Redundant Array of Inexpensive (Independent) Disks
- Use multiple smaller disks (c.f. one large disk)
- Parallelism improves performance
- Plus extra disk(s) for redundant data storage

Provides fault tolerant storage system
- Especially if failed disks can be “hot swapped”

RAID 0
- No redundancy (“AID”?)
  - Just stripe data over multiple disks
- But it does improve performance

"allocation of logically sequential data blocks to separate disks to allow higher performance than a single disk can deliver"
RAID 1 & 2

RAID 1: Mirroring
- N + N disks, replicate data
  - Write data to both data disk and mirror disk
  - On disk failure, read from mirror

RAID 2: Error correcting code (ECC)
- N + E disks (e.g., 10 + 4)
- Split data at bit level across N disks
- Generate E-bit ECC
- Too complex, not used in practice (for disks, but…)
RAID 3: Bit-Interleaved Parity

N + 1 disks
- Data striped across N disks at byte level
- Redundant disk stores parity
- Read access
  - Read all disks
- Write access
  - Generate new parity and update all disks
- On failure
  - Use parity to reconstruct missing data

Not widely used
RAID 4: Block-Interleaved Parity

N + 1 disks
- Data striped across N disks at block level
- Redundant disk stores parity for a group of blocks
- Read access
  - Read only the disk holding the required block
- Write access
  - Just read disk containing modified block, and parity disk
  - Calculate new parity, update data disk and parity disk
- On failure
  - Use parity to reconstruct missing data

Not widely used
RAID 3 vs RAID 4

New Data 1. Read 2. Read 3. Read

D0'  D0  D1  D2  D3  P

+ XOR

D0'  D1  D2  D3  P'

4. Write 5. Write

New Data 1. Read

D0'  D0  D1  D2  D3  P

+ XOR

D0'  D1  D2  D3  P'

2. Read

3. Write 4. Write
RAID 5: Distributed Parity

N + 1 disks
- Like RAID 4, but parity blocks distributed across disks
  - Avoids parity disk being a bottleneck

Widely used
RAID 6: P + Q Redundancy

N + 2 disks
- Like RAID 5, but two lots of parity
- Greater fault tolerance through more redundancy
RAID Summary

RAID can improve performance and availability
  - High availability requires hot swapping

Assumes independent disk failures
  - Too bad if the building burns down!

See “Hard Disk Performance, Quality and Reliability”