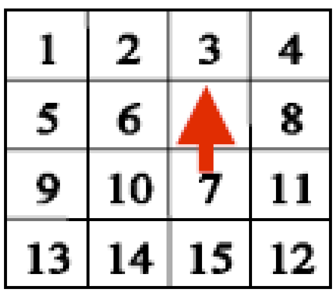
Lecture 4: Principles of Parallel Algorithm Design (part 3)

Exploratory Decomposition

- Decomposition according to a search of a state space of solutions
- Example: the 15-puzzle problem
  - Determine any sequence or a shortest sequence of moves that transforms the initial configuration to the final configuration.



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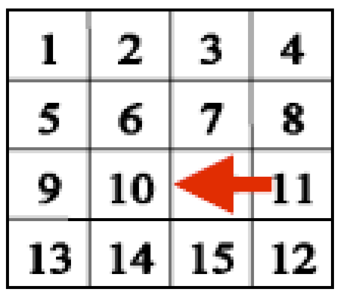

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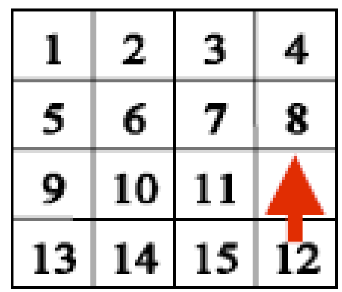

