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Exploring Knowledge Schemes for Efficient Evolution of Hardware

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How do we solve a problem?

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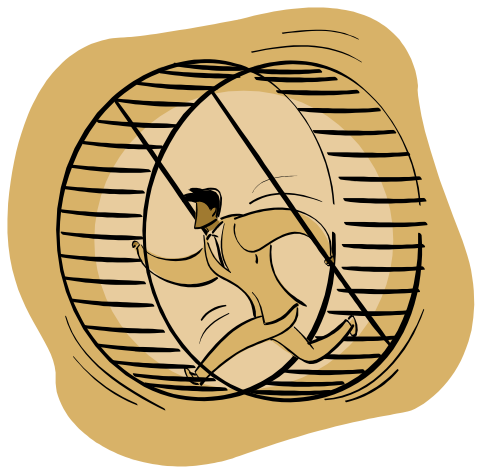
How do we evolve a problem?

- Apply Evolutionary Algorithms with no knowledge about the problem!
- We avoid using available knowledge!
- In this talk, we will discuss how human knowledge can be added to evolution.



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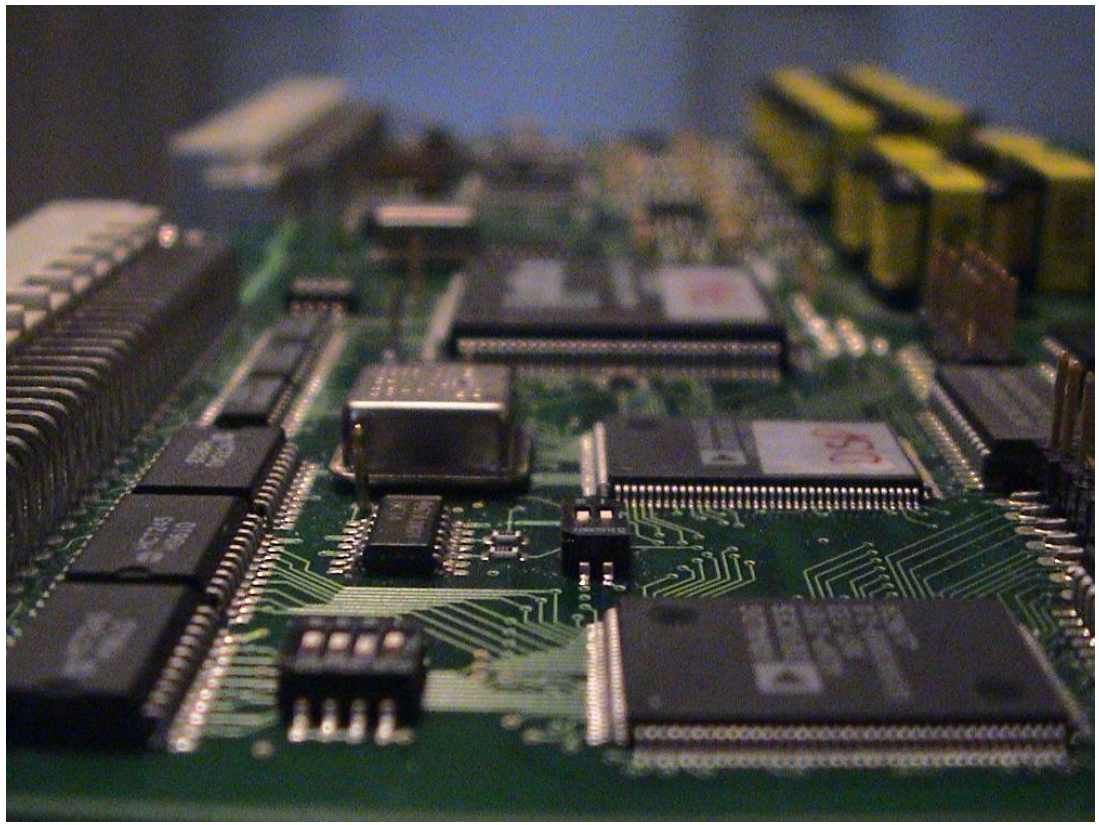
What a priori knowledge is available?



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Design specification

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Partitioning the design task

