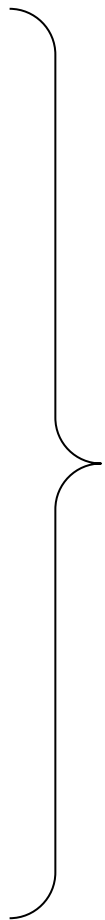


External Sorting with N-way Merge



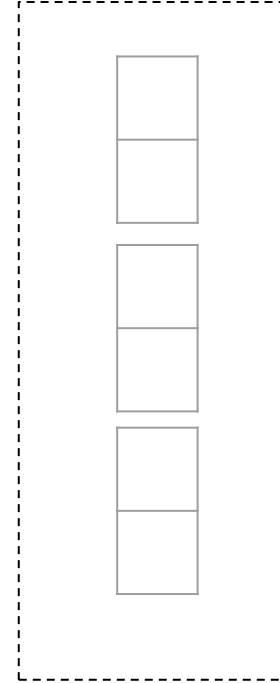
34
82
45
3
78
21
75
16
8
22
56
49



Data File.
Disk Block size =2 records

34
82
45
3
78
21
75
16
8
22
56
49

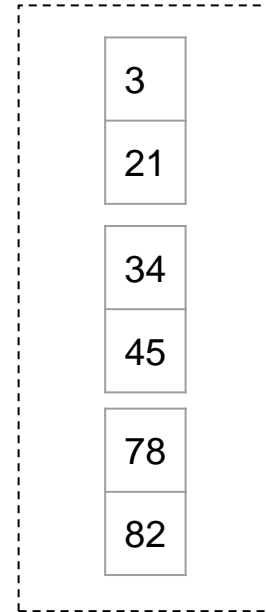
Data File.
Disk Block size = 2 records



Main Memory available
 $M=3$ (i.e., 3 disk blocks can be stored in Main Memory)



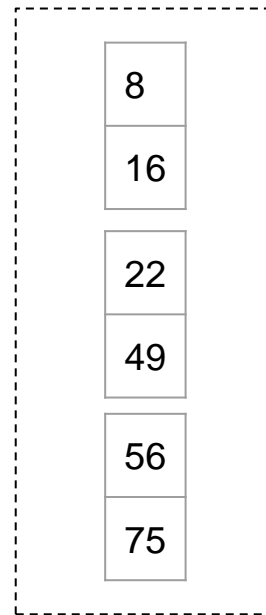
Data File.
Disk Block size = 2 records



Create Runs (sort 3 disk blocks
at a time)



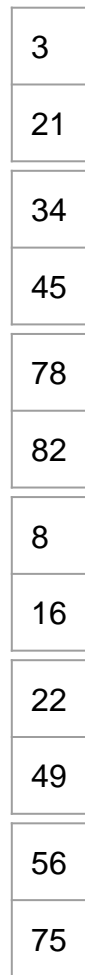
Data File.
Disk Block size = 2 records



Create Runs (sort 3 disk blocks
at a time)

