Peter Kogge

McCourtney Prof. of CSE

IBM Fellow (retired)

Chief Scientist: Emu Solutions

What Drives Me?

I like to build computers

- **Not use them!**
- **And the *more novel (i.e. wacky)* the better**

But I can't get $ to do this unless

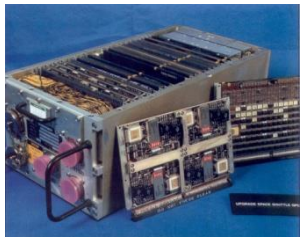
- **They solve some problems "better" than today**
- **AND I can prove it**
- **AND they can be programmed by other than ninja programmers**

So! Understanding inherent properties of computing is crucial

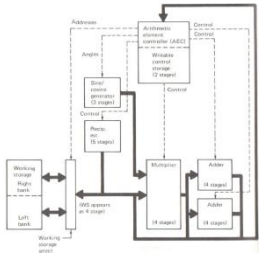
A Trip Down My Memory Lane

```
procedure MORA
begin
 parallel_array A(*, 0::m-1);
 A[i,0] = a_i, (1 ≤ i ≤ N)
 for q = 1 step q+m-1
       until (N-m+1)/2 do
  begin
   for j = 1 step 1 until m-1 do
    begin
      A[i,j]=A[i,j-1),(1≤i≤q+j-1);
      A[I,j]=g(A[i,j-1], a_{i-q-j+q),
              (q+j ≤ i ≤ N);
    end;
   A[i,0] = h(A[i,0], A[i-q, m-1],
       …, A[i-q-m+1,0]), (q+m≤i≤N);
   A[i,0] = A[1, m-1], (1<i≤q+m-1);
  end;
 x_i = f(A[i,0], x_0, … x_{m+1}),(1≤i≤N);
end MORA.
```

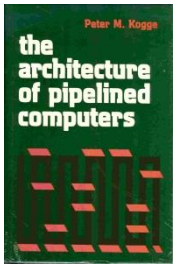
Parallel Recurrences (1971)



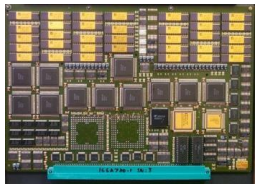
Space Shuttle IOP (1974)



IBM 3838 (1976)



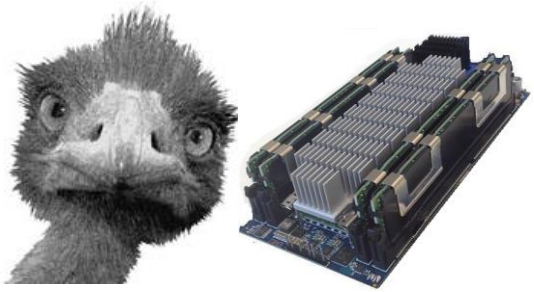
1st Book (1981)



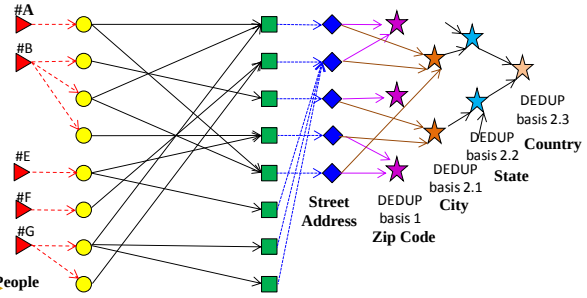
RTAIS: (1990)

2nd Book (1990)

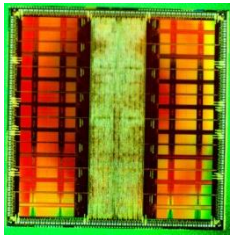
Exascale Report (2008)



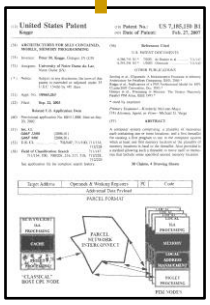
Gossamer Architecture (now)