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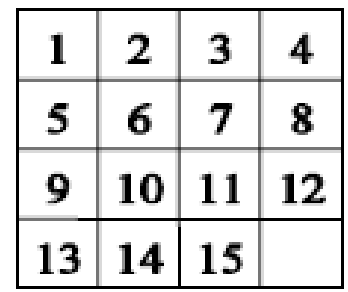
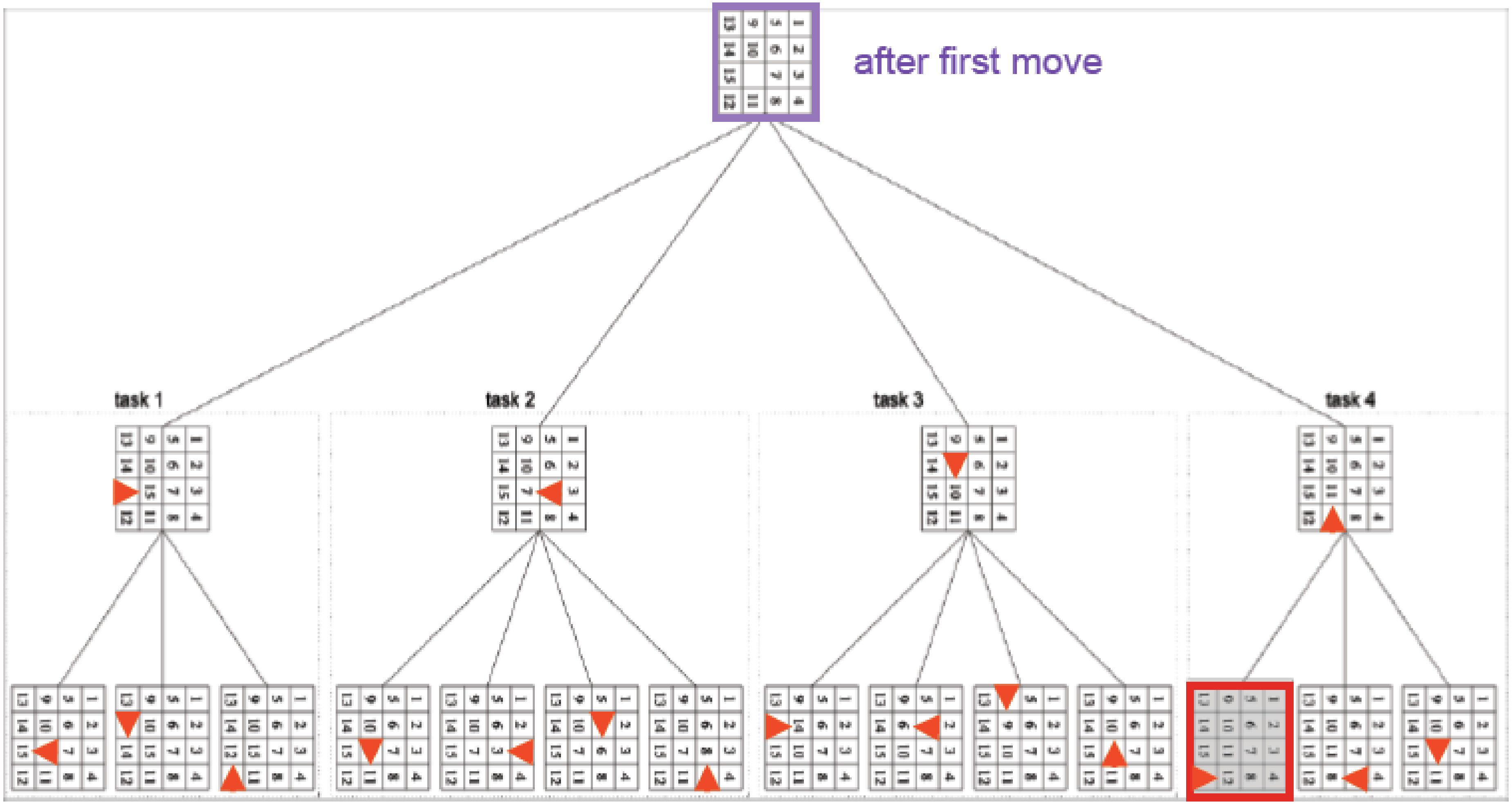
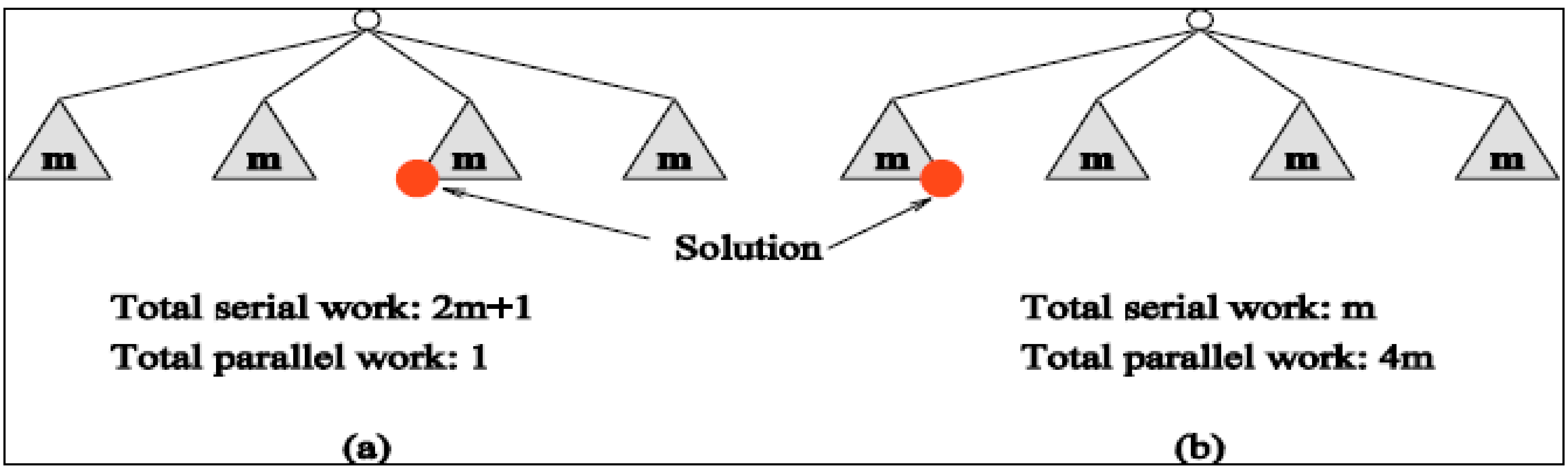


D

- Solution algorithm
  - Subsequent configurations are generated based on current configuration.
  - Each configuration is then explored as an independent task.