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Reuse

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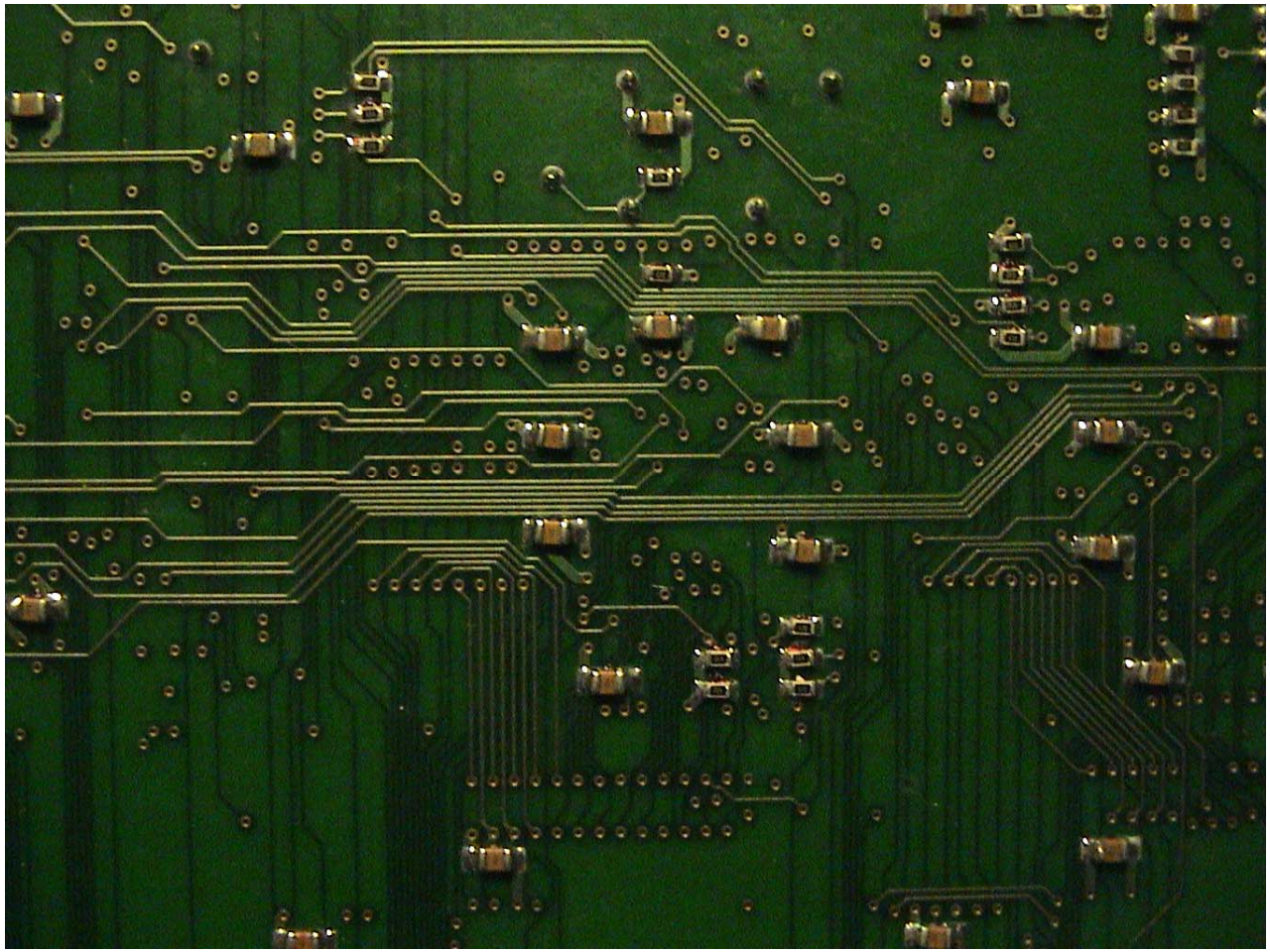
Data buses



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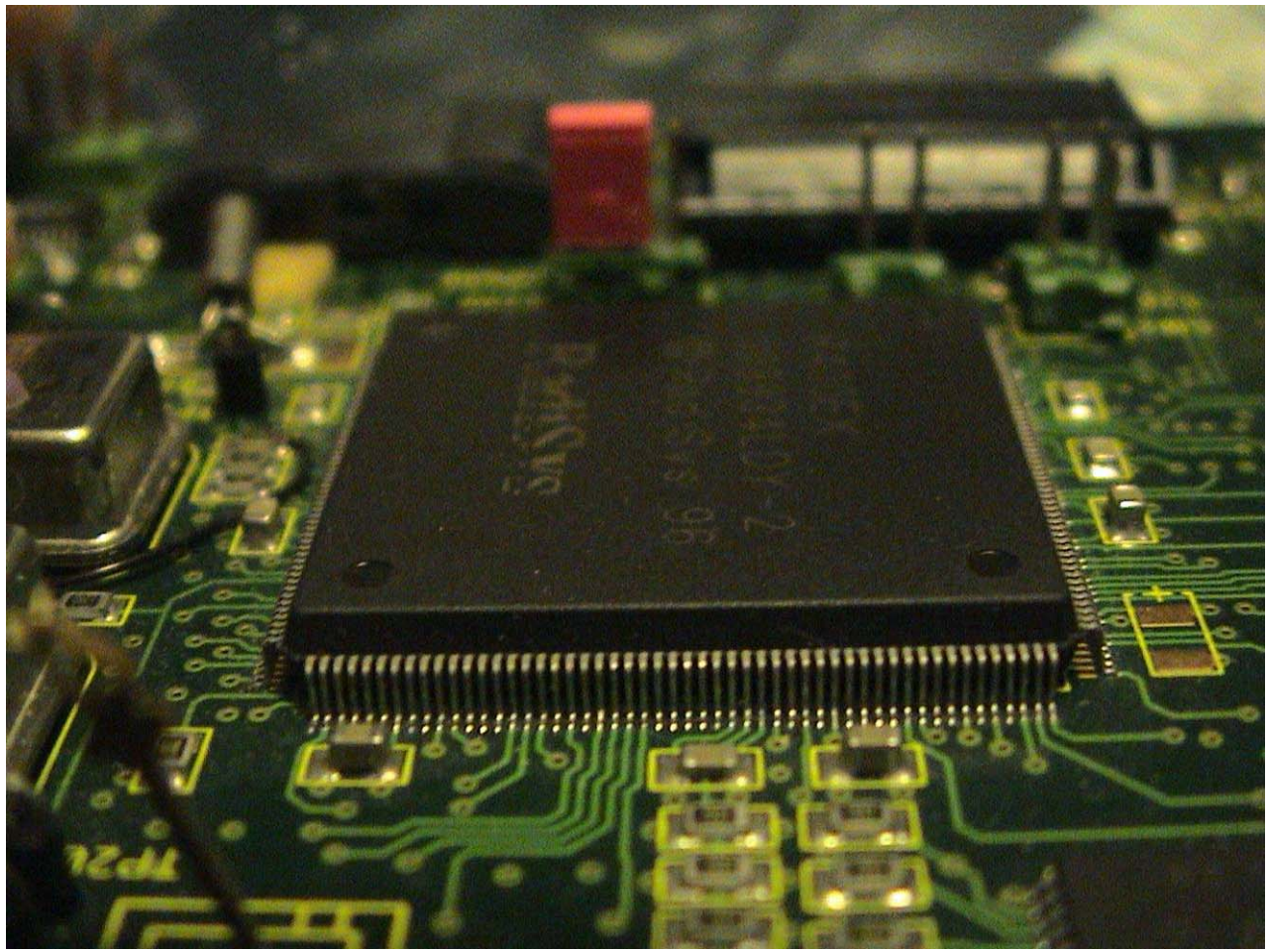
Design optimization knowledge