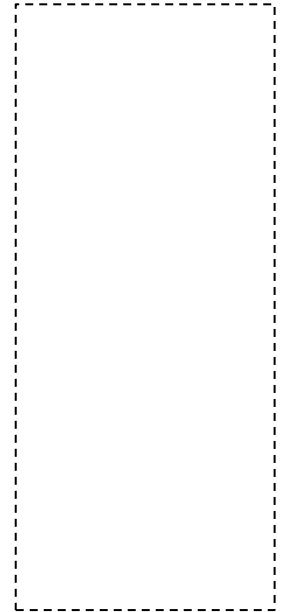


Data File.
Disk Block size = 2 records



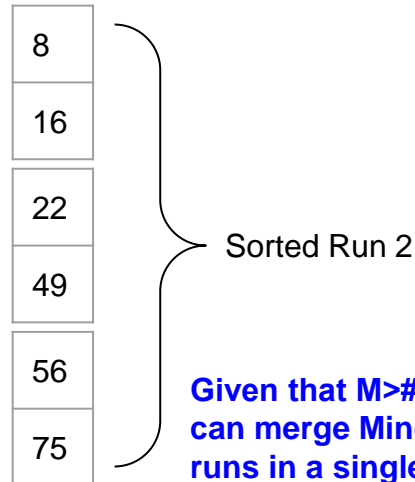
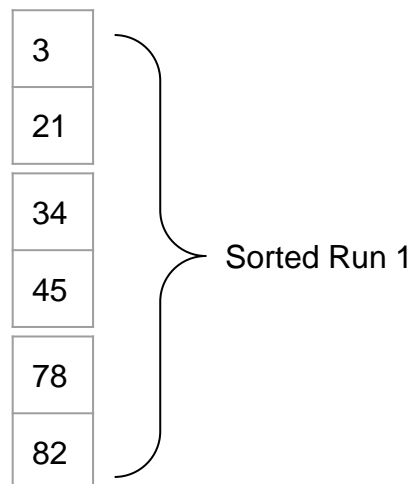
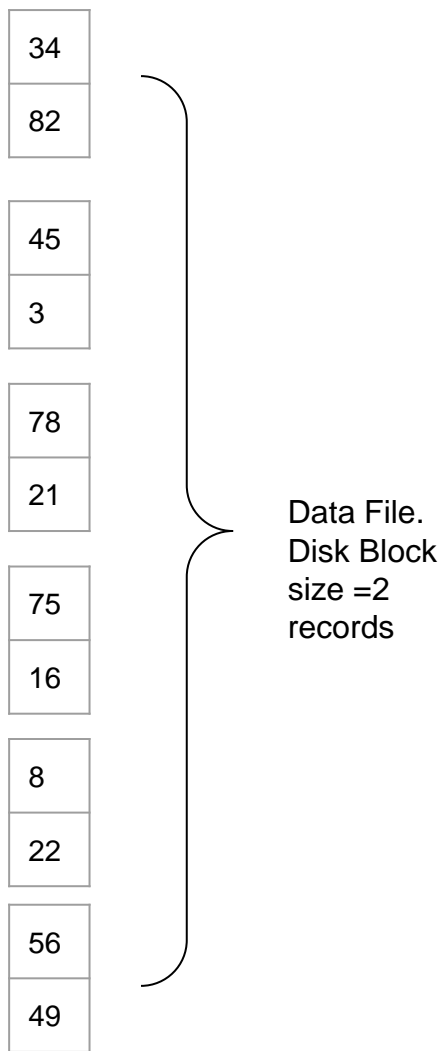
Sorted Run 1

Sorted Run 2



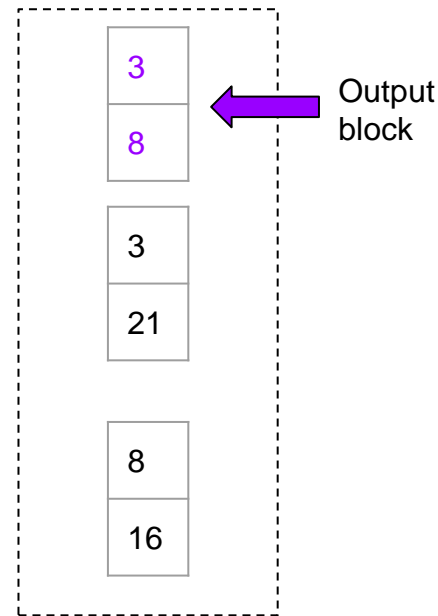
Create Runs (sort 3 disk blocks
at a time)

CASE 1: $M > \#Runs$



Given that $M > \# \text{ runs}$ \rightarrow we can merge $\text{Min}(\text{runs}, M-1)$ runs in a single shot. We use N-way merge operation

CASE: $M > \# \text{Runs}$



Merge the Runs. Bring in one block at a time from the runs and keep writing the output block.

A single N-way merge operation is enough. No passes needed

34
82

45
3

78
21

75
16

8
22

56
49

Data File.
Disk Block
size =2
records

3
21

34
45

78
82

8
16

22
49

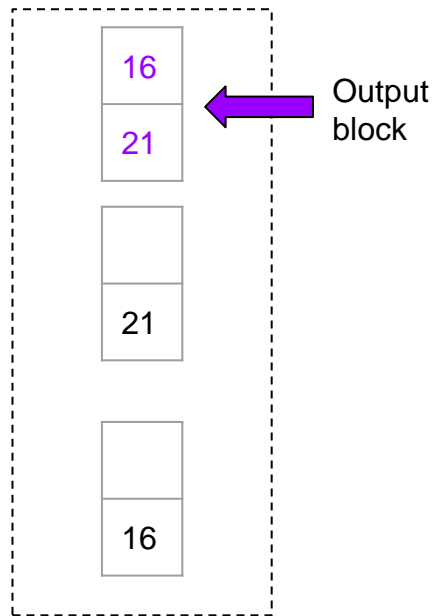
56
75

Sorted Run 1

Sorted Run 2

3
8

CASE: $M > \#Runs$

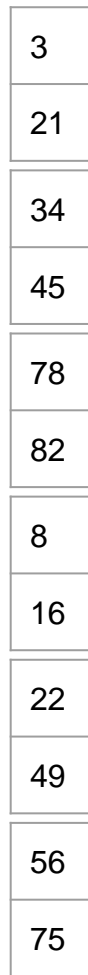


Merge the Runs. Bring in one block at a time from the runs and keep writing the output block.