Big Data and Big Graphs (now)

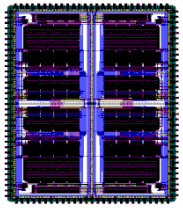


EXECUBE (1993)

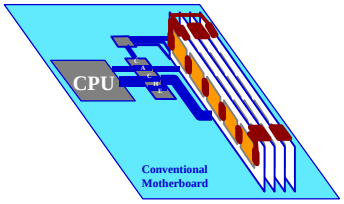


Traveling Threadlets (2007)

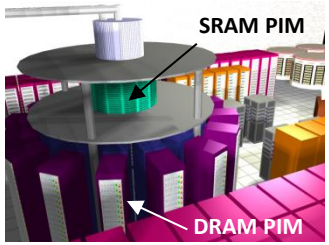
HPCS Cascade (2002-2006)



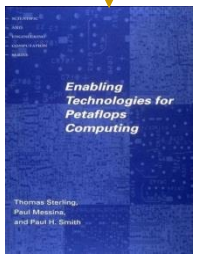
PIM Lite (2004)



DIVA (1998-2001)



HTMT (1997-2001)

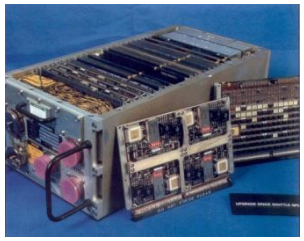


PIM Petaflop Architecture (1994)

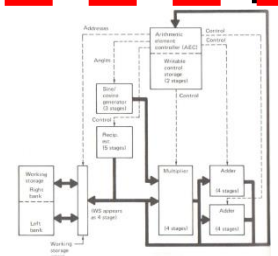
Real Computers

```
procedure MORA;
begin
 parallel_array A(*, 0::m-1);
 A[i,0] = a_i, (1 ≤ i ≤ N)
 for q = 1 step q+m-1
       until (N-m+1)/2 do
  begin
   for j = 1 step 1 until m-1 do
    begin
      A[i,j]=A[i,j-1),(1≤i≤q+j-1);
      A[I,j]=g(A[i,j-1], a_{i-q-j+q},
               (q+j ≤ i ≤ N);
    end;
   A[i,0] = h(A[i,0], A[i-q, m-1],
       …, A[i-q-m+1,0]), (q+m≤i≤N);
   A[i,0] = A[1, m-1], (1<i≤q+m-1);
  end;
 x_i = f(A[i,0], x_0, … x_{-m+1}),(1≤i≤N);
end MORA.
```

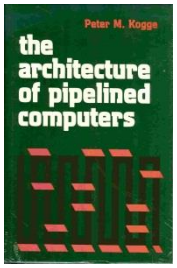
Parallel Recurrences (1971)



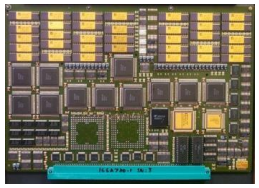
Space Shuttle IOP (1974)



IBM 3838 (1976)



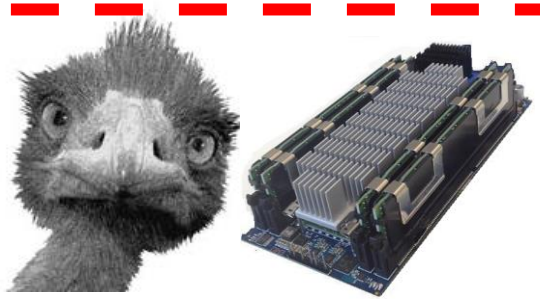
1st Book (1981)