- Difference between data-decomposition and exploratory decomposition
  - Tasks induced by data-decomposition are performed entirely and each task performs useful computation.
  - Tasks induced by exploratory can be terminated before finishing as soon as desired solution is found.
- Work induced by exploratory decomposition and performed by parallel formulation can be either smaller or greater than that performed by serial algorithm

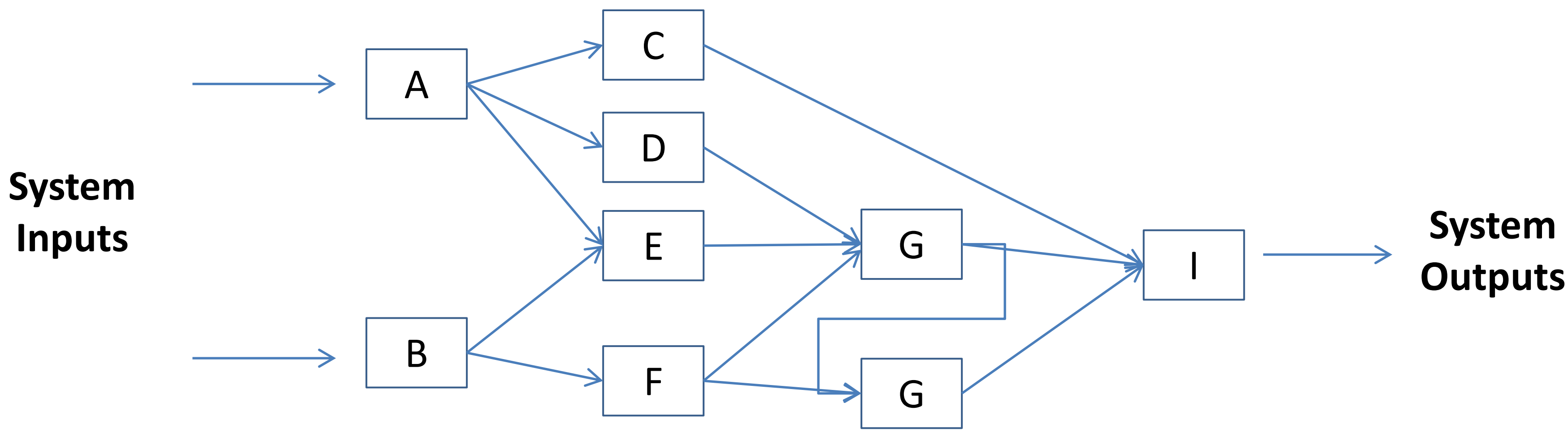


Speculative Decomposition

- This decomposition is used when a program may take one of many possible computationally significant branches depending on the output of other computations that precede it.