A single N-way merge operation is enough. No passes needed

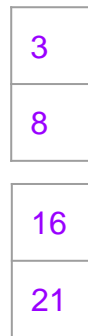


Data File.
Disk Block
size =2
records

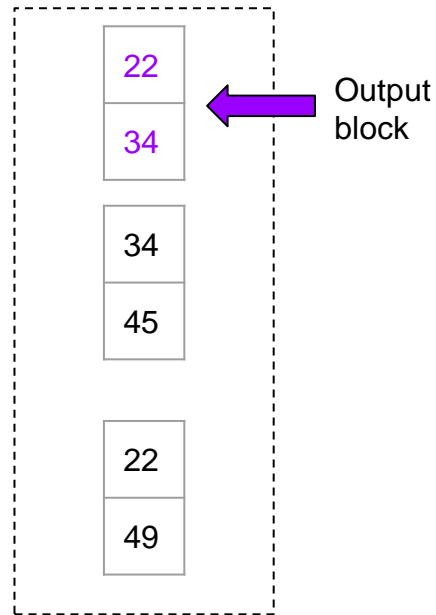


Sorted Run 1

Sorted Run 2



CASE: $M > \#Runs$

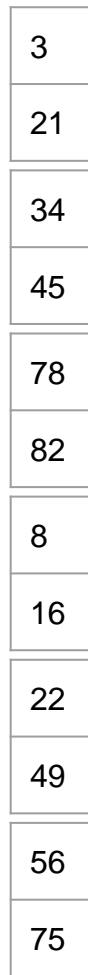


Merge the Runs. Bring in one block at a time from the runs and keep writing the output block.

A single N-way merge operation is enough. No passes needed



Data File.
Disk Block
size =2
records

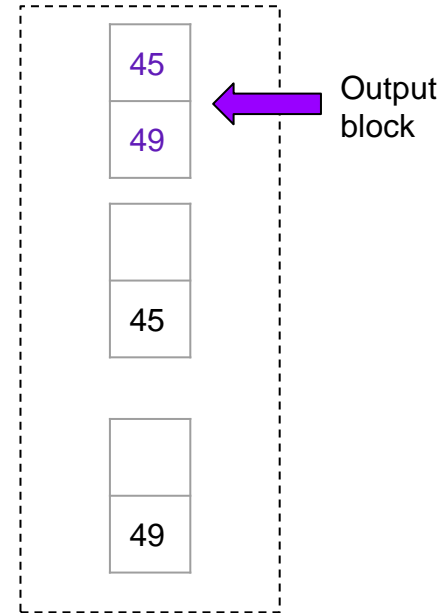


Sorted Run 1

Sorted Run 2



CASE: $M > \#Runs$

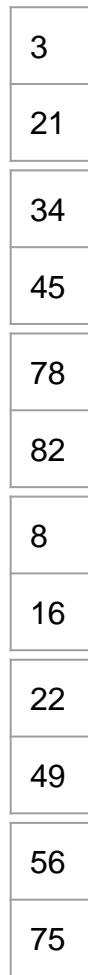


Merge the Runs. Bring in one block at a time from the runs and keep writing the output block.

