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A Short Introduction to PostScript

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Getting Information

- Main reference @ Adobe:
  http://partners.adobe.com/public/developer/ps/index_specs.html
  - PLRM = Postscript Language Reference Manual
    (first document)

- Also @ Adobe:
  partners.adobe.com/public/developer/ps/sdk/index_archive.html
  - The ‘Blue Book’ (Language Tutorial and Cookbook)
  - The ‘Green Book’ (Language Program Design)
    (under section ‘PostScript language books and sample code‘)

- Many Web sites (see Lecture Page)

What is PostScript ?

- Postscript is a *language* to describe graphic objects (& text)
- It is a *vector format*
  - Shapes, characters,.. are defined in an exact, mathematical way
  - → objects / characters can be scaled, magnified, rotated... without loss of quality
  - Other vector formats are, for instance: *pdf* (portable data format) and *svg* (scalable vector graphics)

- Postscript is a *programming* language
  - Complex graphics can be described quickly and efficiently

- Postscript devices (printers) must be intelligent, because they must *interpret* the language
  - Otherwise, the host computer must do the translation. Most often using the (free) tool 'ghostscript'

Why Use & Know About Postscript ?

- Simple manual generation of high quality graphics
- Automatic generation of graphics from programs
- Small files
- Postscript is (still) common for LaTeX
- Sometimes, modification of available .ps or .eps files is required
  - Change a font
  - Modify colors or line width
  - Add water mark
- Generating Graphics can be fun ✪

- Drawbacks
  - Conversion to other formats (mainly pixilated) a bit tricky

- Why not pdf? - Much more complicated! Hard to do ‘by hand’!

Simple Example 1: Triangle + Circle

```
%!PS
 newpath
  10  10 moveto
 100  10 lineto
  50 100 lineto
 closepath stroke

 100 100
 10
 0 360 arc fill

showpage
```

start a new line

start at (10/10)

draw lines

connect to start

show outline

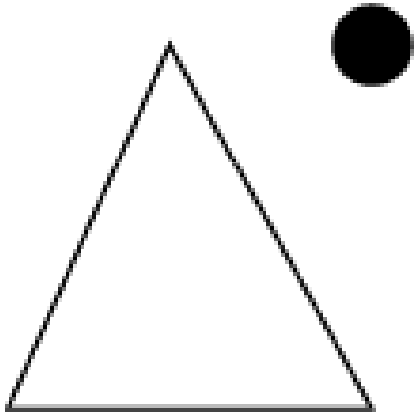
x/y = 100/100

radius = 10

start/stop angle

fill the arc

print everything

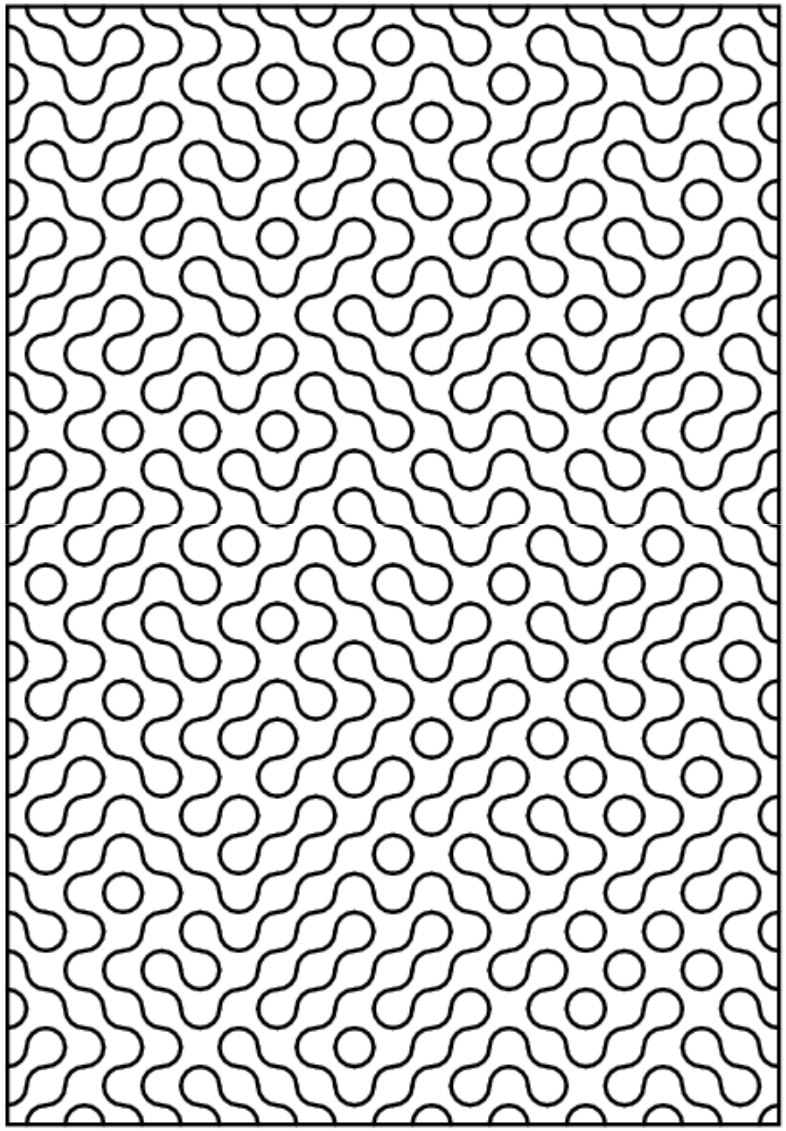


Viewing Postscript Files

- On Linux machines, files can be viewed with
  - ghostview
  - okkular
  - ShowView (?)
  - GSView (?)
- On windows
  - Ghostview
- Always need GhostScript to interpret the language

Advanced Example 2: Truchet Pattern

```
%!PS-Adobe-3.0 EPSF-3.0
%%BoundingBox: 0 0 595 842

2.835 dup scale
5 4 translate 1 setlinecap
0 0 200 290 rectstroke
100 145 translate

/W 10 def /W2 { W 2 div } bind def

/DRAWUNIT {
  gsave  translate rotate
 W2 neg W2 neg W2   0  90 arc stroke
 W2 W2 W2 180 270 arc stroke
  grestore
} def

-95 W 95 {
  /x exch def
  -140 W 140 {
    /y exch def
    rand 4 mod 90 mul  x y  DRAWUNIT
  } for
} for

showpage
```



File Structure

- File MUST start with `%!PS` (or later versions)
  - If forgotten, (most) printers will output (a lot of) ASCII stuff…
- PostScript is *CaseSensitive*!
- Blanks and Line breaks are irrelevant

