Clicker Questions

• Please Try to solve the clicker questions for this tutorial.
• The Clicker questions will be closed at 3:20 and we will begin discussing their solutions
Embedded Systems

Exercise 6: Models and Architecture Synthesis

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Dependance Graph (DG)

- A dependence graph describes order relations for the execution of single operations or tasks.
- It represents parallelism in a program but no branches in control flow.
Dependence graph Example

- Clicker question 1
- $W = a + b$;
- $X = a \times b$;
- $Y = X + c$;
- $Z = X - W$;

Answer: 2
Scheduling : timing inequations

Based on the dependence graph: we start formulating timing constraints represented by inequations:

\[ \tau(W) \geq \tau(t_0) \]
\[ \tau(X) \geq \tau(t_0) \]
\[ \tau(Y) \geq \tau(X) + 1 \]
\[ \tau(Z) \geq \tau(X) + 1 \]
\[ \tau(Z) \geq \tau(W) + 1 \]

Clicker question answer : 1\textsuperscript{st} choice
Design space exploration

- Its goal is finding a balance between the number of resources used and the latency for executing the program, and choosing an implementation according to the available resources and any constraints on latency.
Design space exploration Example

• No of resources = 1
  • Latency = 4
• No of resources = 2
  • Latency = 2
• No of resources = 3
  • Latency = 2

Clicker question answer: 3rd choice
Marked Graphs

A marked graph $G = (V, A, del)$ consists of

- nodes (actors) $v \in V$
- edges $a = (v_i, v_j) \in A$, $A \subseteq V \times V$
- number of initial tokens on edges $del : A \rightarrow \mathbb{N}$
Marked Graph Example

Given the 2 nodes in the marked graph, How many times can node B fire before Node A has to fire to enable node B firing again?

Clicker question answer : 3\textsuperscript{rd} choice : 2
Question 1 (1)

\[
\begin{align*}
\tau(v_1) &\geq \tau(v_0) \\
\tau(v_2) &\geq \tau(v_0) \\
\tau(v_6) &\geq \tau(v_0) \\
\tau(v_8) &\geq \tau(v_0) \\
\tau(v_{10}) &\geq \tau(v_0)
\end{align*}
\]
Question 1 (1)

\[ \tau(v_3) \geq \tau(v_1) + 1 \]
\[ \tau(v_3) \geq \tau(v_2) + 1 \]
\[ \tau(v_4) \geq \tau(v_3) + 1 \]
\[ \tau(v_5) \geq \tau(v_4) + 1 \]
\[ \tau(v_5) \geq \tau(v_7) + 1 \]
\[ \tau(v_7) \geq \tau(v_6) + 1 \]
\[ \tau(v_9) \geq \tau(v_8) + 1 \]
\[ \tau(v_{11}) \geq \tau(v_{10}) + 1 \]
Question 1 (1)

\[ \tau(v_n) \geq \tau(v_5) + 1 \]
\[ \tau(v_n) \geq \tau(v_9) + 1 \]
\[ \tau(v_n) \geq \tau(v_{11}) + 1 \]

Initial condition: \( \tau(v_0) = 0 \)
Question 1 (2,3)

Initial condition: $\tau(v_0) = 0$

Objective function:
$\min \; \tau(v_n) - \tau(v_0)$

Minimum latency and valid starting times:

- One resource: $L_{min} = 11$
- Unlimited resources: $L_{min} = 4$

1 resource: e.g.
$\tau(v_1) = 0; \tau(v_2) = 1; \tau(v_3) = 2; \tau(v_4) = 3; \tau(v_6) = 4; \\
\tau(v_7) = 5; \tau(v_5) = 6; \tau(v_8) = 7; \tau(v_9) = 8; \tau(v_{10}) = 9; \\
\tau(v_{11}) = 10; \tau(v_n) = L = 11$
Question 2

- No of resources = 1
- Latency = 11
Question 2

- No of resources = 2
- Latency = 6
Question 2

- No of resources = 3
- Latency = 4
Question 2

- No of resources = 4
- Latency = 4
Question 2

Latency bounds: $4 \leq L \leq 11$. Cost bounds: $1 \leq c \leq 5$. Pareto-points:
Question 3 (1 I)

I) \[ b(1) = a(1) + s \]
\[ b(k) = a(k) + b(k - 1) \text{ for } k > 1 \]

with \( s \) being the data value of the initial mark
II) For \( n = 0 \) the output sequence is empty.
For \( n > 0 \):
\[
\begin{align*}
b(k) &= a(k) + s_k \text{ for } k \leq n \\
b(k) &= a(k) + b(k - n) \text{ for } k > n
\end{align*}
\]
with \( s_1, \ldots, s_n \) being the data values of the initial marks.
Question 3 (2)

\[ v(1) = 2 \times s_2 \times (u(1) + s_1) \]
\[ v(2) = 2 \times v(1) \times (u(2) + s_2) \]
\[ v(k) = 2 \times v(k - 1) \times (u(k) + v(k - 2)) \text{ for } k > 2 \]
**Question 4**

\[
Fib(n) = \begin{cases} 
0 & \text{if } n = 0 \\
1 & \text{if } n = 1 \\
Fib(n - 1) + Fib(n - 2) & \text{if } n > 1 
\end{cases}
\]

\[
Fib(n) = Fib(n - 1) + Fib(n - 2) \\
x1(n) = Fib(n - 2) \\
x2(n) = x1(n) + Fib(n - 1)
\]
Question 5

\[
\begin{align*}
  w & := a + b \times d; \\
  x & := a - b \times e; \\
  y & := w \times c; \\
  z & := a + b + d; \\
  \text{IF} (z < 0) \text{ THEN} \\
  & \quad z := -z; \\
  \text{END IF} \\
  \text{IF} (y > 0) \text{ THEN} \\
  & \quad v := 1 / y; \\
  \text{ELSE} \\
  & \quad v := z \times y; \\
  \text{END IF}
\end{align*}
\]