A single N-way merge operation is enough. No passes needed



Data File.
Disk Block
size =2
records

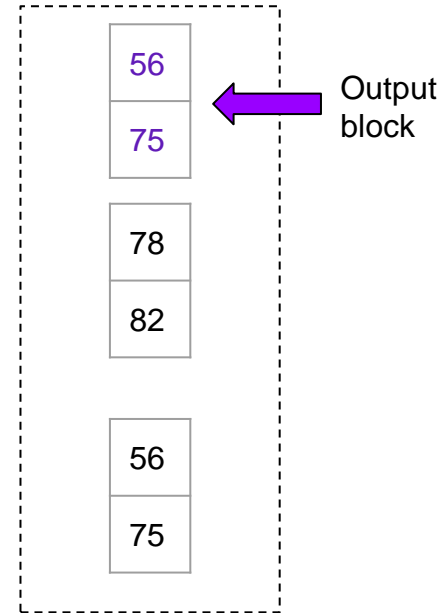


Sorted Run 1

Sorted Run 2



CASE: $M > \#Runs$

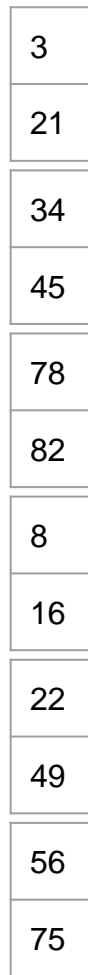


Merge the Runs. Bring in one block at a time from the runs and keep writing the output block.

A single N-way merge operation is enough. No passes needed

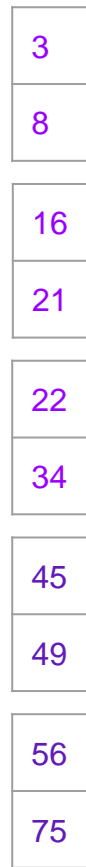


Data File.
Disk Block
size =2
records

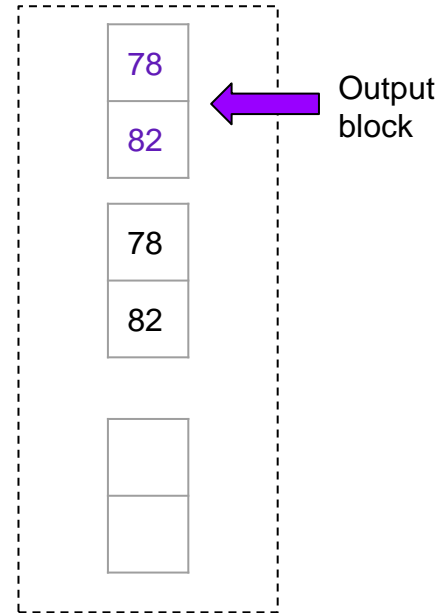


Sorted Run 1

Sorted Run 2



CASE: $M > \#Runs$



Merge the Runs. Bring in one block at a time from the runs and keep writing the output block.

A single N-way merge operation is enough. No passes needed

34
82
45
3
78
21
75
16
8
22
56
49

Data File.
Disk Block
size =2
records

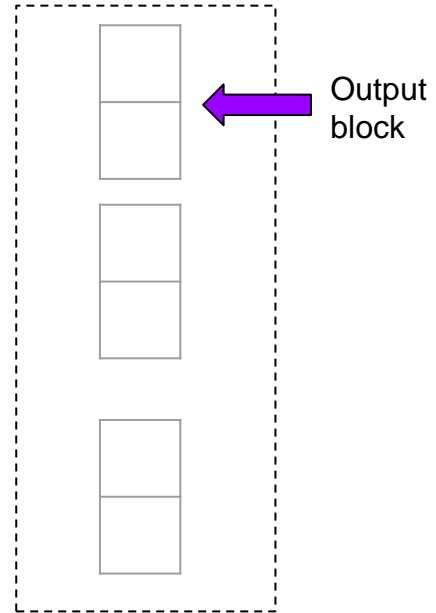
3
21
34
45
78
82
8
16
22
49
56
75

Sorted Run 1

Sorted Run 2

3
8
16
21
22
34
45
49
56
75
78
82

CASE: $M > \#Runs$



Merge the Runs. Bring in one block at a time from the runs and keep writing the output block.