- Comments
  - In-Line comments start with

```
% … commented code here …
```

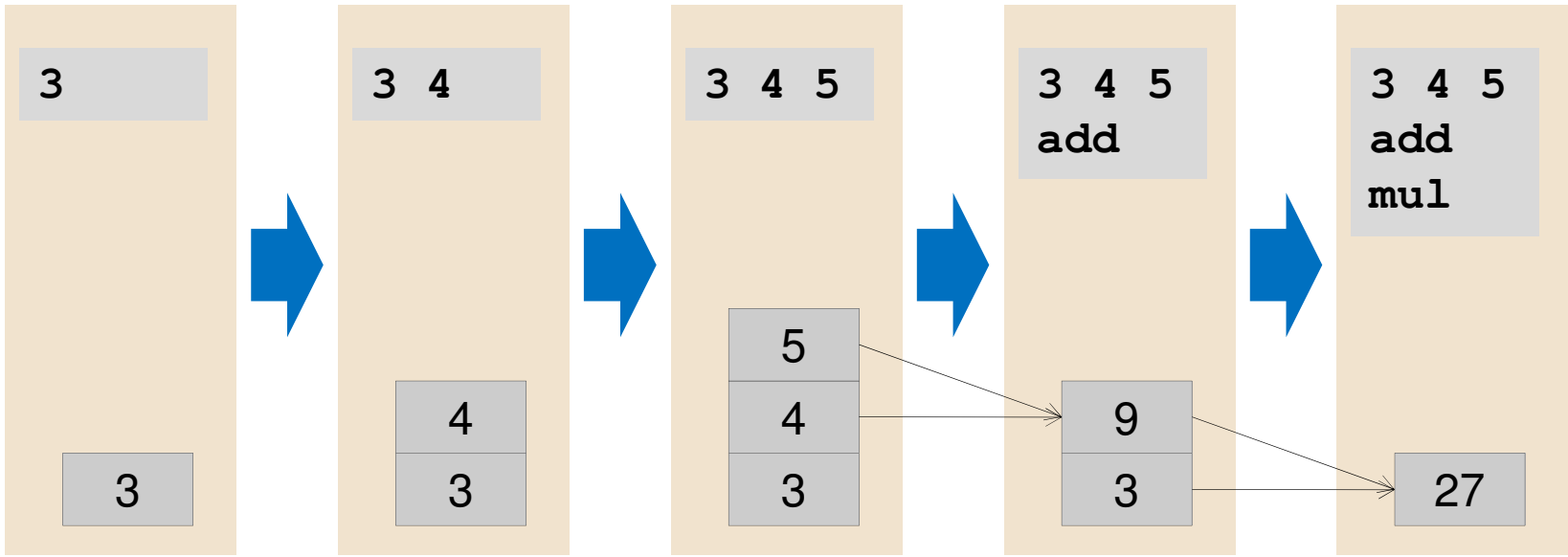
  - Larger code blocks can be commented with

```
false {
 … commented code here …
} if
```

- Files have extension *.ps*
- To *print*, the file must end with **`showpage`**

The Stack

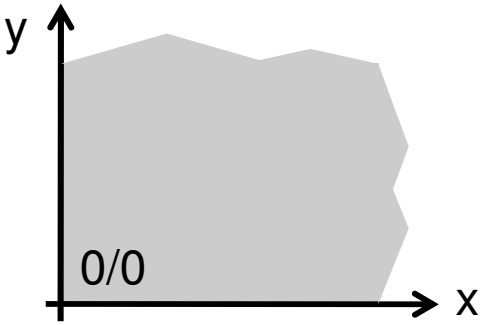
- PostScript uses
  - a stack (Last In - First out)
  - RPN (Reverse Polish Notation) = UPN (Umgekehrt Poln. Notation): Operands are first put to stack, operator is last
- Example `3 4 5 add mul` → (4+5) × 3



- Operators can have *1 or more* arguments

Coordinate System, Lengths and Points

- Origin (0/0) is *BOTTOM LEFT*
- X is to the *RIGHT*
- Y is *UPWARD*



- 1 PostScript Unit = 1 Point = **1/72 inch = 0.353 mm**
  - (1 inch = 2.54 cm)

- Convert *mm* to *point* by multiplying with 72 / 25.4 = 2.835..
- By defining a command (see later...)

```
/mm { 2.835 mul } def
```

  you can just write

```
15 mm
```

  in your code!

- Later we sill use the **`scale`** command to change units...

The Page / Sheet Size

- ‘sheet’ size & orientation are undefined.
  - They depend on the ‘viewer’ or printer

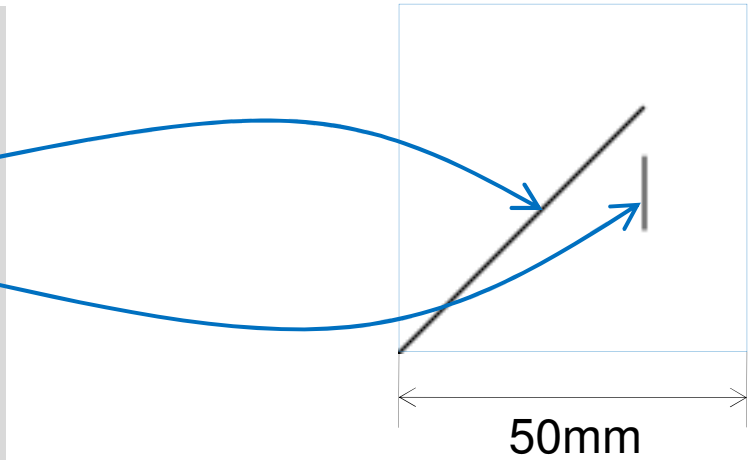
- The size can be ‘fixed’ as a ‘bounding box’ using an encapsulated postscript (eps) command
  - **`%!PS-Adobe-3.0 EPSF-3.0`**
  - **`%%BoundingBox: llx lly urx ury`**
    (***`llx`*** = lower left x, … using *integer postscript* units)
  - Such ‘Encapsulated Postscript’ files have file extension **.eps**

- A4 paper has (portrait)
  - width = 210 mm = 595.28... points
  - height = 297 mm = 841.89... points

Hello World

- Shapes / Outlines are defined as *paths*.
  A *path* is a sequence of straight lines / bends / gaps / …
- **`x y moveto`** moves ‚pen' to coordinate [x y]
- **`x y lineto`** draws a line from last point to [x y]
- **`stroke`** executes the path drawing

```
%!PS
0 0 moveto
100 100 lineto
100 80 moveto
100 50 lineto
stroke
showpage
```



- Remember: 100 Units = 100 × 0.353mm = 35.3mm

- **`rmoveto`** and **`rlineto`** are *relative* to the *last* point

Drawing and Filling Paths

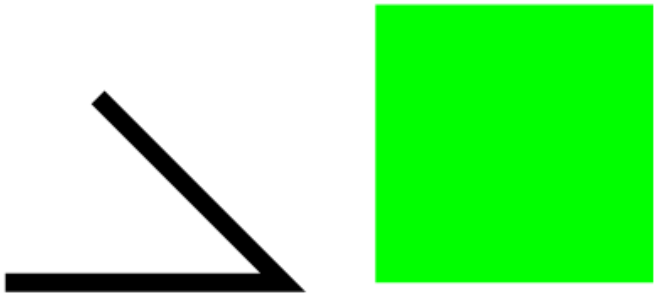
- A path *can* be started with **`newpath`**
- The command **`closepath`** connects the last active point to the starting point (see Example 1)
- A path can be used for further operations (e.g. clipping,…)
- Using a path is not always necessary

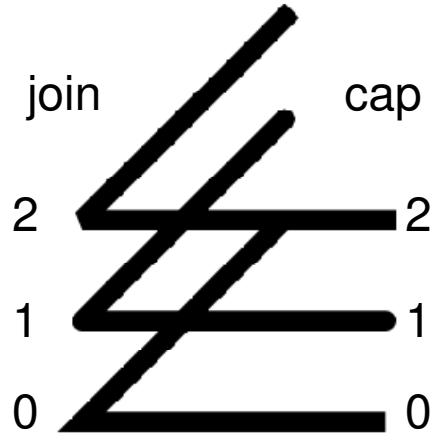
- To draw a path (or sequence of **`moveto`** / **`lineto`** commands)
  - **`stroke`** draws the **outline**
    - the *width* of the line can be set with **`value setlinewidth`**
    - the shape of the line *end* can be set with **`value setlinecap`**
    - the shape of corners is set with **`value setlinejoin`**.
  - **`fill`** fills the **inner part** with the presently selected color
  - **`x y w h rectstroke`** is a shortcut to draw a rectangle

- Color can be set with **`r g b setrgbcolor`** (r,g,b = 0.0 … 1.0) or with **`g setgray`** (for gray values)