Example: Speculative Decomposition

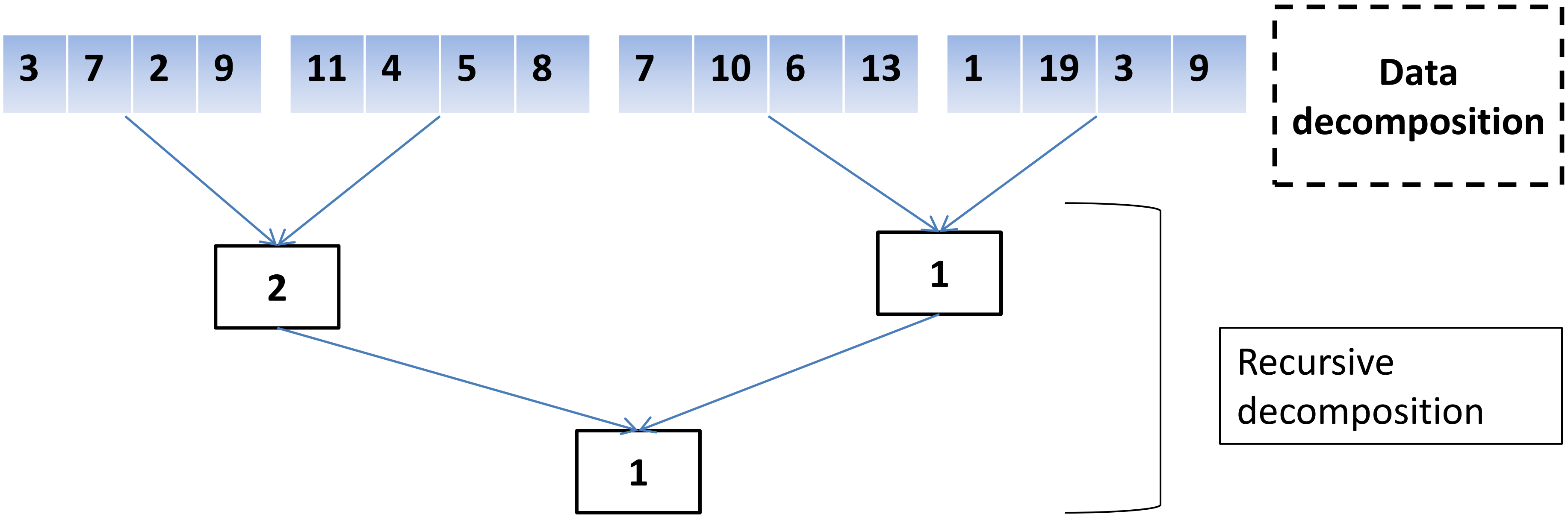
- Parallel discrete event simulation
  - The nodes of a directed network have input buffer of jobs. After processing the job, the node put results in the input buffer of nodes which are connected to it by outgoing edges. A node has to wait if the input buffer of one of its outgoing neighbors is full. *There is a finite number of input job types.*



- Inherently sequential problem
- Can be improved by starting simulating a subpart of the network, each assume one of several possible inputs to that stage.

Hybrid Decomposition

- Use several decomposition methods together
- Example: finding the minimum of any array of size 16 using 4 tasks.



Characteristics of Tasks

Key characteristics of tasks influencing choice of mapping and performance of parallel algorithm:

1. Task generation
   - Static or dynamic generation
2. Task sizes
   - Amount of time required to compute it: uniform, non-uniform
3. Knowledge of task sizes
4. Size of data associated with tasks
   - Data associated with the task must be available to the process performing the task

Task Generation

- Static task generation
  - All the tasks are known before computation
  - Data or recursive decomposition often leads to static task generation: matrix-matrix multiplication, finding min.
- Dynamic task generation
  - Actual tasks and task-dependency graph are not explicitly available *a priori*
  - Recursive, exploratory decomposition can generate tasks dynamically: quicksort, puzzle game