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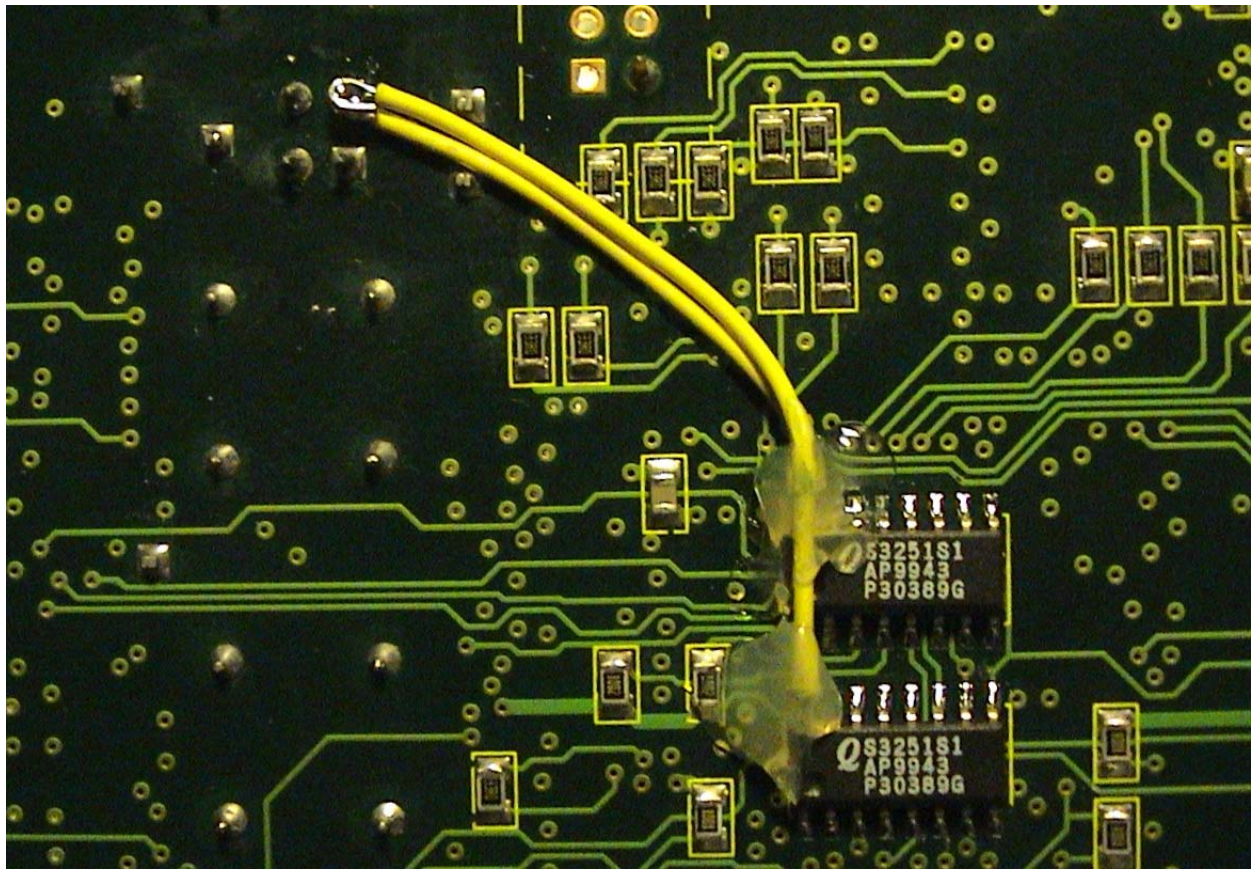
Prototyping



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Hardware/software co-design

Jul 29, 03 15:15 **link.c** Page 3/4

```
      link.out.writeptr = link.out.buffer;
    //Increment the number of frames in line.
    link.out.waiting++;
    return(TRUE);
  }
  //The frame buffer is full.
  DELETE_FRAME(newframe);
  return(FALSE);
}
////////////////////////////////////////////////////////////////////////////////



////////////////////////////////////////////////////////////////////////////////
//Function:     Pop
//
//Parameters:   -buf:    The buffer to place the contents of the frame in
//              -length: The length of the buffer.
//
//Return Value: Integer value telling how many bytes that are read.
//
//Description:  Pop the first frame of the incomming frame buffer, strip
//              off the head and return the payload.
////////////////////////////////////////////////////////////////////////////////
uint8_t Pop(uchar_t* buf, uint8_t size){
  frame_t* frame;
  uint8_t  length;

  //If there are no frames in the incomming buffer,
  //then return zero.
  if(link.in.waiting == 0)
    return(0);
  //Else there are one ore more frames to process.
  //Pop of the first in line.
  frame = *link.in.readptr;
  //Get the length of the frame.
  length = frame->size;
  //Get the received frames data.
  if(length <= size)
    memcpy(buf, frame->body, size);
  else
    length = 0;
  //Decrease the number of frames in line.
  link.in.waiting--;
  //Increase or wrap the read pointer.
  link.in.readptr++;
  if(link.in.readptr == link.in.buffer+FRAMEBUF_SIZE)
    link.in.readptr = link.in.buffer;
  //Delete the frame, but not the body.
  DELETE_FRAME(frame);
  return(length);
}
////////////////////////////////////////////////////////////////////////////////
```