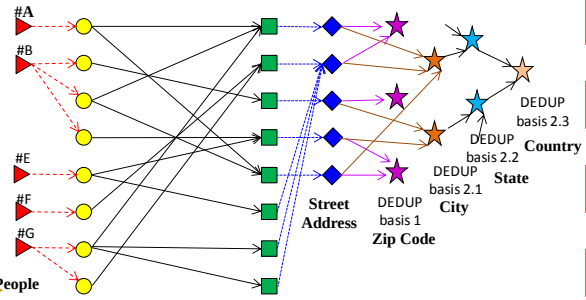
RTAIS: (1990)

2nd Book (1990)

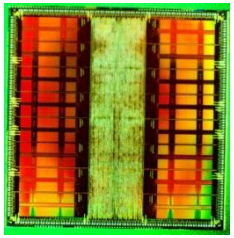
Exascale Report (2008)



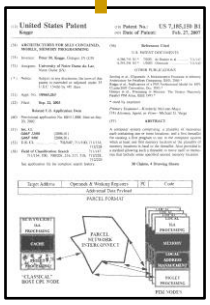
Gossamer Architecture (now)



Big Data and Big Graphs (now)

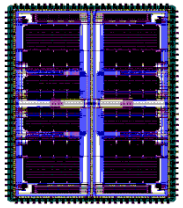


EXECUBE (1993)

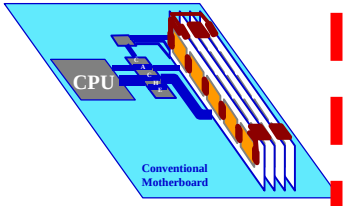


Traveling Threadlets (2007)

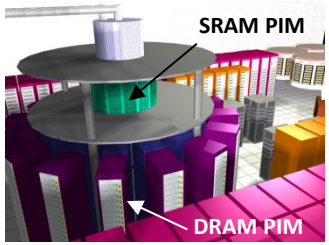
HPCS Cascade (2002-2006)



PIM Lite (2004)



DIVA (1998-2001)



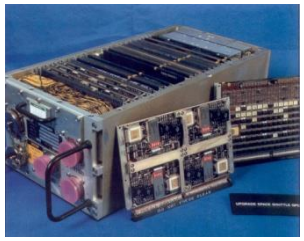
HTMT (1997-2001)

PIM Petaflop Architecture (1994)

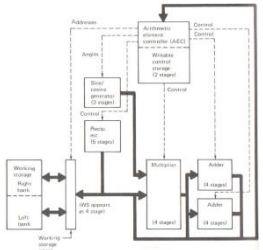
Novel Architectures

```
procedure MORA;
begin
 parallel_array A(*, 0::m-1);
 A[i,0] = a_i, (1 ≤ i ≤ N)
 for q = 1 step q+m-1
       until (N-m+1)/2 do
  begin
   for j = 1 step 1 until m-1 do
    begin
      A[i,j]=A[i,j-1),(1≤i≤q+j-1);
      A[I,j]=g(A[i,j-1], a_{i-q-j+q},
               (q+j ≤ i ≤ N);
    end;
   A[i,0] = h(A[i,0], A[i-q, m-1],
       …, A[i-q-m+1,0]), (q+m≤i≤N);
  A[i,0] = A[1, m-1], (1<i≤q+m-1);
  end;
 x_i = f(A[i,0], x_0, … x_{-m+1}),(1≤i≤N);
end MORA.
```

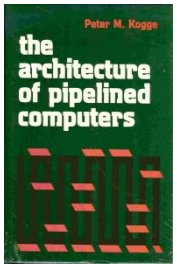
Parallel Recurrences (1971)



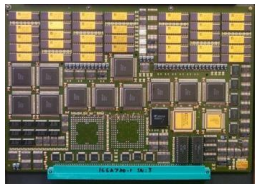
Space Shuttle IOP (1974)



IBM 3838 (1976)



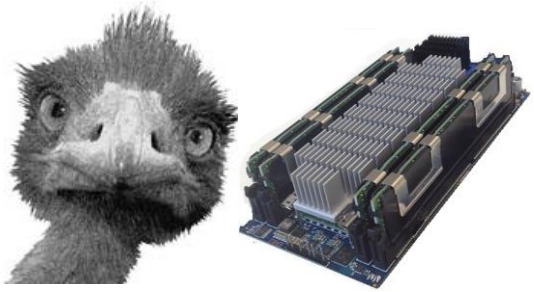
1st Book (1981)