Characteristics of Task Interactions

1. Static versus dynamic
2. Regular versus irregular
3. Read-only versus read-write
4. One-way versus two-way

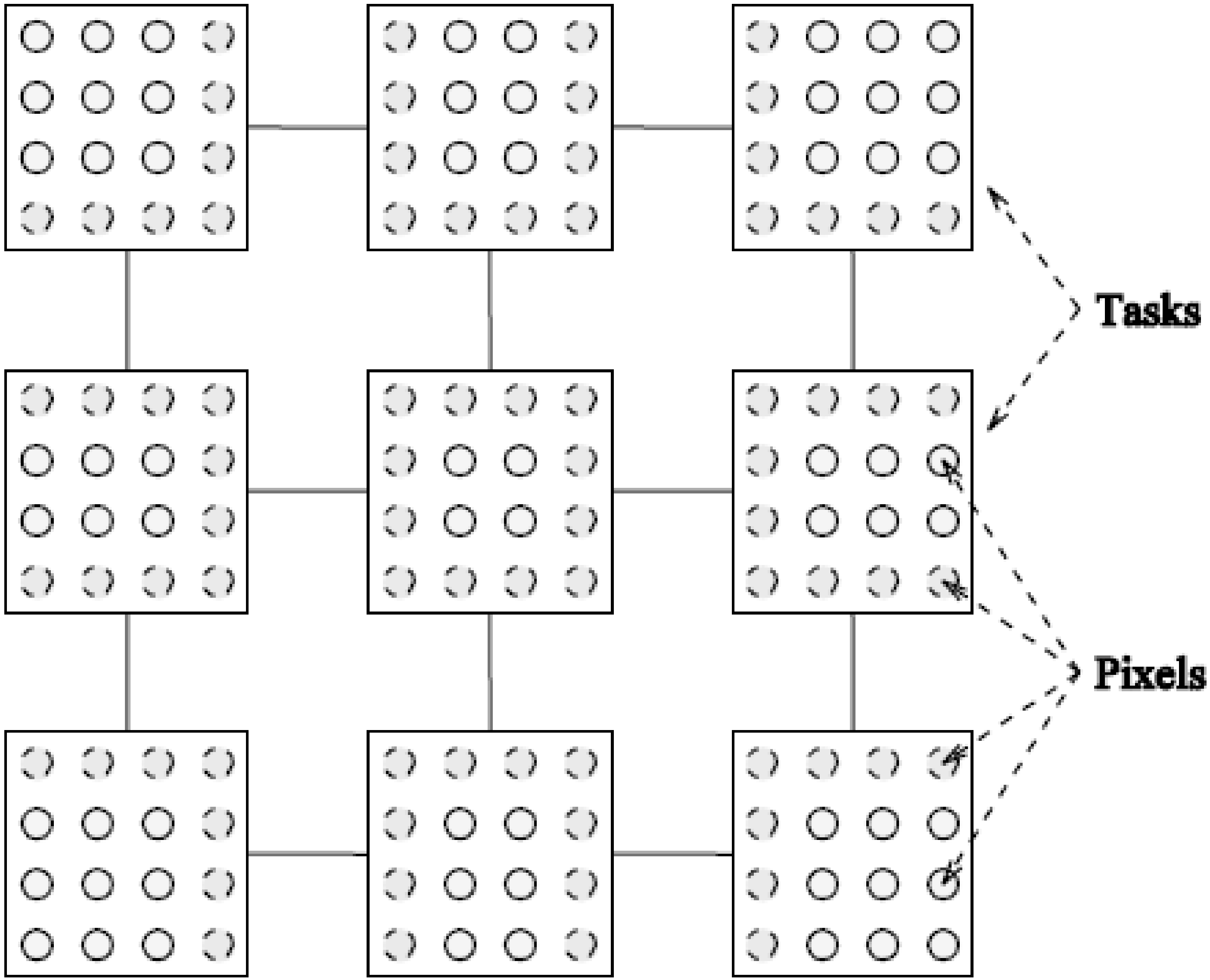
Static vs. Dynamic Interactions

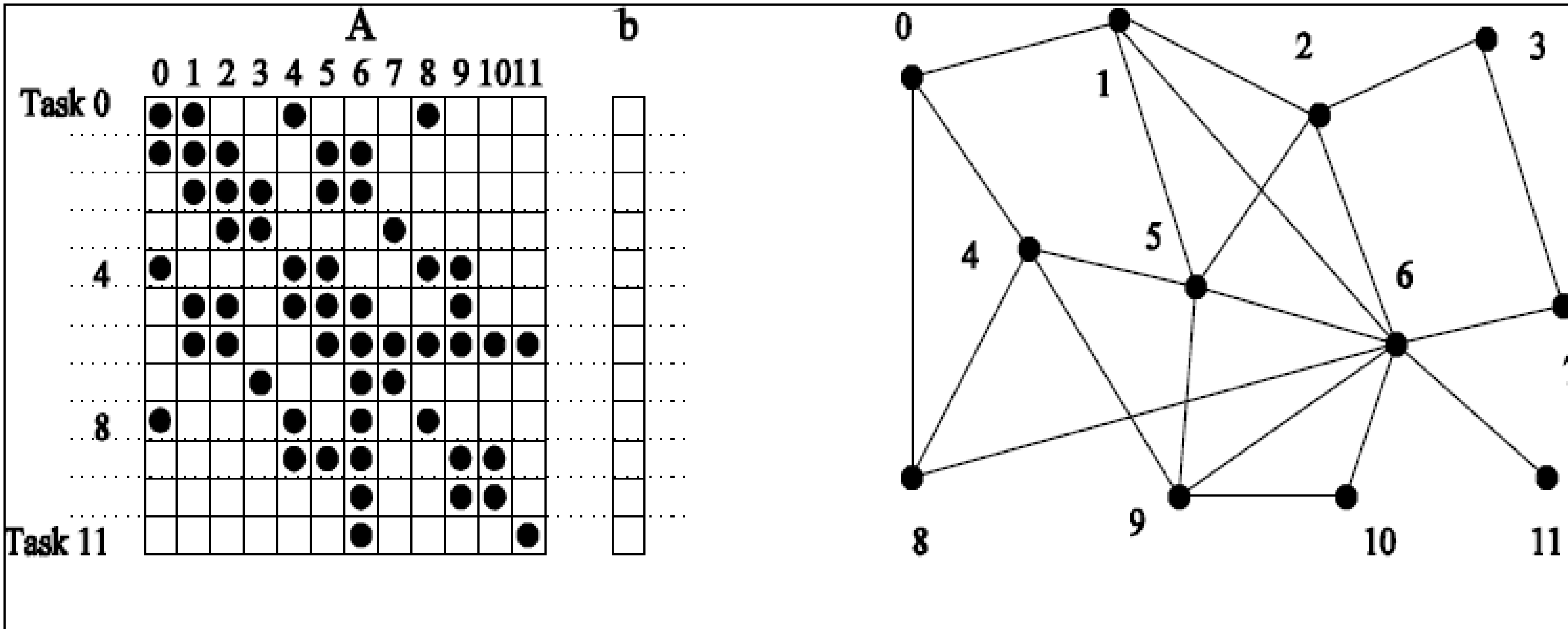
- Static interaction
  - Tasks and associated interactions are predetermined: task-interaction graph and times that interactions occur are known: matrix multiplication
  - Easy to program
- Dynamic interaction
  - Timing of interaction or sets of tasks to interact with can not be determined prior to the execution: puzzle game
  - Difficult to program using massage-passing; Shared-memory space programming may be simple

Regular vs. Irregular Interactions

- Regular interactions
  - Interaction has a spatial structure that can be exploited for efficient implementation: ring, mesh
  - Example: 1D heat eqn. Image dithering
- Irregular Interactions
  - Interactions has no well-defined structure
  - Example: Sparse matrix-vector multiplication

Static regular interaction for image dithering





(a) (b)

Read-Only vs. Read-Write Interactions

- Read-only interactions
  - Tasks only require read-only interactions
  - Example: matrix multiplication
- Read-write interactions
  - Multiple tasks need to read and write on some shared data

One-Way vs. Two-Way Interactions

- One-way interactions
  - One of a pair of communicating tasks initiates the interaction and completes it with interrupting the other one.
  - Example: read-only can be formulated as one-way
- Two-way interactions
  - Both tasks involve in interaction
  - Example: read-write can be formulated as two-way