Jul 29, 03 15:06 **kernel.vhd** Page 13/24

```
        --The mode has been changed, return to home position
        --and change mode.
        rotation_Drive <= HALT;
        OpState        <= HOMING_START;
      end if;
------------------------------------------------------------------------------
when ASCAN_DIVERT =>
  --Set current status in status register.
  Status <= STAT_ASCAN;
  --Decide next state.
  if ElevationPosition = ElevationDest then
    --No change in elevation position.
    OpState <= ASCAN_CONTINUE;
  else
    --The desired elevation position has changed, reposition.
    rotation_Drive <= HALT;
    OpState        <= MERIDIAN_REPOS;
  end if;
------------------------------------------------------------------------------
when ASCAN_CONTINUE =>
  --Set current status in status register.
  Status <= STAT_ASCAN;
  --Start up rotation motor.
  rotation_Drive <= DRIVE;
  OpState        <= ASCAN_RUN;
------------------------------------------------------------------------------
------------------------------------------------------------------------------



------------------------------------------------------------------------------
-- Tracking mode.
------------------------------------------------------------------------------
when TRACK_INIT =>
  --Change value in the status register.
  Status <= STAT_TRACK;
  --Enable sampling registers.
  sampleClr <= '0';
  --Decide elevation direction.
  if ElevationDest > ElevationPosition then
    elevation_Direction <= FORWARD;
  else
    elevation_Direction <= BACKWARD;
  end if;
  --Decide rotation direction.
  if RotationDest < RotationPosition then
    rotation_Direction <= FORWARD;
  else
    rotation_Direction <= BACKWARD;
  end if;
  --Proceed to the next state.
  OpState <= TRACK_STEP;
------------------------------------------------------------------------------
```

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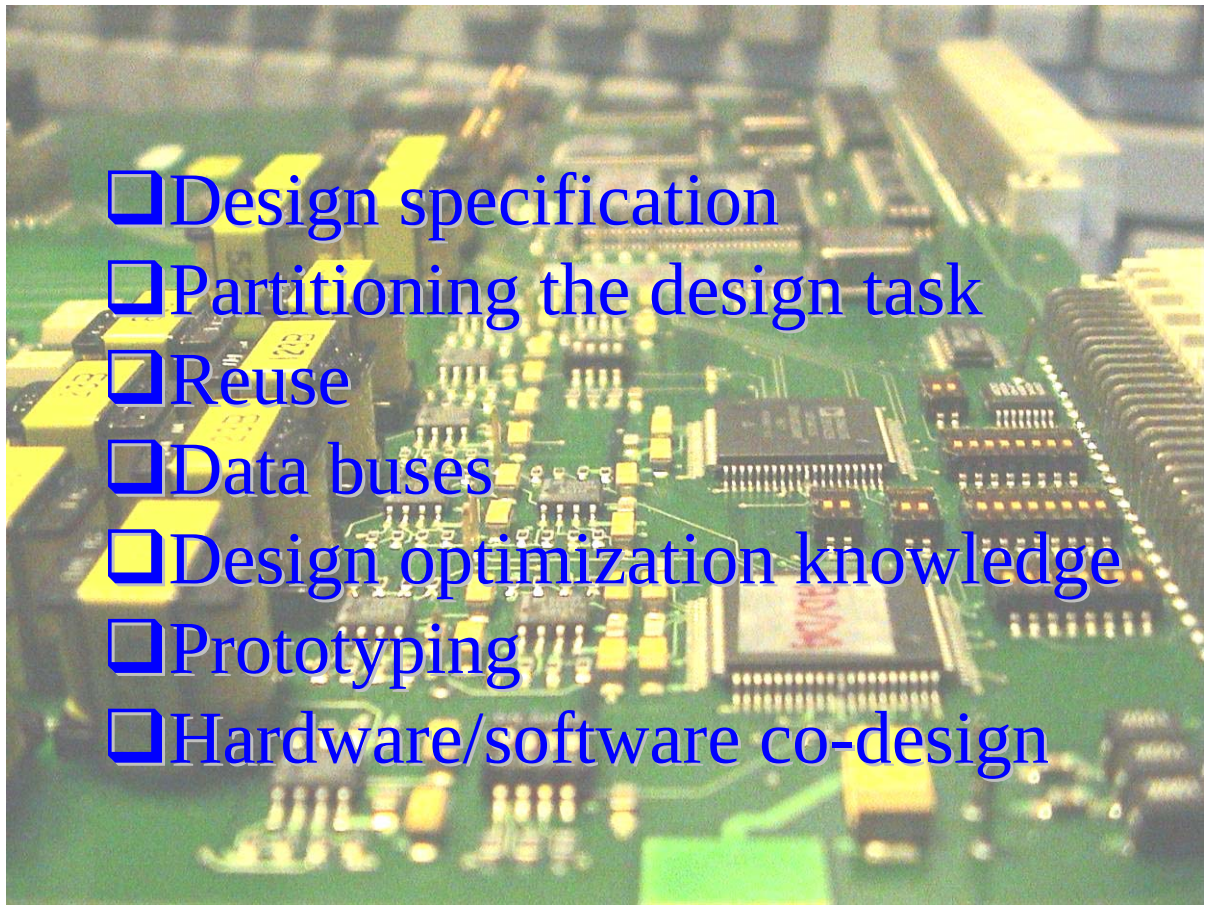
Complex design by a priori knowledge



