point will be (1, b- ½) at each mid-point decide if you need to shift region by gradient evaluation.

   $F(1, b - 1/2) = b^2 + a^2 (b - 1/2)^2 - a^2b^2 = b^2 + a^2(-b + 1/4)$.

```
void MidpointEllipse (int a, int b, int value)
/* Assumes center of ellipse is at the origin. Note that overflow may occur */
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{
   double d2;

   int x = 0;
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   double d1 = b^2 - (a^2 b) + (0.25 a^2);
   EllipsePoints (x, y, value);                    /* The 4-way symmetrical WritePixel */

   /* Test gradient if still in region 1 */
   while (a^2(y - 0.5) > b^2(x + 1)) {             /* Region 1 */
      if (d1 < 0)                                  /* Select E */
         d1 += b^2(2x + 3);
      else {                                       /* Select SE */
         d1 += b^2(2x + 3) + a^2(-2y + 2);
         y--;
      }
      x++;
      EllipsePoints (x, y, value);
   } /* Region 1 */

   d2 = b^2(x + 0.5)^2 + a^2(y - 1)^2 - a^2b^2;
   while (y > 0) {                                 /* Region 2 */
      if (d2 < 0) {                                /* Select SE */
         d2 += b^2(2x + 2) + a^2(-2y + 3);
         x++;
      } else
         d2 += a^2(-2y + 3);                       /* Select S */
      y--;
      EllipsePoints (x, y, value);
   } /* Region 2 */
/* MidpointEllipse */
```

Fig. 3.21 Pseudocode for midpoint ellipse scan-conversion algorithm.

Thank You

- End of Session 2
- All material taken from text.
- Computer Graphics
  - Principles and Practice in C
  - By James D. Foley, Andries van Dam, Steven K. Feiner, F. Hughes John
- Text Reference:
  - Chapter 3: Section 3.1 to 3.6

2 Midpoint circle algorithm

- Bresenham: More efficient that 8-way symmetry. Go all the way round the circle.
- Mid-point algorithm: integer centre and radius.
- Second Octant: Consider 45^0 between x=0 to x=y=R/√2.
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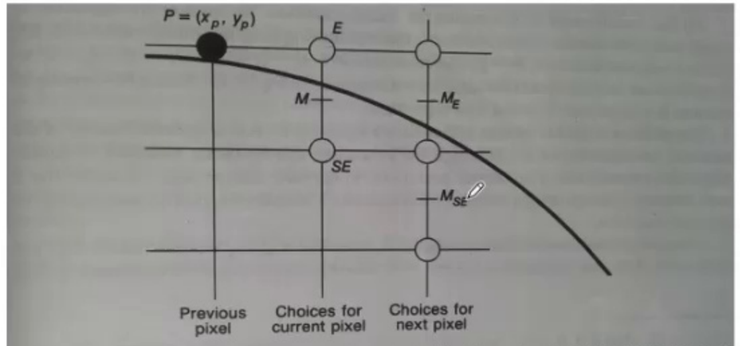

Fig. 3.14 The pixel grid for the midpoint circle algorithm showing *M* and the pixels *E* and *SE* to choose between.

If pixel P is at (x_p, y_p) has been choosen previously select between E and SE.
$F(x,y) = X^2 + y^2 - R^2$ is 0 on the circle +ve outside and –ve inside. If mid-point outside select SE else E

2 Midpoint circle algorithm

$d_{old} = F(x_p+1, y_p -½)$
$= (x_p+1)^2 + (y_p -½)^2 + R^2$
If $d_{old} < 0$
E $d_{new} = F(x_p+2, y_p -½)$
$= (x_p+2)^2 + (y_p -½)^2 + R^2$
$= d_{old} + (2x_p + 3)$. $\Delta_E = (2x_p + 3)$
If $d_{old} >= 0$
SE $d_{new} = F(x_p+2, y_p – 3/2)$
$= (x_p+2)^2 + (y_p – 3/2)^2 + R^2$
$= d_{old} + (2x_p – 2y_p + 5)$. $\Delta_{SE} = 2x_p – 2y_p + 5$

- Δ_E and Δ_{SE} Vary at each step unlike the linear case.
- (x_p, y_p) is called the point of evaluation
- Chose the pixel based on the sign of variable d in the previous iteration
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- The next mid-point is (1, R- ½)
- F (1, R- ½) = 1 +(R^2 +- R + ¼) - R^2 = 5/4 – R

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void MidpointCircle (int radius, int value)
/* Assumes center of circle is at origin */
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    int x = 0;
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    CirclePoints (x, y, value);

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            d += 2.0 * x + 3.0;
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Fig. 3.15 The midpoint circle scan-conversion algorithm.