Exercise 1

- Draw a line from (10,10) to (40, 10) to (20,30)
  - Change the width of the line
  - Play with the line end shape and the shape of the bend (use values 0…2 and a ‘thick’ line).
  - Can you find out the difference between 0 and 2?
- Draw a square of 30 units size with its lower left corner at (50,10)
  - Use **`moveto`** and **`lineto`**
  - Use also **`newpath`** and **`closepath`**
  - Fill the square with green color





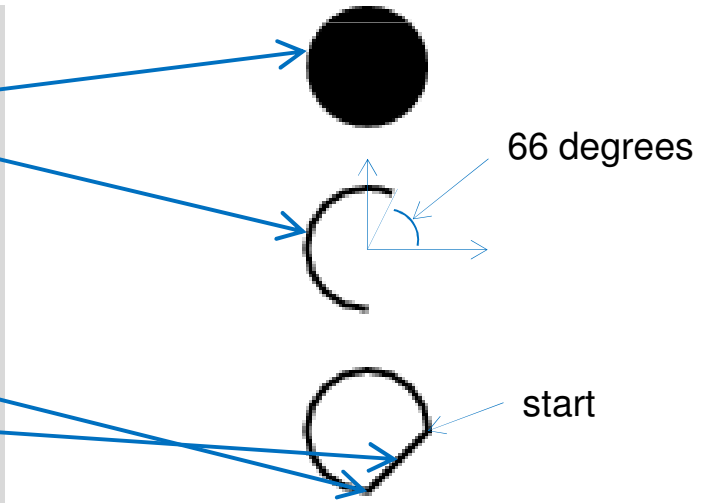
Mathematics

- PostScript knows several mathematical functions.
- Remember RPN: **`operand(s) operator`**
  - **`x y sub`** → x - y. Similar: **`add`**, **`mul`**, **`div`**, **`idiv`**, **`mod`**
  - **`x abs`** → |x|. Similar: **`neg`**, **`round`**, **`floor`**
  - **`x sin`** → sin(x). Similar: **`cos`**, **`ln`**, **`log`**, **`sqrt`**,…
  - **`rand`** → random *integer* number
- Angles are given (as floats) in *degrees* (i.e. 0…360)
- Z.B.:
  - (2 + 3) * 4 → **`2 3 add 4 mul`**
  - 2 + 3 * 4 → **`2 3 4 mul add`**
  - Sqrt(3 + 4) → **`3 4 add sqrt`**

Drawing Arcs

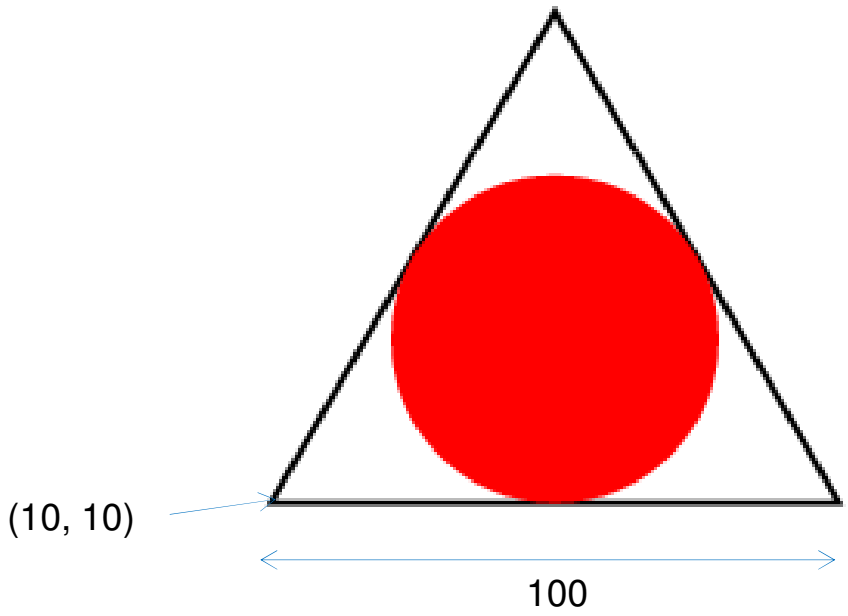
- Arcs (parts of circles) are defined using
  `x y radius phistart phistop arc`
- Angles are in degrees, relative to *x-axis*
- They can be **`filled`** or **`stroked`**.
- **`arc`** turns *counter clock wise,* **`arcn`** turns *clock wise*
- Example:

```
%!PS
20 80 10 0 360  arc fill
20 50 10 66 270 arc stroke

newpath
20 20 10 0 270 arc
closepath
stroke

showpage
```



Exercise 2

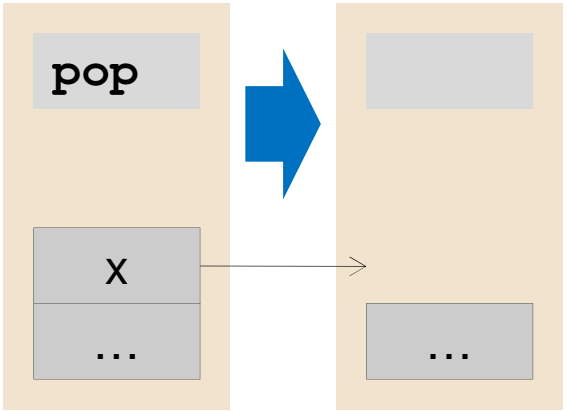
- Draw a triangle with *equal* sides
  - side length =100, start at (10,10)
- Add a red, filled circle to the center which just touches



Manipulating the Stack: `pop`, `dup`, `exch`

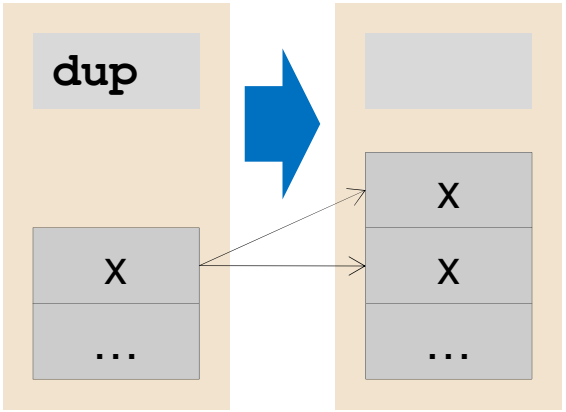
`pop`

drop top element:



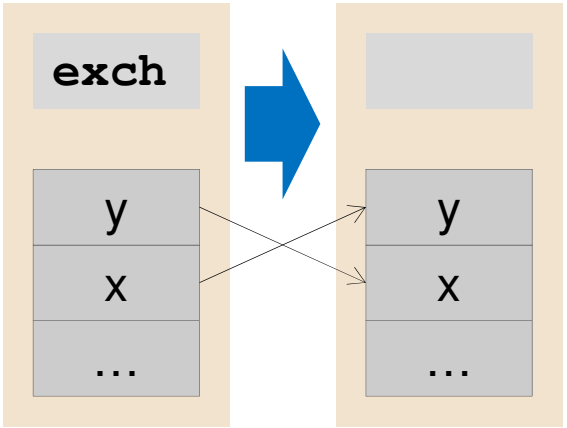
`dup`

duplicate top element:



`exch`

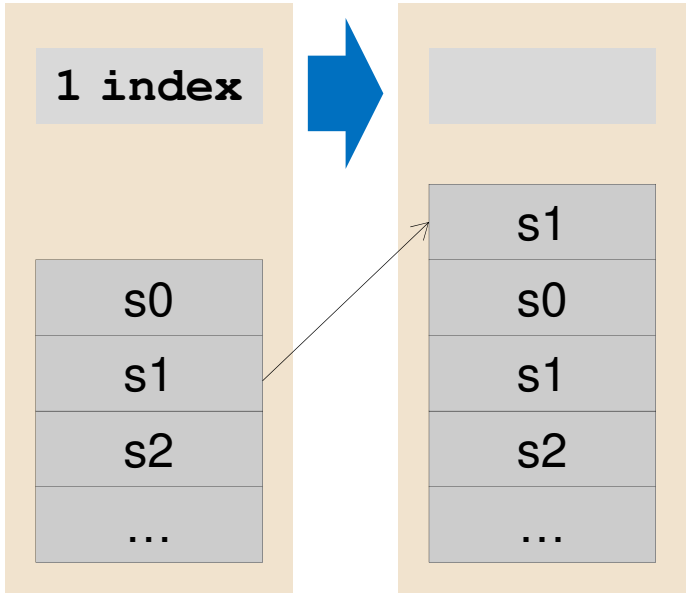
swap topmost elements:



Manipulating the Stack: `index`, `copy`

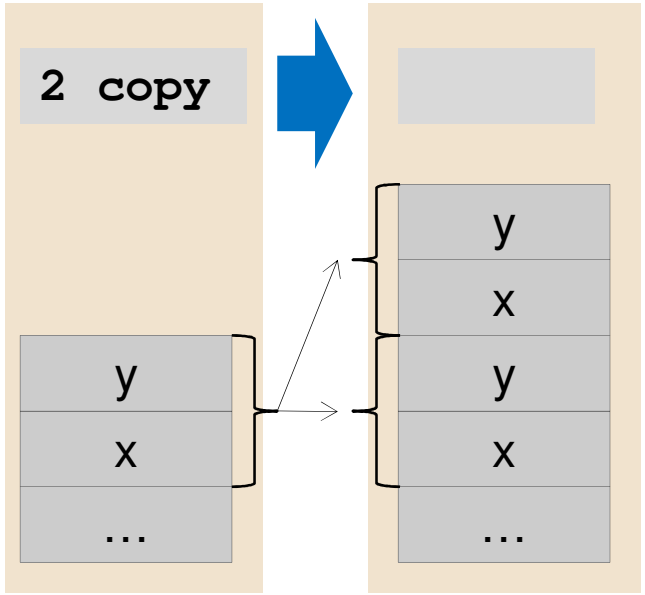
`n index`

copy t-th element:



`n copy`

duplicate *n* elements:



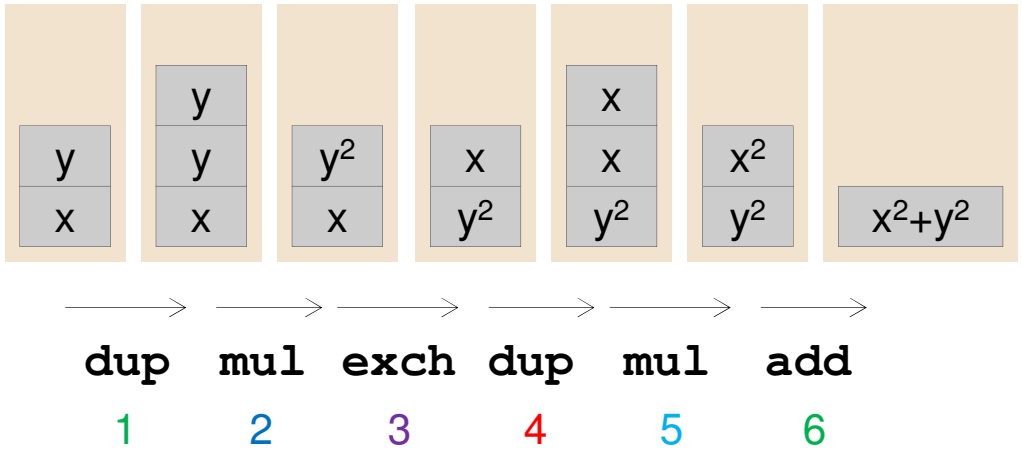
Defining Constants & Functions

- Defining a ‘fix’ constant:
  - **`/name value def`**
  - Example: **`/PI 3.141 def`**
- Defining a ‘calculated’ constant:
  - **`/name commands def`**
  - Example: **`/TWO_PI  PI 2 mul  def`**
- (*Constants* can be called more efficiently with a double slash: **`//PI 2 div ...`**)
- Defining a *function*:
  - **`/name { commands } def`**
  - Example: **`/ADDFIVE { 5 add } def`**
    `3 ADDFIVE` → 8
- What happens?
  - The (name definition) pair is stored in a dictionary by **`def`**

Passing Values to Functions

- Parameters are passed *on the stack*
  - They can be used using stack manipulation commands
  - Example: Define DIST(x,y) = sqrt(x^2+y^2)

```
/DIST {
  dup   %1
  mul   %2
  exch  %3
  dup   %4
  mul   %5
  add   %6
  sqrt
} def
```



- Usage: `3.2 1.7 DIST` → 3.6235..
- Note: Functions can remove parameters or leave the stack intact

Defining and Assigning Local Variables

- Values on the stack can be assigned to local variables:
  - **`/NAME exch def`**
  - (assume x is on the stack, then **`x /NAME exch`** leads to **`/NAME x`**, so that the **`def`** works normally)

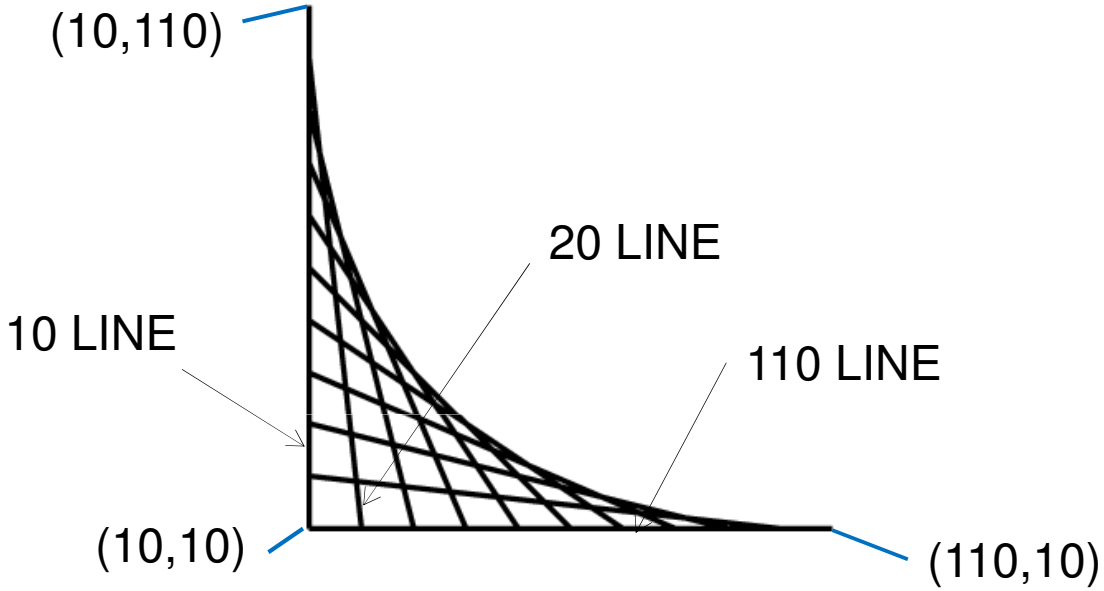
- Example: Define DIST(x,y) = sqrt(x^2+y^2)

```
/DIST {
  /y exch def   % topmost argument first!
  /x exch def   % now the stack is empty!
  x x mul       % on stack: x^2
  y y mul       % on stack: x^2 y^2
  add
  sqrt
} def
```

- This is much less efficient, because names must be looked up in a ‘Dictionary’. (Furthermore, the variable are global!)