- Design specification
- Partitioning the design task
- Reuse
- Data buses
- Design optimization knowledge
- Prototyping
- Hardware/software co-design

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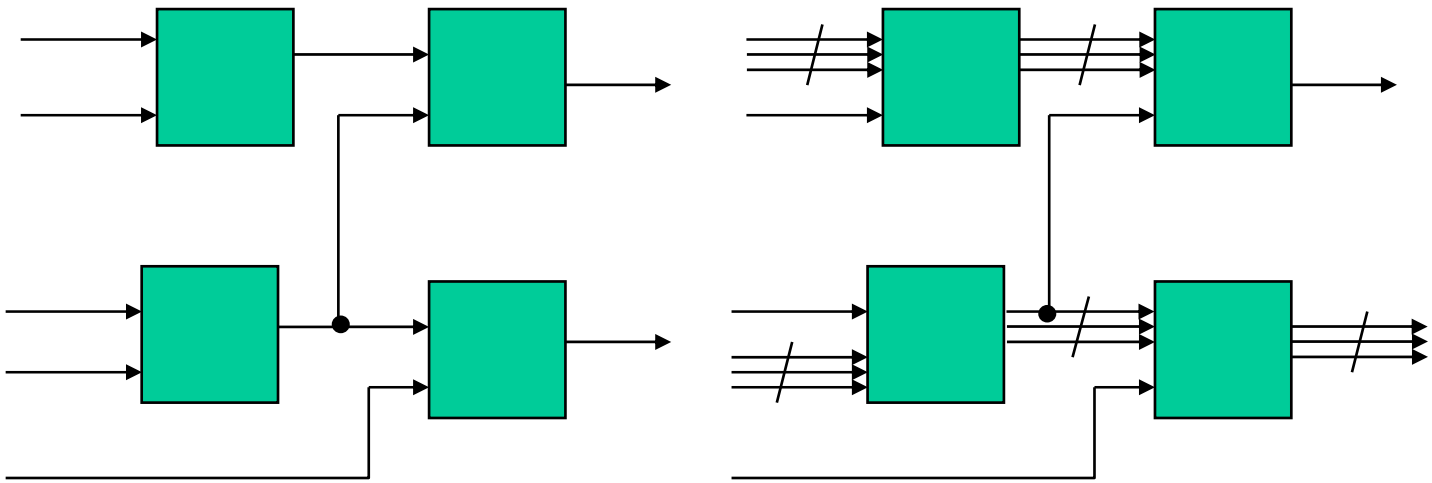
Evolution with Data Buses



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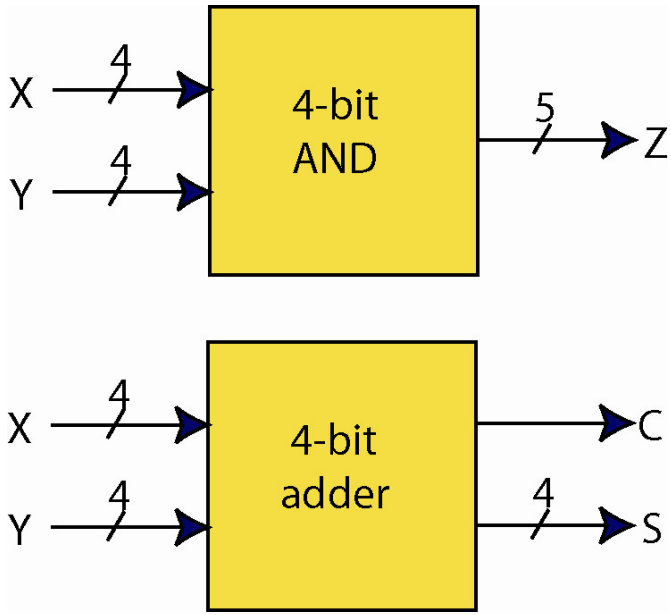
Building Blocks for Evolving a Multiplier



Inputs:

- 4 bits buses
- 1 bit lines

$$x_3x_2x_1x_0 \cdot y_3y_2y_1y_0$$

$$\begin{array}{cccccc} & & & x_0y_3 & x_0y_2 & x_0y_1 & x_0y_0 \\ & & x_1y_3 & x_1y_2 & x_1y_1 & x_1y_0 & \\ & x_2y_3 & x_2y_2 & x_2y_1 & x_2y_0 & & \\ + \; x_3y_3 & x_3y_2 & x_3y_1 & x_3y_0 & & & \\ \hline \end{array}$$