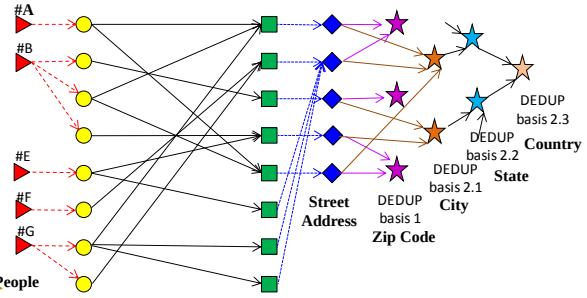
RTAIS: (1990)

2nd Book (1990)

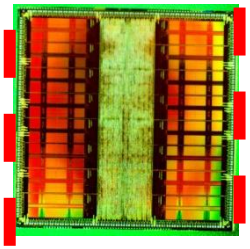
Exascale Report (2008)



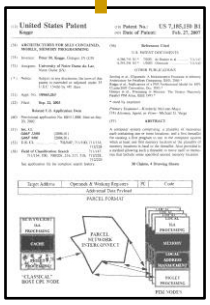
Gossamer Architecture (now)



Big Data and Big Graphs (now)

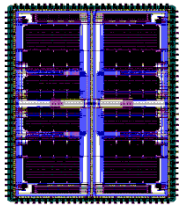


EXECUBE (1993)

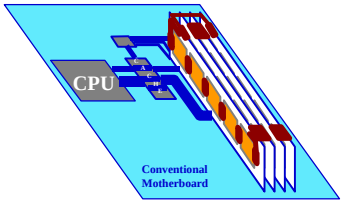


Traveling Threadlets (2007)

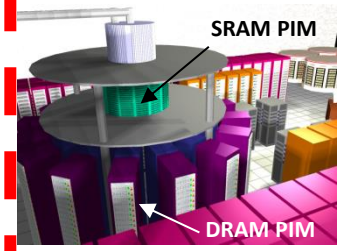
HPCS Cascade (2002-2006)



PIM Lite (2004)



DIVA (1998-2001)



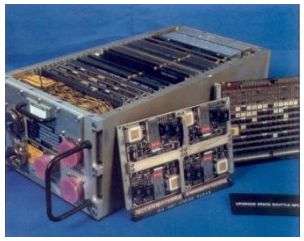
HTMT (1997-2001)

PIM Petaflop Architecture (1994)

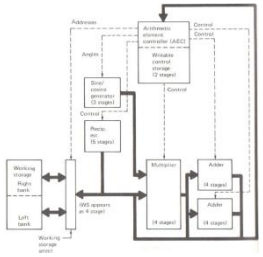
Algorithms

```
procedure MORA;
begin
 parallel_array A(*, 0::m-1);
 A[i,0] = a_i, (1 ≤ i ≤ N)
 for q = 1 step q+m-1
       until (N-m+1)/2 do
  begin
   for j = 1 step 1 until m-1 do
    begin
      A[i,j]=A[i,j-1),(1≤i≤q+j-1);
      A[I,j]=g(A[i,j-1], a_{i-q-j+q},
                (q+j ≤ i ≤ N);
    end;
   A[i,0] = h(A[i,0], A[i-q, m-1],
       …, A[i-q-m+1,0]), (q+m≤i≤N);
  A[i,0] = A[1, m-1], (1<i≤q+m-1);
 end;
x_i = f(A[i,0], x_0, … x_{-m+1}),(1≤i≤N);
end MORA.
```

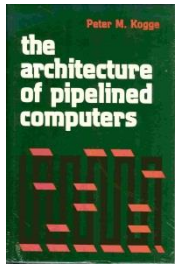
Parallel Recurrences (1971)