2 Midpoint circle algorithm

- Bresenham: More efficient that 8-way symmetry. Go all the way round the circle.
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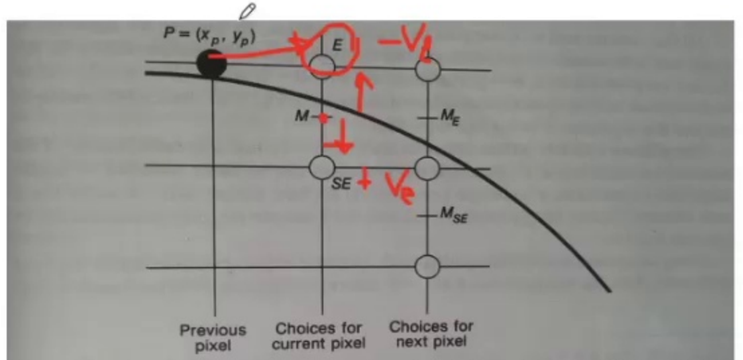

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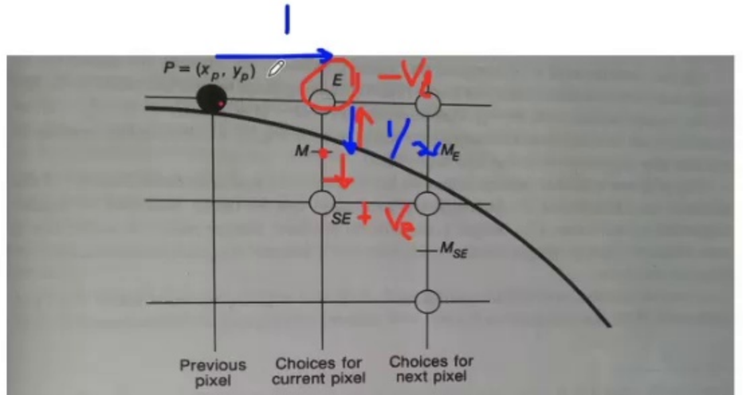

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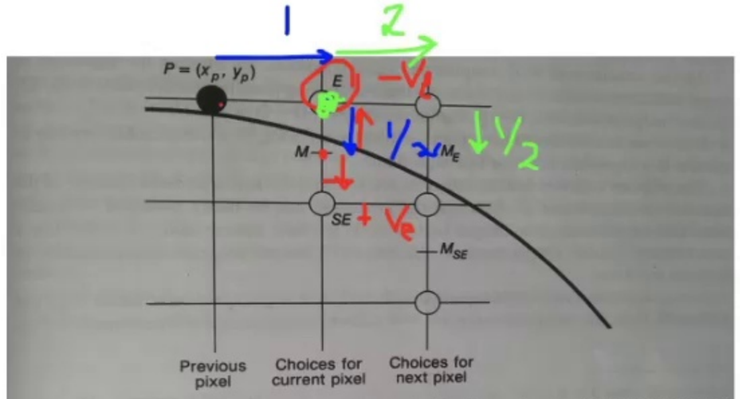

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2020ITB022 PAVAN_KUMAR has left the meeting

Indrajit Banerjee
2020ITB009 DIPA...
2020ITB046 AADA...
2020ITB102 GURU...
2020ITB066 GOLI_...
2020ITB064 VISHA...
2020ITB036 KODA...
2020ITB054 MON...
2020ITB073 AKAN...
2020ITB094 CHER...
2020ITB058 ADITY...
2020ITB089 ABHIS...
2020ITB055 DEBO...
2020ITB029 JATIN...
2020ITB075 TAMO...

R510819001 JISHU_SHIT has raised a hand
Open queue