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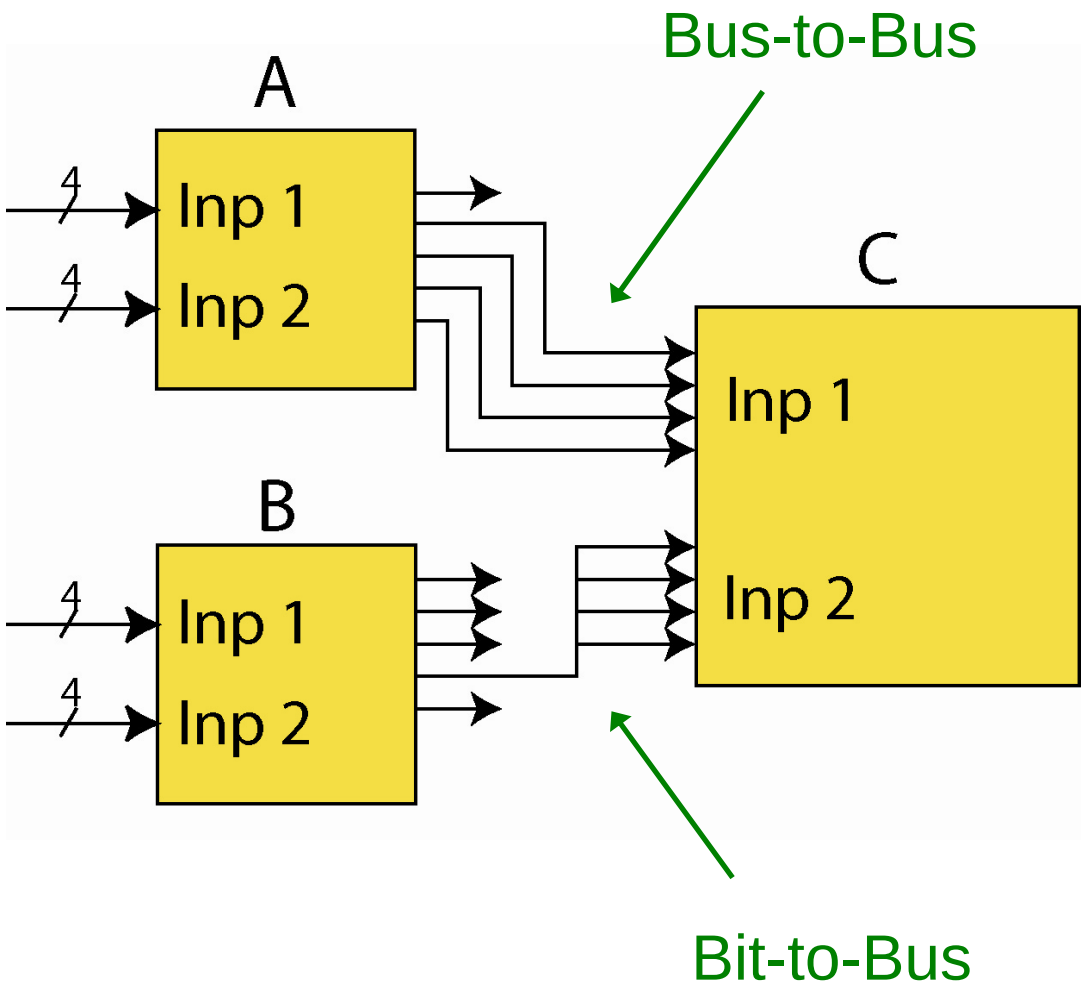
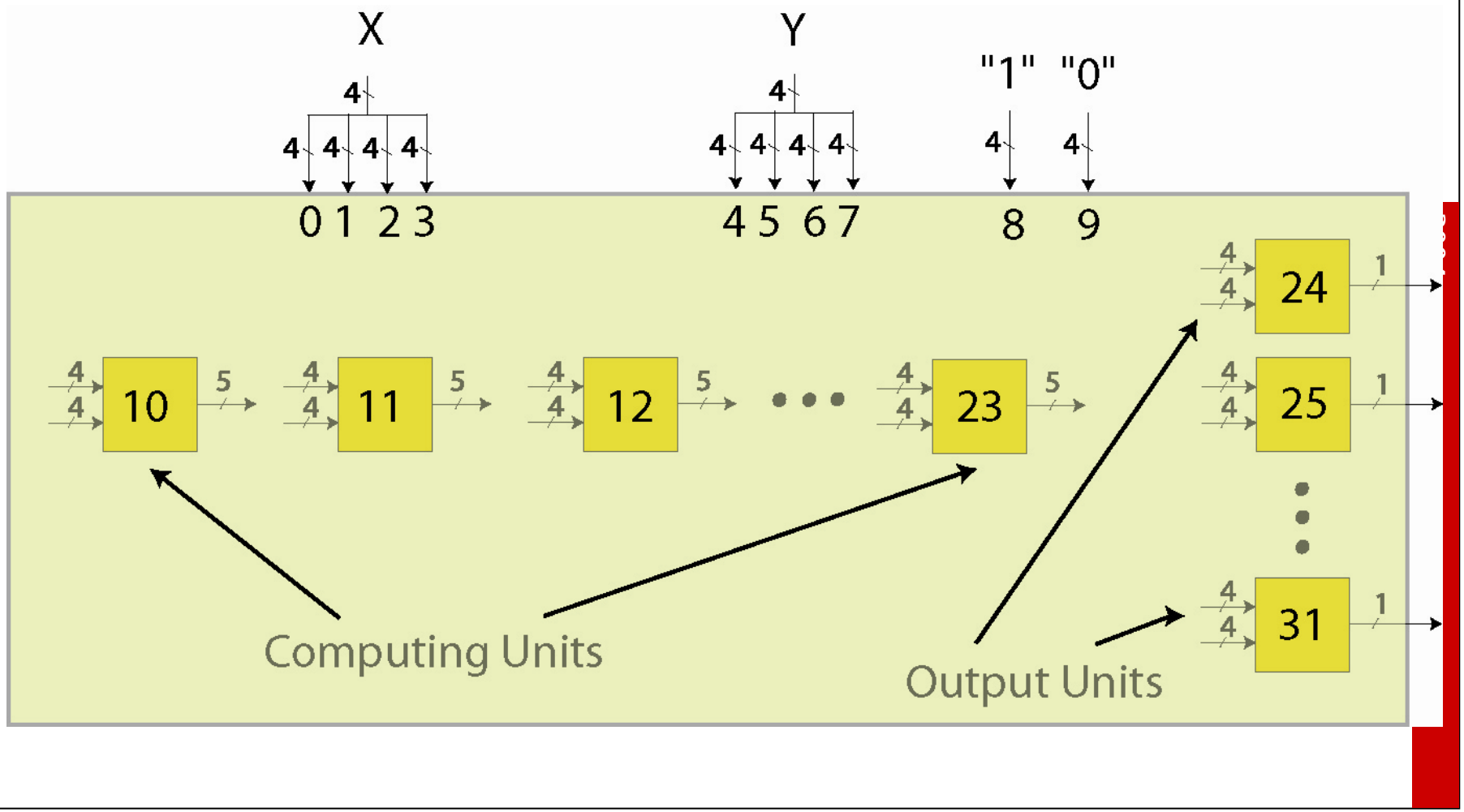
Connection Between Units