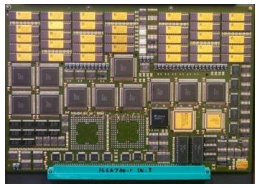
Space Shuttle IOP (1974)



IBM 3838 (1976)



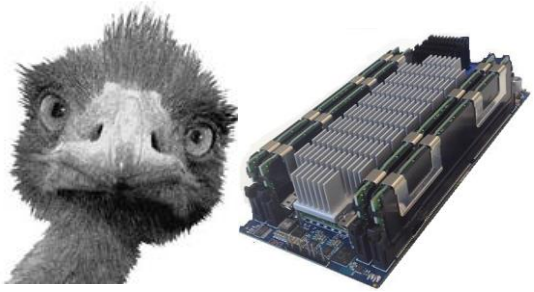
1st Book (1981)



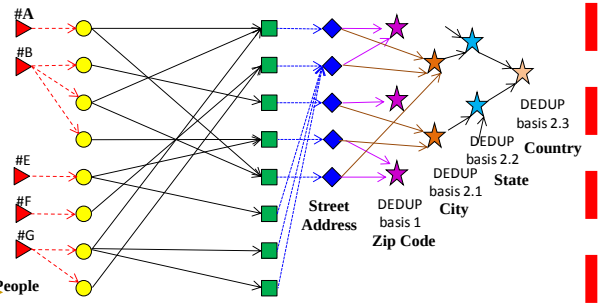
RTAIS: (1990)

2nd Book (1990)

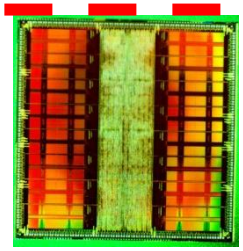
Exascale Report (2008)



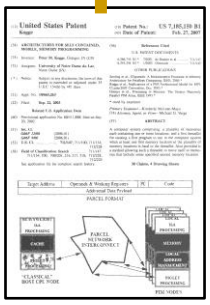
Gossamer Architecture (now)



Big Data and Big Graphs (now)

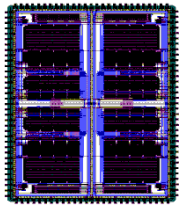


EXECUBE (1993)

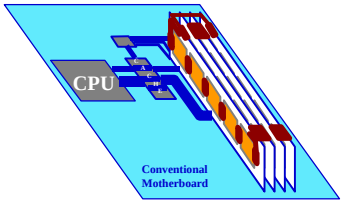


Traveling Threadlets (2007)

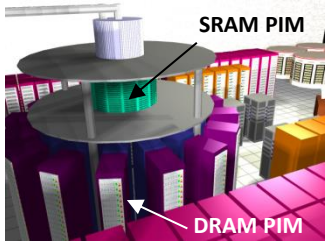
HPCS Cascade (2002-2006)



PIM Lite (2004)



DIVA (1998-2001)



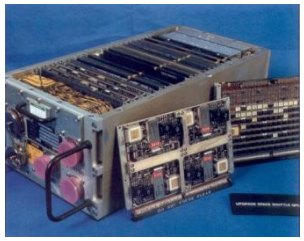
HTMT (1997-2001)

PIM Petaflop Architecture (1994)

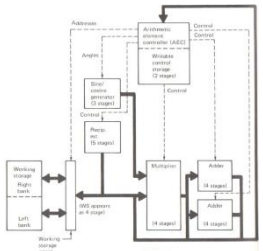
Programming Languages

```
procedure MORA;
begin
 parallel_array A(*, 0::m-1);
 A[i,0] = a_i, (1 ≤ i ≤ N)
 for q = 1 step q+m-1
       until (N-m+1)/2 do
  begin
   for j = 1 step 1 until m-1 do
    begin
      A[i,j]=A[i,j-1),(1≤i≤q+j-1);
      A[I,j]=g(A[i,j-1], a_{i-q-j+q},
               (q+j ≤ i ≤ N);
    end;
   A[i,0] = h(A[i,0], A[i-q, m-1],
       …, A[i-q-m+1,0]), (q+m≤i≤N);
  A[i,0] = A[1, m-1], (1<i≤q+m-1);
 end;
x_i = f(A[i,0], x_0, … x_{-m+1}),(1≤i≤N);
end MORA.
```