Exercise 3

- Draw the following picture:



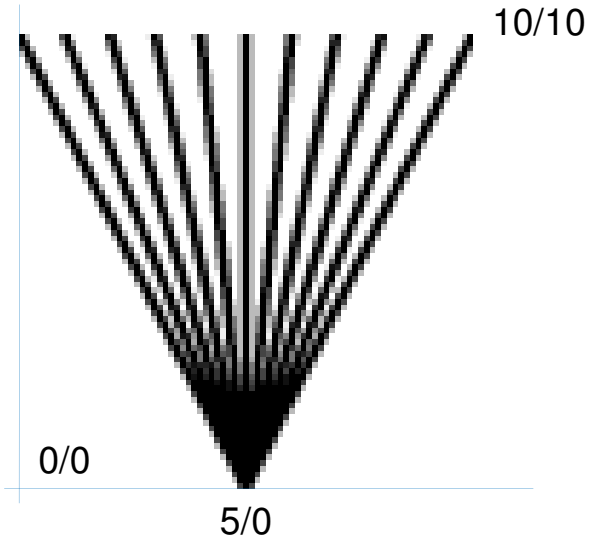
- First use individual lines
- Next, define a function **`LINE`** which gets *one* value from the stack which indicates the start of the line on the x-axis.
- The drawing is then done by a sequence of **`LINE`** commands:
  `10 LINE  20 LINE  30 LINE` …

Loops

- There are several possibilities for repeating code
- We only treat ‘for’ - loops here:
  `istart istep imax { …commands… } for`
  - The loop value is put on the stack in each iteration (istart, istart+istep, istart+2 istep, …, *including* imax)
  - Then the commands are called
    They MUST consume (remove) the value on the stack
  - The loop variable can be assigned with **`/i exch def`**
- Example:

```
%!PS
0.2 setlinewidth
0 1 10 {
  5  0 moveto
  5 10 lineto
} for
stroke
showpage
```

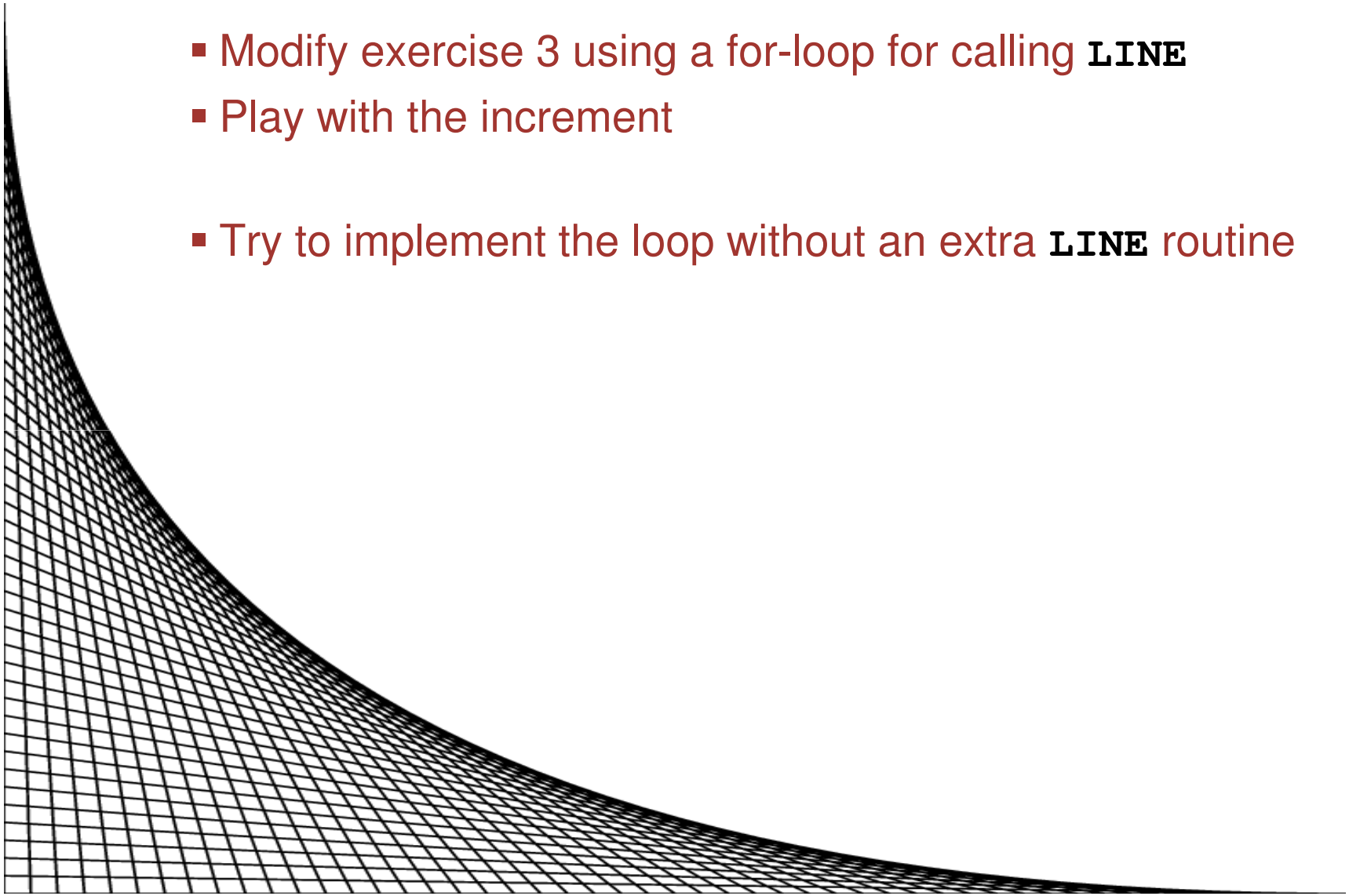
Here we use the sweep variable which is still on the stack!!!



Exercise 4

- Modify exercise 3 using a for-loop for calling **`LINE`**
- Play with the increment

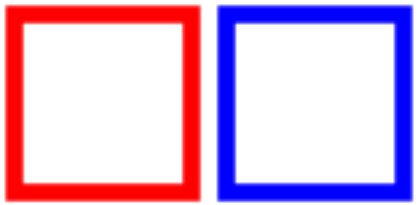
- Try to implement the loop without an extra **`LINE`** routine



Conditionals

- Conditional expression are possible
  - ***boolval*** **{…*commands*…}** **if**
  - ***boolval*** ***{…cmds (true)…}*** **{…*comds (false)*…}** **ifelse**
- Boolean values can be
  - **true**
  - **false**
  - **x y eq**
  - **x y gt**
  - **bool1 bool2 or**
  - **bool not**
  - **…**

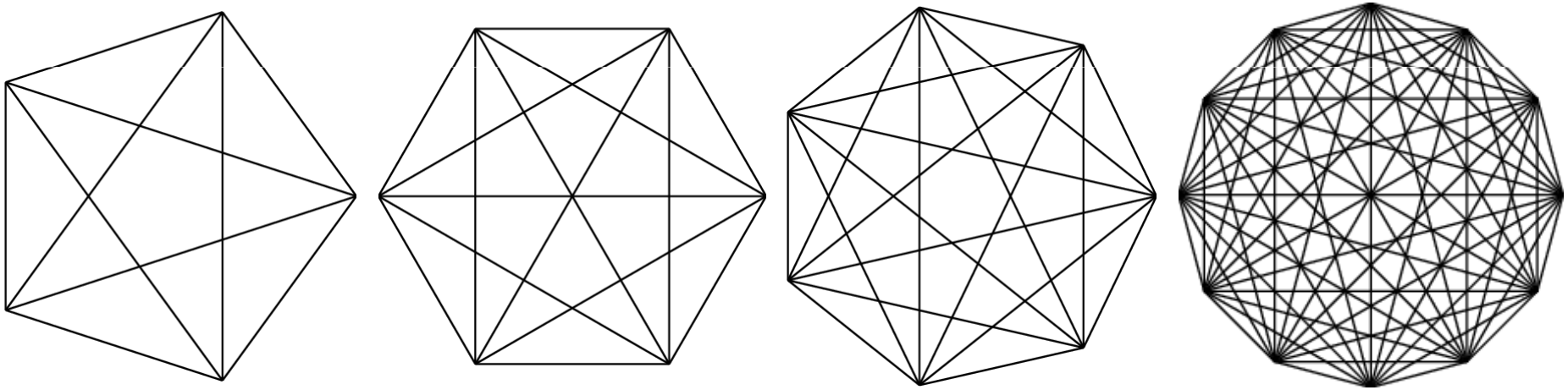
```
%!PS
/BOX {
 {1 0 0} {0 0 1} ifelse setrgbcolor
 0 0 10 10 rectstroke
} def

1  1 translate true  BOX
12 0 translate false BOX

showpage
```