A single N-way merge operation is enough. No passes needed

CASE 1: $M \leq \#Runs$

Data File.
Disk Block
size =1
records

g	24
a	19
d	31
c	33
b	14
e	16
r	16
d	21
m	3
p	2
d	7
a	14

initial
relation

a	19
d	31
g	24

Main Memory
size $M=3$ disk
blocks

Read 3 disk
blocks at a time
and create runs

Data File.
Disk Block
size =1
records

g	24
a	19
d	31
c	33
b	14
e	16
r	16
d	21
m	3
p	2
d	7
a	14

a	19
d	31
g	24

initial
relation runs
create
runs

b	14
c	33
e	16

Main Memory
size $M=3$ disk
blocks

Read 3 disk
blocks at a time
and create runs

Data File.
Disk Block
size =1
records

g	24
a	19
d	31
c	33
b	14
e	16
r	16
d	21
m	3
p	2
d	7
a	14

a	19
d	31
g	24

b	14
c	33
e	16

initial
relation runs
create
runs

d	21
m	3
r	16

Main Memory
size M=3 disk
blocks

Read 3 disk
blocks at a time
and create runs

Data File.
Disk Block
size =1
records

g	24
a	19
d	31
c	33
b	14
e	16
r	16
d	21
m	3
p	2
d	7
a	14

initial
relation

a	19
d	31
g	24

b	14
c	33
e	16

d	21
m	3
r	16

runs

create
runs

a	14
d	7
p	2

Main Memory
size $M=3$ disk
blocks

Read 3 disk
blocks at a time
and create runs

Data File.
Disk Block
size =1
records

g	24
a	19
d	31
c	33
b	14
e	16
r	16
d	21
m	3
p	2
d	7
a	14

initial
relation

a	19
d	31
g	24

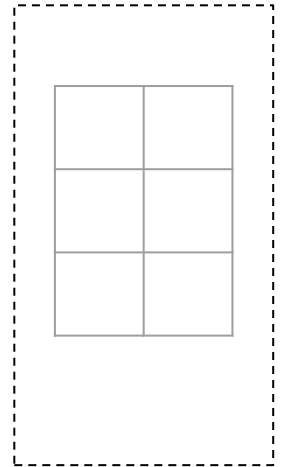
b	14
c	33
e	16

d	21
m	3
r	16

a	14
d	7
p	2

runs

create
runs



Main Memory
size $M=3$ disk
blocks

In general, we can merge
 $\text{Min}(\# \text{runs}, M-1)$ runs at a
time. As $M=3$ in our case,
we merge 2 runs at a time.

We merge two runs at a
time. One block in main
memory is saved for
output result. Each Run
spans across blocks

Data File.
Disk Block
size =1
records

g	24
a	19
d	31
c	33
b	14
e	16
r	16
d	21
m	3
p	2
d	7
a	14

initial
relation

create
runs

a	19
d	31
g	24

b	14
c	33
e	16

d	21
m	3
r	16

a	14
d	7
p	2

runs

a	19
a	19
b	14

Output
block

Main Memory
size $M=3$ disk
blocks

Read one block each
from each of the two
runs. Save one block
for output. Perform
Merge operation

Data File.
Disk Block
size =1
records

g	24
a	19
d	31
c	33
b	14
e	16
r	16
d	21
m	3
p	2
d	7
a	14

initial
relation

create
runs

a	19
d	31
g	24

b	14
c	33
e	16

d	21
m	3
r	16

a	14
d	7
p	2

runs

a	19
---	----

b	14
d	31
b	14

Output
block

Main Memory
size $M=3$ disk
blocks

Read one block each
from each of the two
runs. Save one block
for output. Perform
Merge operation

Data File.
Disk Block
size =1
records

g	24
a	19
d	31
c	33
b	14
e	16
r	16
d	21
m	3
p	2
d	7
a	14

initial
relation

create
runs

a	19
d	31
g	24

b	14
c	33
e	16

d	21
m	3
r	16

a	14
d	7
p	2

runs

a	19
b	14

c	33
d	31
c	33

Output
block

Main Memory
size $M=3$ disk
blocks

Read one block each
from each of the two
runs. Save one block
for output. Perform
Merge operation

Data File.
Disk Block
size =1
records

g	24
a	19
d	31
c	33
b	14
e	16
r	16
d	21
m	3
p	2
d	7
a	14

initial
relation

create
runs

a	19
d	31
g	24

b	14
c	33
e	16

d	21
m	3
r	16

a	14
d	7
p	2

runs

a	19
---	----

b	14
---	----

c	33
---	----

d	31
d	31
e	16

Output
block

Main Memory
size $M=3$ disk
blocks

Read one block each
from each of the two
runs. Save one block
for output. Perform
Merge operation

Data File.
Disk Block
size =1
records

g	24
a	19
d	31
c	33
b	14
e	16
r	16
d	21
m	3
p	2
d	7
a	14

initial
relation

create
runs

a	19
d	31
g	24

b	14
c	33
e	16

d	21
m	3
r	16

a	14
d	7
p	2

runs

a	19
---	----

b	14
---	----

c	33
---	----

d	31
---	----

e	16
g	24
e	16

Output
block

Main Memory
size $M=3$ disk
blocks

Read one block each
from each of the two
runs. Save one block
for output. Perform
Merge operation