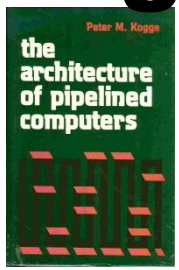
Parallel Recurrences (1971)



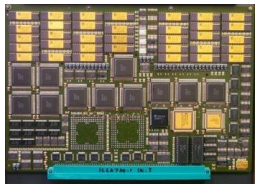
Space Shuttle IOP (1974)



IBM 3838 (1976)



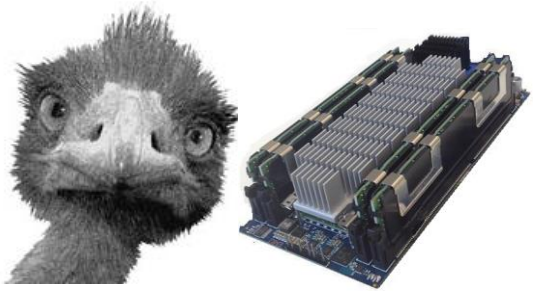
1st Book (1981)



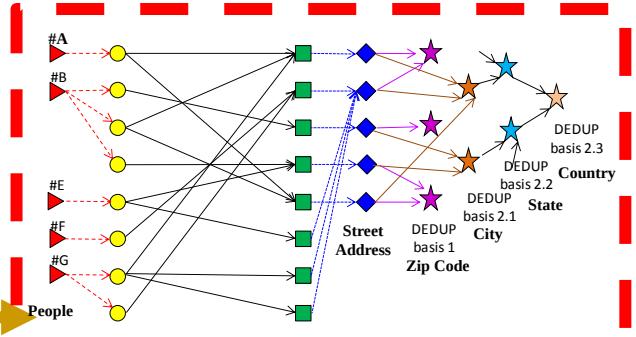
RTAIS: (1990)

2nd Book (1990)

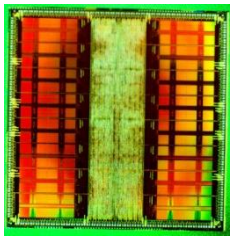
Exascale Report (2008)



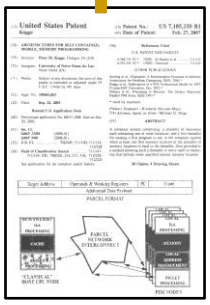
Gossamer Architecture (now)



Big Data and Big Graphs (now)

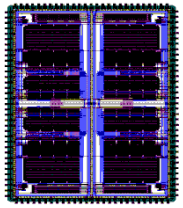


EXECUBE (1993)

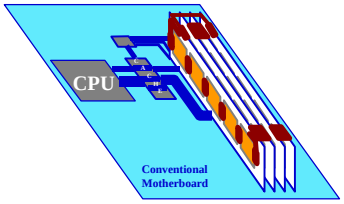


Traveling Threadlets (2007)

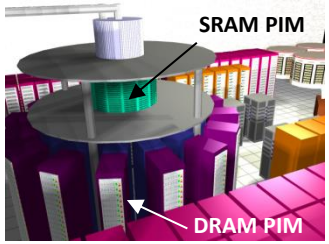
HPCS Cascade (2002-2006)



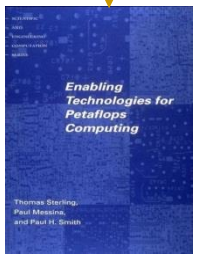
PIM Lite (2004)



DIVA (1998-2001)



HTMT (1997-2001)



PIM Petaflop Architecture (1994)