

| | Allocation | Max | Available | Need |
|----------------|--------------------|--------------------|--------------------|--------------------|
| T ₀ | A B C D 3 1 4 1 | A B C D 6 4 7 3 | A B C D 2 2 2 4 | A B C D 3 3 3 2 |
| T ₁ | A B C D 2 1 0 2 | A B C D 4 2 3 2 | | A B C D 2 1 3 0 |
| T ₂ | A B C D 2 4 1 3 | A B C D 2 5 3 3 | | A B C D 0 1 2 0 |
| T ₃ | A B C D 4 1 1 0 | A B C D 6 3 3 2 | | A B C D 2 2 2 2 |
| T ₄ | A B C D 2 2 2 1 | A B C D 5 6 7 5 | | A B C D 3 4 5 4 |

- a. Illustrate that the system is in a safe state by demonstrating an order in which the threads may complete.

Safe State: $\langle T_2, T_1, \bar{T}_3, \bar{T}_0, \bar{T}_4 \rangle$

$$\begin{array}{r}
 & & 2 & 2 & 2 & 4 \\
 & \underline{\langle T_2 \rangle + 2 \ 4 \ 1 \ 3} \\
 & & 4 & 6 & 3 & 7 \\
 & \underline{\langle T_1 \rangle + 2 \ 1 \ 0 \ 2} \\
 & & 6 & 7 & 3 & 9 \\
 & \underline{\langle \bar{T}_3 \rangle + 4 \ 1 \ 1 \ 0} \\
 & & 10 & 8 & 4 & 9 \\
 & \underline{\langle \bar{T}_0 \rangle + 3 \ 1 \ 4 \ 1} \\
 & & 13 & 9 & 8 & 10
 \end{array}$$

- b. If a request from thread T₄ arrives for (2, 2, 2, 4), can the request be granted immediately?

$$(2, 2, 2, 4) \leq (3, 4, 5, 4) \Rightarrow \text{True}$$

$$(2, 2, 2, 4) \leq (2, 2, 2, 4) \Rightarrow \text{True}$$

Safe State: $\langle X \rangle$

因為 Available 總和為 0, 3, 11, 11

| | Allocation | Need | Available | the request cannot be granted immediately. |
|----------------|--------------------|--------------------|--------------------|--|
| T ₀ | A B C D 3 1 4 1 | A B C D 3 3 3 2 | A B C D 0 0 0 0 | |
| T ₁ | A B C D 2 1 0 2 | A B C D 2 1 3 0 | | |
| T ₂ | A B C D 2 4 1 3 | A B C D 0 1 2 0 | | |
| T ₃ | A B C D 4 1 1 0 | A B C D 2 2 2 2 | | |
| T ₄ | A B C D 4 4 4 5 | A B C D 1 2 3 0 | | |

c. If a request from thread T_2 arrives for $(0, 1, 1, 0)$, can the request be granted immediately?

$$(0, 1, 1, 0) \leq (2, 1, 3, 0)$$

Safe State: $\langle T_2, T_1, T_3, T_0, T_4 \rangle$

$$(0, 1, 1, 0) \leq (2, 2, 2, 4)$$

| | Allocation | Need | Available | |
|-------|------------|---------|-----------|--|
| | A B C D | A B C D | A B C D | |
| T_0 | 3 1 4 1 | 3 3 3 2 | 2 1 1 4 | $\begin{array}{r} 2 \ 1 \ 1 \ 4 \\ \hline \langle T_2 \rangle + \end{array}$ |
| T_1 | 2 1 0 2 | 2 1 3 0 | | $\begin{array}{r} 2 \ 5 \ 2 \ 3 \\ \hline 4 \ 6 \ 3 \ 7 \end{array}$ |
| T_2 | 2 5 2 3 | 0 0 1 0 | | $\begin{array}{r} 2 \ 1 \ 0 \ 2 \\ \hline b \ 7 \ 3 \ 9 \end{array}$ |
| T_3 | 4 1 1 0 | 2 2 2 2 | | $\begin{array}{r} 4 \ 1 \ 1 \ 0 \\ \hline \langle T_0 \rangle + \end{array}$ |
| T_4 | 2 2 2 1 | 3 4 5 4 | | $\begin{array}{r} 3 \ 1 \ 4 \ 1 \\ \hline 13 \ 9 \ 8 \ 10 \end{array}$ |

Ans: Yes, the request can be granted immediately.

Because it have safe state.

d. If a request from thread T_3 arrives for $(2, 2, 1, 2)$, can the request be granted immediately?

$$(2, 2, 1, 2) \leq (2, 2, 2, 2)$$

Safe State: $\langle T_3, T_2, T_1, T_0, T_4 \rangle$

$$(2, 2, 1, 2) \leq (2, 2, 2, 4)$$

| | Allocation | Need | Available | |
|-------|------------|---------|-----------|--|
| | A B C D | A B C D | A B C D | |
| T_0 | 3 1 4 1 | 3 3 3 2 | 0 0 1 2 | $\begin{array}{r} 0 \ 0 \ 1 \ 2 \\ \hline \langle T_3 \rangle + \end{array}$ |
| T_1 | 2 1 0 2 | 2 1 3 0 | | $\begin{array}{r} 6 \ 3 \ 2 \ 2 \\ \hline b \ 3 \ 3 \ 4 \end{array}$ |
| T_2 | 2 4 1 3 | 0 1 2 0 | | $\begin{array}{r} 2 \ 4 \ 1 \ 3 \\ \hline 8 \ 7 \ 4 \ 7 \end{array}$ |
| T_3 | 6 3 2 2 | 0 0 1 0 | | $\begin{array}{r} 2 \ 1 \ 0 \ 2 \\ \hline \langle T_1 \rangle + \end{array}$ |
| T_4 | 2 2 2 1 | 3 4 5 4 | | $\begin{array}{r} 10 \ 8 \ 4 \ 9 \\ \hline 3 \ 1 \ 4 \ 1 \end{array}$ |

Ans: Yes, the request can be granted immediately.

Because it have safe state.