- Can be used to comment out larger parts of code

Exercise 5

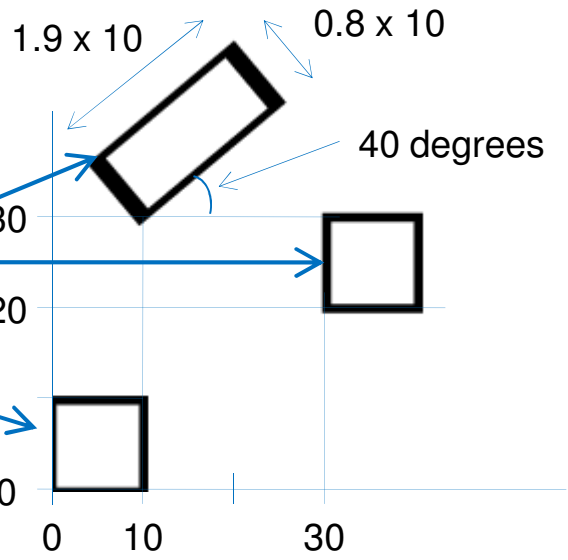
- This exercise is inspired by a problem in the ‘Mathekalender’ 2011 which offers a mathematics competition every year at http://www.mathekalender.de
- Draw an N-fold polygon with all inner connections…



Translating and Scaling Things

- The coordinate system can be *translated*, *scaled* and *rotated* at any time.
- New transformations are 'added on top'
  - **`x y translate`**
  - **`x y scale`** % negative arguments are allowed → flip
  - **`phi rotate`** % angle in degree, as always

```
%!PS
/BOX {
  0 0 10 10 rectstroke
} def

BOX
30 20 translate BOX
-20 10 translate
40 rotate
1.9 0.8 scale
BOX
showpage
```



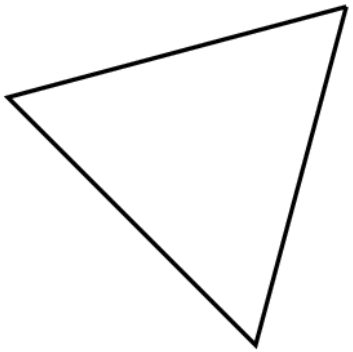
Applications of Coordinate Transformations

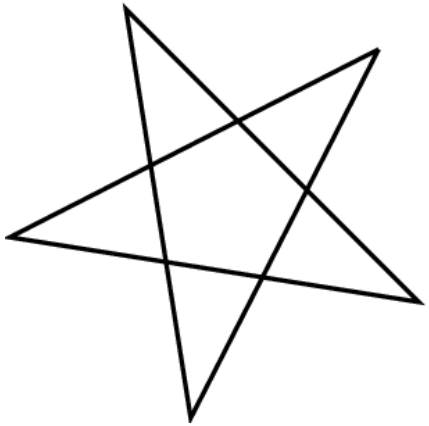
- Coordinate Transformations can simplify code *a lot*:

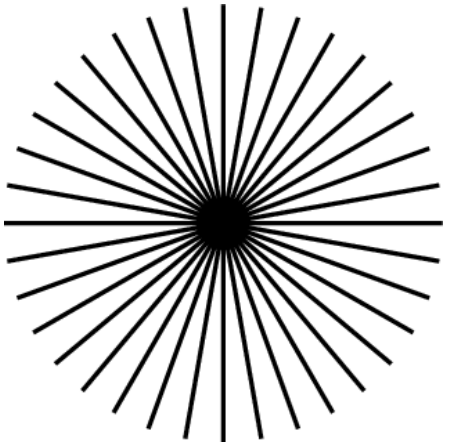
```
35 35 moveto
1 1 3 {
  pop
  120 rotate
  35 35 lineto
} for
stroke
```

```
35 35 moveto
1 1 5 {
  pop
  144 rotate
  35 35 lineto
} for
stroke
```

```
0 0 moveto
1 1 36 { pop
   50 0 lineto
    0 0 moveto
  10 rotate
} for
stroke
```







Converting Orientation and Units

- With

```
%!PS
2.835 dup scale  % now one unit is 1 mm
5 dup translate  % shift by 5/5 mm to center
0.1 setlinewidth
newpath
  0   0 moveto
  0 287 lineto
200 287 lineto
200   0 lineto
closepath
stroke
100 143.5 translate
```

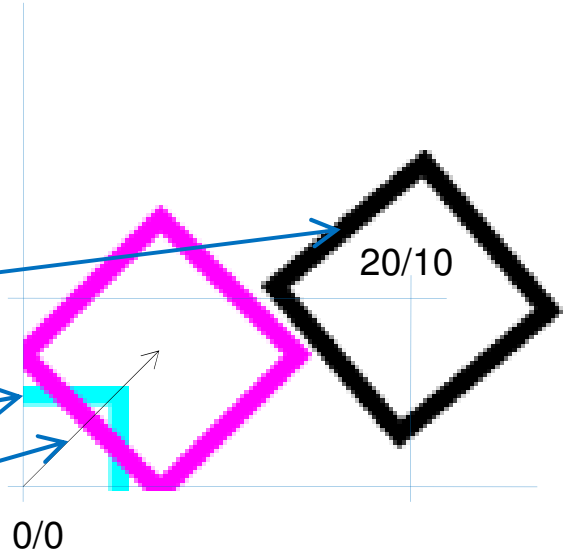
drawing can start in the center, in mm units.

- A frame is drawn around a A4 sheet.

Saving the Graphic State

- Temporary scaling / translating… operations often lead to unwanted coordinate systems
- The graphics state can be remembered with **`gsave`** and restored with **`grestore`**
- Example:

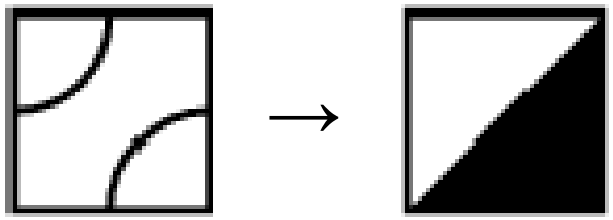
```
%!PS

/BOX { -5 -5 10 10 rectstroke } def
gsave
20 10 translate
40 rotate
0 0 0 setrgbcolor BOX % black

grestore
0 1 1 setrgbcolor BOX % magenta

45 rotate
10 0 translate
1 0 1 setrgbcolor BOX % pink
```



Exercise 6

- Understand how the Truchet Pattern on page 7 works
- Copy the code and play
  - Change the number of tiles
  - Change the size of the tiles