Data File.
Disk Block
size =1
records

g	24
a	19
d	31
c	33
b	14
e	16
r	16
d	21
m	3
p	2
d	7
a	14

initial
relation

a	19
d	31
g	24

b	14
c	33
e	16

d	21
m	3
r	16

a	14
d	7
p	2

runs

create
runs

a	19
---	----

b	14
---	----

c	33
---	----

d	31
---	----

e	16
---	----

g	24
g	24
	1

Output
block

Main Memory
size $M=3$ disk
blocks

Read one block each
from each of the two
runs. Save one block
for output. Perform
Merge operation

Data File.
Disk Block
size =1
records

g	24
a	19
d	31
c	33
b	14
e	16
r	16
d	21
m	3
p	2
d	7
a	14

initial
relation

a	19
d	31
g	24

b	14
c	33
e	16

d	21
m	3
r	16

a	14
d	7
p	2

runs

create
runs

a	19
---	----

b	14
---	----

c	33
---	----

d	31
---	----

e	16
---	----

g	24
---	----



Output
block

Main Memory
size M=3 disk
blocks

Read one block each
from each of the two
runs. Save one block
for output. Perform
Merge operation

Data File.
Disk Block
size =1
records

g	24
a	19
d	31
c	33
b	14
e	16
r	16
d	21
m	3
p	2
d	7
a	14

initial
relation

create
runs

a	19
d	31
g	24

b	14
c	33
e	16

d	21
m	3
r	16

a	14
d	7
p	2

runs

a	19
---	----

b	14
---	----

c	33
---	----

d	31
---	----

e	16
---	----

g	24
---	----

Merge Run 3 and Run 4
as well

d	21
a	14

Output
block

Main Memory
size M=3 disk
blocks

Read one block each
from each of the two
runs. Save one block
for output. Perform
Merge operation

Data File.
Disk Block
size =1
records

g	24
a	19
d	31
c	33
b	14
e	16
r	16
d	21
m	3
p	2
d	7
a	14

initial
relation

a	19
d	31
g	24

b	14
c	33
e	16

d	21
m	3
r	16

a	14
d	7
p	2

runs

create
runs

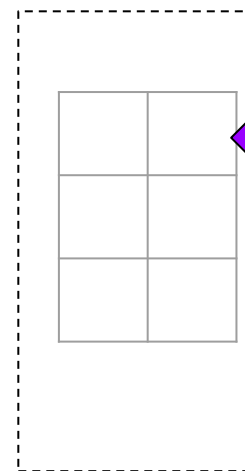
a	19
b	14
c	33
d	31
e	16
g	24

a	14
d	7
d	21
m	3
p	2
r	16

runs

merge
pass-1

merge
pass-2



Main Memory
size $M=3$ disk
blocks

Read one block each
from each of the two
runs. Save one block
for output. Perform
Merge operation

Data File.
Disk Block
size =1
records

g	24
a	19
d	31
c	33
b	14
e	16
r	16
d	21
m	3
p	2
d	7
a	14

initial
relation

a	19
d	31
g	24

b	14
c	33
e	16

d	21
m	3
r	16

a	14
d	7
p	2

runs

create
runs

a	19
b	14
c	33
d	31
e	16
g	24

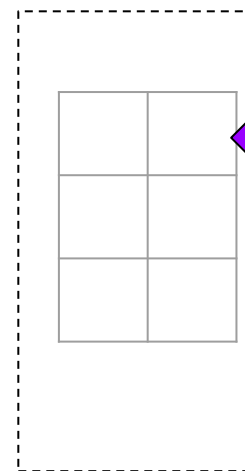
a	14
d	7
d	21
m	3
p	2
r	16

runs

merge
pass-1

merge
pass-2

Merge these
runs which
got created in
the previous
pass



Output
block

Main Memory
size M=3 disk
blocks

Read one block each
from each of the two
runs. Save one block
for output. Perform
Merge operation

Data File.
Disk Block
size =1
records

g	24
a	19
d	31
c	33
b	14
e	16
r	16
d	21
m	3
p	2
d	7
a	14

initial
relation

a	19
d	31
g	24

b	14
c	33
e	16

d	21
m	3
r	16

a	14
d	7
p	2

runs

create
runs

a	19
b	14
c	33
d	31
e	16
g	24

a	14
d	7
d	21
m	3
p	2
r	16

runs

merge
pass-1

merge
pass-2

a	14
a	19
b	14
c	33
d	7
d	21
d	31
e	16
g	24
m	3
p	2
r	16

sorted
output

In this example, ties were
broken according to the
values in the second field.
However, such things
depend on the
specification. Algorithm is
independent of such
aspects