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X
Y
"1"
"0"
4
4 4 4 4
0 1 2 3
4 5 6 7
8
9
10
11
12
23
24
25
31
5
1
Computing Units
Output Units

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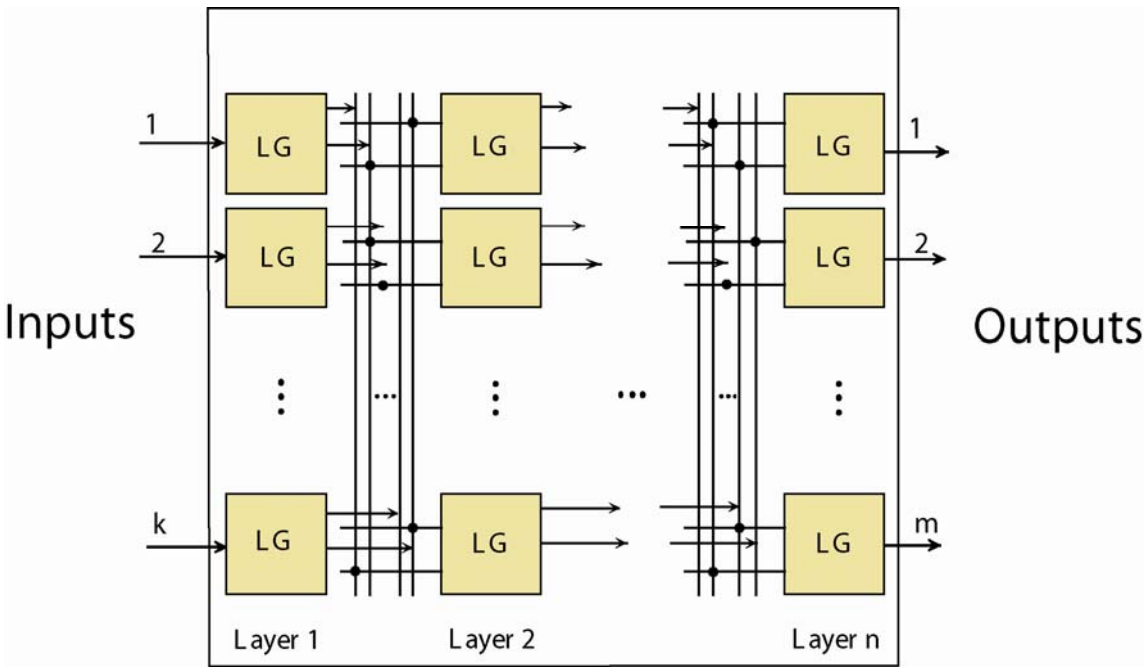
Experiment

- Evolve multiplier circuits with genetic algorithms.
- Compare evolving the new architecture with gate array:



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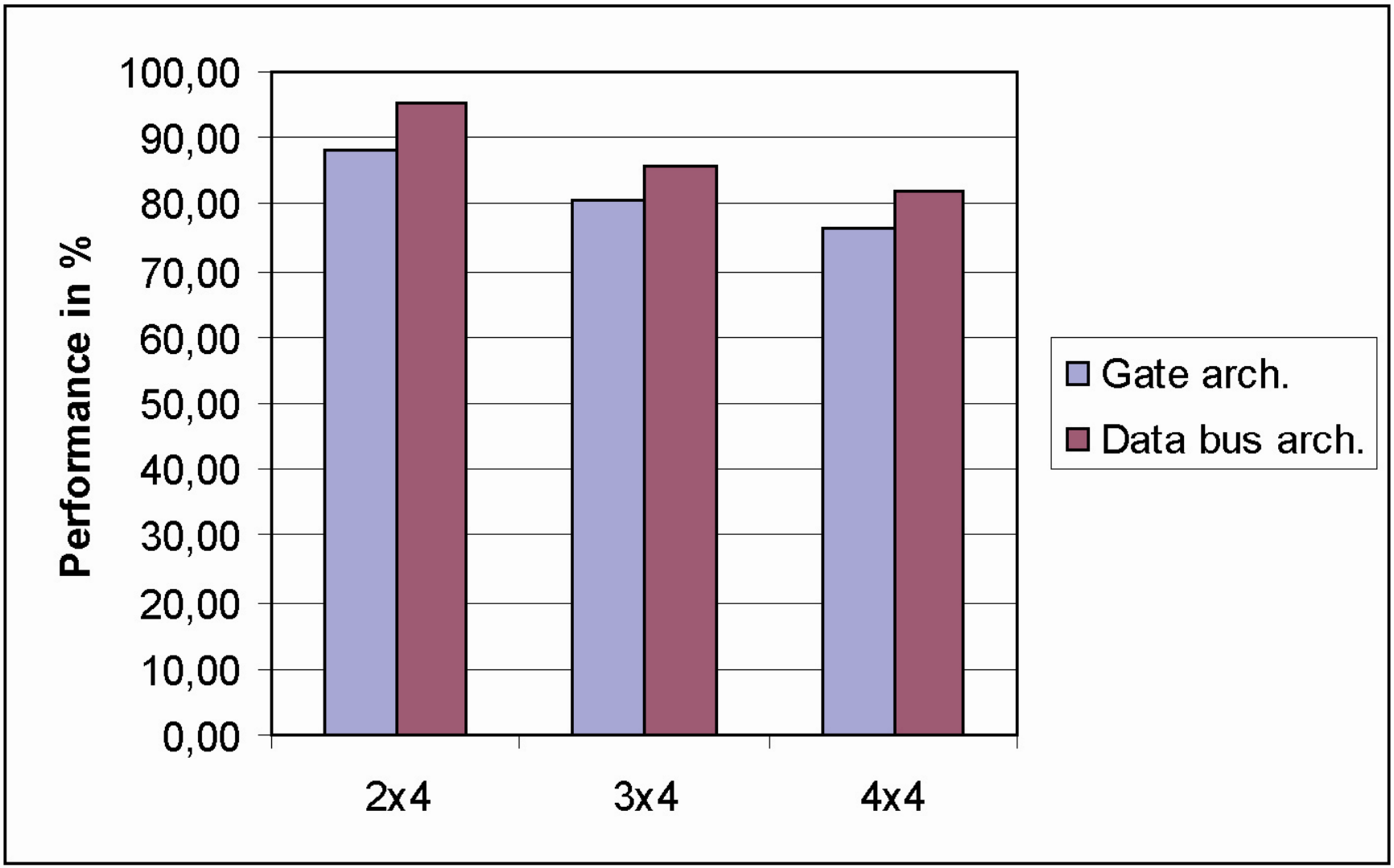
Results