- Replace the rounded tile by a triangle



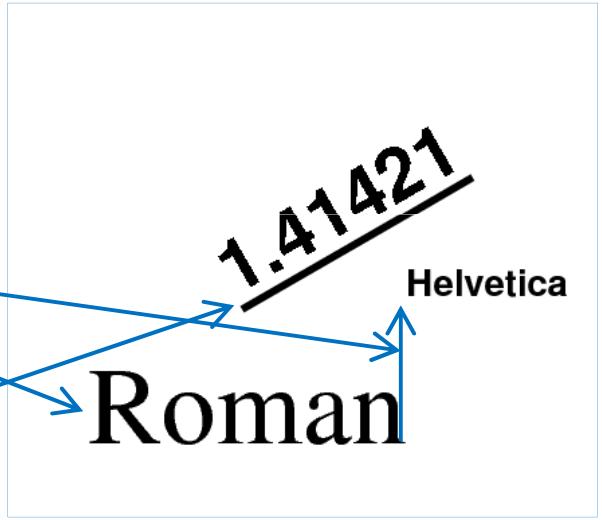
Drawing Text

- Strings are delimited by `()`. Example: `(text)`
- Before drawing a font must be selected:
  - `/name findfont` put font '*name*' to stack (height is 1 unit)
    Some font names:
    - Times-Roman
    - Helvetica-Bold
    - Courier
  - `value scalefont` resize (multiply) font (leave on stack)
  - `selectfont` use it from now on (remove from stack)
- Show a string (on stack): `show`
  - start at current point
  - current point moves to end of string!
- Convert a number to a string: `value 10 string cvs`
- Get width of a string: `strval stringwidth` (get x *and* y)
  - Note that for some reason, y is always zero and must be `pop`ed

Drawing Text: Example

- Example:

```
%!PS-Adobe-3.0 EPSF-3.0
%%BoundingBox: 0 0 80 70

10 10 translate 0 0 moveto
/Times-Roman findfont
15 scalefont setfont
(Roman) show

0 20 rmoveto
/Helvetica-Bold findfont
5 scalefont setfont (Helvetica) show

/x 2 sqrt 10 string cvs def

20 20 translate 30 rotate 0 0 moveto
currentfont 2 scalefont setfont
x show
0 -2 moveto
x stringwidth rlineto stroke

showpage
```



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Exercise 7

- Draw a box from (10,10) to (50,30)
- Print some text *centered* in the box
  - Use **`stringwidth`** to get the x- and y size of the text
  - Unfortunately, the y size is zero and cannot be used! Use the font height instead.

Advanced: Clipping

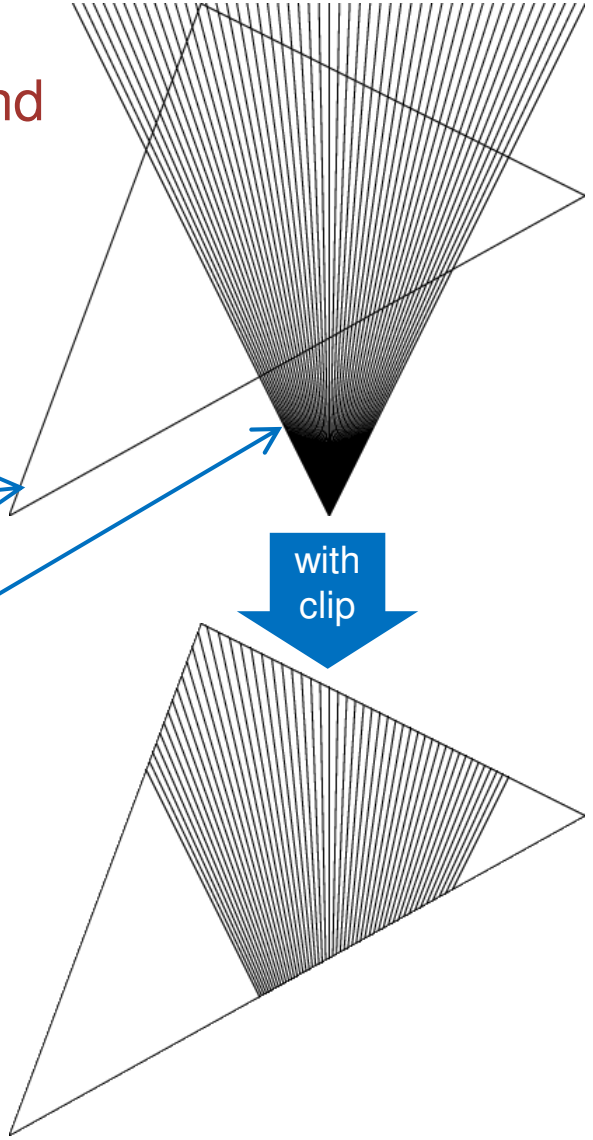
- A path can be used to restrict the drawing area using the **`clip`** command
- **`initclip`** clears the clipping path

```
%!PS
0.2 setlinewidth

newpath 0 0 moveto
30 80 lineto 90 50 lineto
closepath
clip

0 2 100 {
  50 0 moveto 100 lineto
} for
stroke

showpage
```



For fun: charpath

- The outline of characters can be converted to a path using the **`charpath`** command.
- Example using **`clip`**:

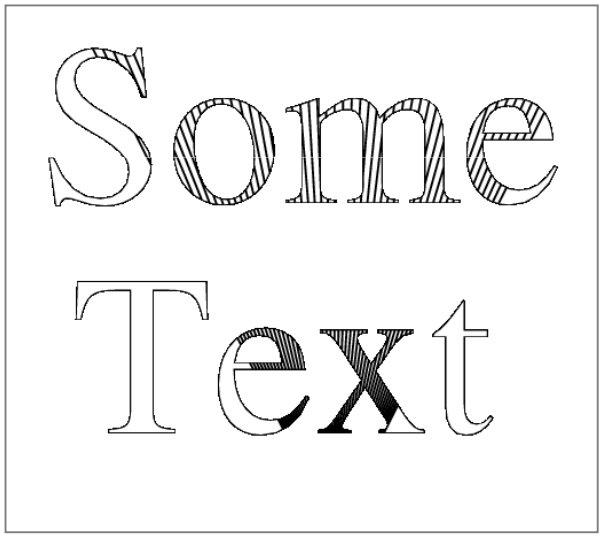
```
%!PS-Adobe-3.0 EPSF-3.0
%%BoundingBox: 0 0 90 80
0.3 setlinewidth

/Times-Roman findfont
35 scalefont setfont
 5 50 moveto (Some) false charpath
10 15 moveto (Text) false charpath

clip

0 2 100 {
  50  0 moveto
    100 lineto
} for
stroke

showpage
```



Advanced: Bit Maps

- The command **`image`** draws a bit map in a unit square
  - To change size: scale before in x- and y
- Parameters are:
  - Pixels in x
  - Pixels in y
  - Bits per pixel
  - A rotation matrix
  - A function to get the values. Simplest case is a list of values
- Similar command is **`colorimage`**
  - It has some more parameters…

```
%!PS-Adobe-3.0 EPSF-3.0
%%BoundingBox: 0 0 100 100

10 10 translate % move image to middle of page
80 80 scale     % make image one inch on a side
4 4 2 [4 0 0 4 0 0] {<fc1be400>} image
showpage
```

Example for colorimage

```
%!PS-Adobe-3.0 EPSF-3.0
%%BoundingBox: 0 0 102 102

1 1 translate
100 100 scale

/picstr 6 string def

2 2 4 [2 0 0 -2 0 2]
{ currentfile picstr readhexstring pop}
false 3
colorimage
f000080f0088

showpage
```

String variable

NX NY bits_per_col

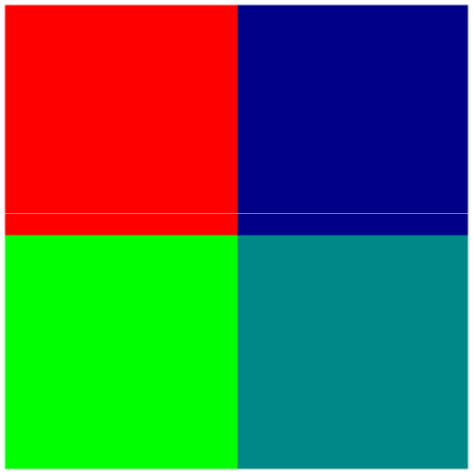
colors separate ?

matrix

NCOL

Function to retrieve data from file

data



Error Messages

- GhostScript produces Error messages
  - To Clear the Console, Start Viewer from Scratch!
  - Scroll up to **First** error

- Some typical Errors
  - Stack underflow — command has too few arguments
  - No current point — `show` or `stroke` without point data
  - Variable not known — …
  - …

Converting to Other Formats

- Linux:
  - ps2eps
  - ps2pdf
  - epstopdf
- Convert
  - http://www.imagemagick.org/script/convert.php

Interactive Mode

- GhostScript can be run interactively
  - List stack using **`stack`** command
  - Not further covered here…

```
GPL Ghostscript 8.60 (2007-08-01)
Copyright (C) 2007 Artifex Software, Inc.  All rights :
This software comes with NO WARRANTY: see the file PUB
GS>2 3 4
GS<3>stack
4
3
2
GS<3>add
GS<2>stack
7
2
GS<2>/SUM2 { add dup mul } def
GS<2>SUM2
GS<1>stack
81
GS<1>_
```

History

- PostScript has been developed by Adobe
  - Level1 1984
  - (Display PostScript) 1988
  - Level 2 1991
  - PostScript 3 1997/98
- Info at http://www.adobe.com/devnet/postscript.html

- pdf is an ‚extension' of PostScript
  - All graphics possibilities are preserved
  - transparency
  - Better page structure (can scroll to pages without code analysis)
  - Interactive elements
  - …

Quelle: wikipedia

Encapsulated Postscript

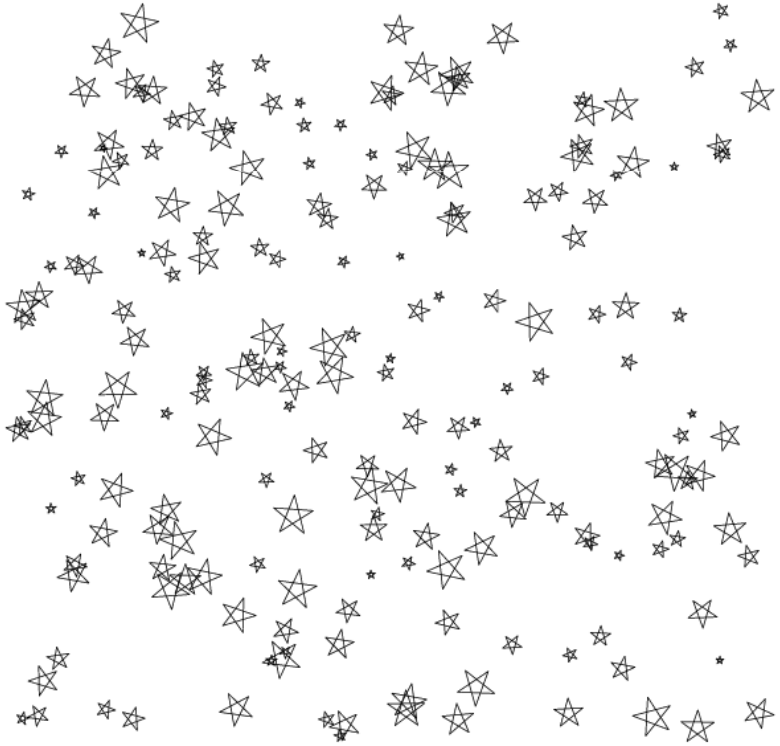
- Encapsulated Postscript adds some meta information in standardized form
- Most important is the document size
  - Needed by other programs to know image size without ‘understanding’ PostScript code
- fields
  - `%!PS-Adobe-3.0 EPSF-3.0`
  - `%%BoundingBox: llx lly urx ury  (Postscript Units!)`
  - `%%Pages:          0`
  - `%%Creator:        Peter Fischer`
  - `%%DocumentMedia: A4 595 842 0 () ()`
  - `%%EndComments`

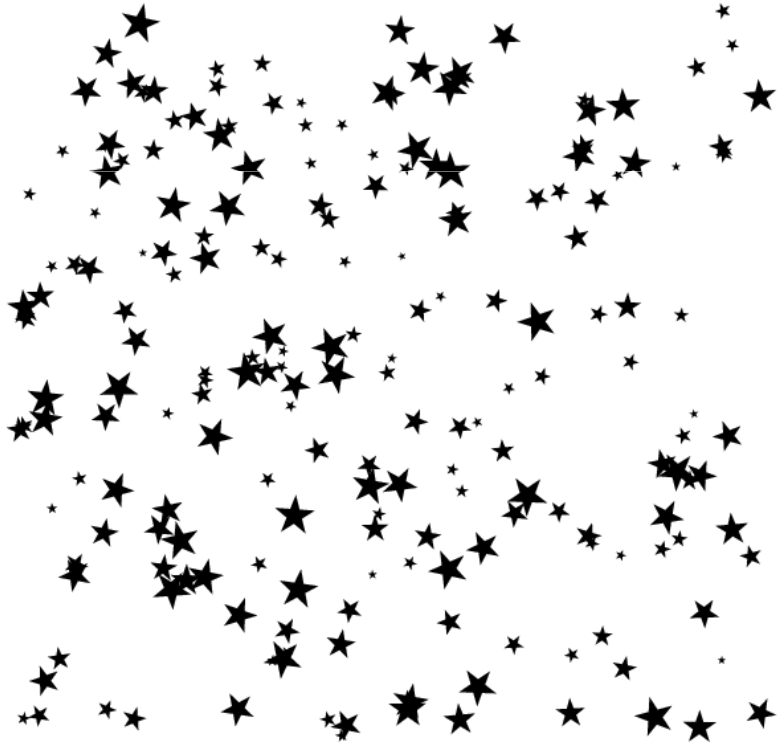
What Else ?

- Other PostScript features are
  - Control structures: repeat, loop, forall, …
  - Access to external files
  - Arrays
  - Dictionaries
  - …
- Crazy Stuff (from the web)
  - Raytracer
  - Cellular Automaton
  - Henon Attractor
  - …

Exercise 8

- Draw a sheet full of stars (snow flakes)
  - Use random positions, sizes and rotations
  - Define a function to draw one (5 fold) star
  - Create 200 stars in a loop





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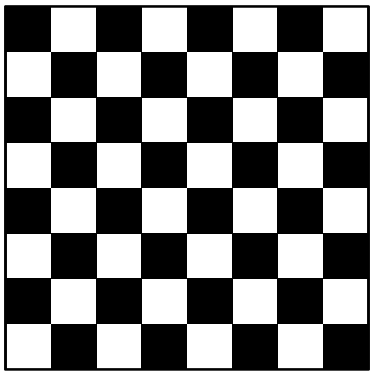
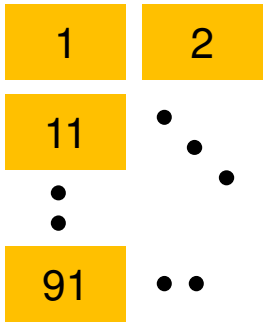
Exercises 9

- A. Draw a chess board with outline



- B. Draw 10 × 10 rectangular stickers
  - Add numbers 1-100, centered to the boxes



- C. Draw the logo of the Bioquant facility
  - Try to add the text, scaled to match exactly the logo width (chose a font in some size, get the width of the text and rescale the font size)

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TODO

- Links->Adobe checken und auf Webseite
- Obfuscated auf Webseite
- Letzer Foliensatz auf Webseite

- Alle Musterlösungen machen
- Aufräumen

- rol Befehl einführen