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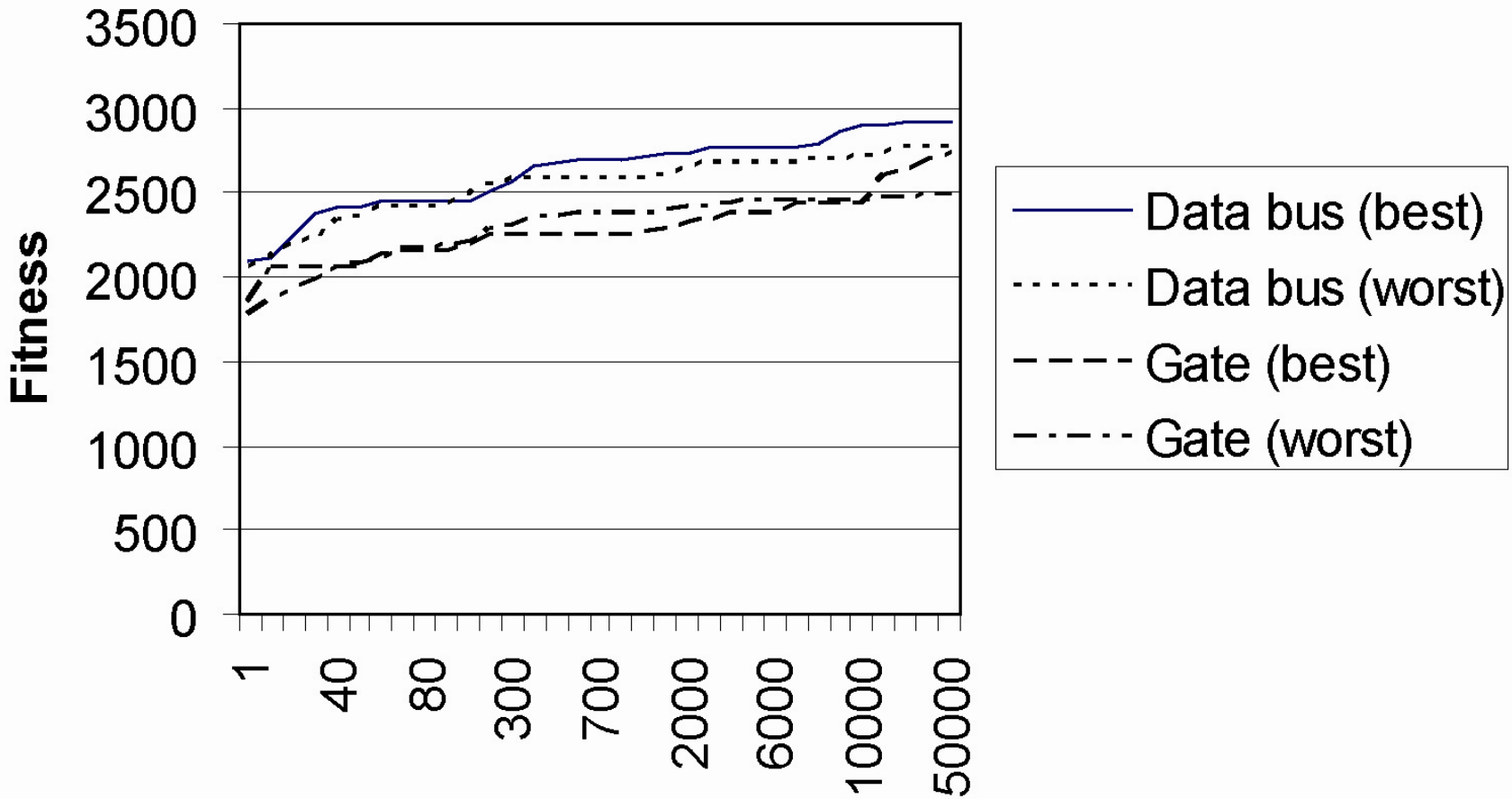
Results: Best and Worst Circuit



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Conclusions

- A number of traditional design aspects have been discussed.
- Experiments involving *data buses* in evolution of multiplier circuits have been reported.
- Results are better than for traditional gate level evolution.
- Further development of the architecture and the a priory knowledge inclusion is future work.