# Université de Sherbrooke, Département d’informatique

IGL501 : Méthodes formelles en génie logiciel, Examen périodique

Professeur : Marc Frappier, mardi 7 octobre 2014, 15h30 à 18h20, local D4-2022

Documentation permise. La correction est, entre autres, basée sur le fait que chacune de vos réponses soit *claire*, c’est-à-dire lisible et compréhensible pour le lecteur; *précise*, c’est-à-dire exacte et sans erreur; *concise*, c’est-à-dire qu’il n’y ait pas d’élément superflu; *complète*, c’est-à-dire que tous les éléments requis sont présents.

Pondération :

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 1 | 12 pts | 2 | 8 pts | 3 | 25 pts | 4 | 45 pts | 5 | 10 pts | Total | 100 pts |

Prénom: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Nom: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Matricule : \_\_\_\_\_\_\_\_\_\_\_\_\_\_

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1. (12 pts) Soit A ={a1,a2,a3} et B ={b1,b2,b3}. Indiquez si les expressions suivantes sont vraies ou fausses, Justifiez votre réponse.

1. {a1↦a2} ∈ P(A×A); \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
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2. {{a1↦a2}}⊆A ↔︎ A; \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
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3. { a1↦a2, a1↦a3}∈ A⇸A; \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
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4. { a1↦a1, a2↦a3, a3↦a2} ∈ A⤖A; \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
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5. A⇸B ⊆ A↔A ; \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
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6. A⤔B ⊆ A↣**A** ; \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
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2. (8 pts) Calculez le résultat des expressions suivantes.

1. dom({a1↦a2, a1↦a3, a3↦a2}) = ? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
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2. {a1↦a2, a1↦a3, a3↦a2};{a1↦a2, a1↦a3, a3↦a2} = ? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
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3. {a1}⊳{a1↦a2, a1↦a3, a3↦a2}⊲{a2} = ? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
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4. {a1↦a2, a1↦a3, a3↦a2}<+{ a1↦a1}= ? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
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3. (25 pts) Pour chaque opération ainsi que pour l'initialisation de la machine suivante, indiquez si l'invariant est préservé, en faisant le calcul de l'obligation de preuve.

**MACHINE** *Q3*

**CONSTANTS** *A*

**PROPERTIES** *A* = 0..1

**VARIABLES** *x*, *z*

**INVARIANT** *x*  1..3

  *z*  *A* ⤖ *A*

**INITIALISATION**

**ANY** *a* **WHERE** *a*  *A* **THEN** *z* := id(*A*) || *x* := *a* **END**

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**OPERATIONS**

**op1** =

**PRE** *x*  1..2

**THEN**

 *x*:= *x* +1

|| **ANY** *a* **WHERE** *a*  *A* **THEN** *z(a)* := *a* **END**

**END;**

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**op2**(*y1,y2*) = **PRE** *y1* ⋀ *y2*  **THEN** *z(y1) :=z(y2)* **||** *z(y2) :=z(y1)* **END** **END**

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**op3**(*y*) =

 **PRE** *y*  -1..1⋀ *y < x* **THEN**

 **SELECT** *y* > 0 **THEN** *x* := *y+1*

 **WHEN** *y*  *x* **THEN** *x* := *y*

 **END**

 **END;**

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 **Op4** = **CHOICE** *x := 0* **OR** *x := 1* **END**

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**END**

4. (45 pts) Écrivez une spécificartion B pour le système suivant. Le système gère un système de transactions d'une firme de courtage la bourse. Chaque courtier est soumis à une limite quotidienne pour le total de ses transactions. Cette limite quotidienne varie en fonction du courtier, mais elle ne doit pas dépasser une certaine limite globale fixée par la firme de courtage. Une transaction qui dépasse une certaine limite doit être approuvée par le superviseur du courtier; cette limite pour une transaction varie en fonction du courtier. Chaque courtier a un superviseur. On distingue les transactions complétées (ie, approuvées ou qui n'ont pas besoin d'approbation à cause de leur montant), des transactions en attente d'approbation. Le respect des limites quotidiennes d'un courtier doit prendre en compte autant les transactions en attente que les transactions complétées. Pour simplifier, votre modèle n'a pas a prendre en compte l'évolution du temps; il ne doit gérer que les transactions d'une journée; il n'a pas a prendre en compte plusieurs journées à la fois; les limites fixées ne varient pas durant une journée. Le système doit garder une trace des approbations et des refus, aux fins de vérification externe par des vérificateurs de l'Autorité des marchés financiers. Vous aurez besoin de l'opérateur **somme**(*S*), définit ci-dessous, qui retourne la somme des éléments de *S*; il retourne 0 si *S* est vide. Complétez la spécification suivante.

**MACHINE** *Courtier*

**SETS**

 *COURTIER* = {*c1*,*c2*};

 *SUPERVISEUR* = {*s1*,*s2*};

 *TRANSACTION* = {*t1*,*t2*,*t3*,*t4*,*t5*}

**DEFINITIONS**

 *somme*(*S*) == (*z*).(*z*  *S* | *z*)

**VARIABLES**

 *courtier*, *superviseur*, *supervisePar*, *limiteQuotidienne*, *limiteParTransaction*, *limiteGlobale*, *transaction*, *montant*, *auteur*, *transactionEnAttente*, *approbation*, *refus*

**INVARIANT**

 *courtier*  *\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_* /\* ensemble des courtiers \*/

  *superviseur*  *\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_* /\* ensemble des superviseurs \*/

  *supervisePar*  *\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_* /\* indique le superviseur du courtier \*/

  *limiteQuotidienne*  *\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_* /\* indique la limite quotidienne du courtier \*/

  *limiteGlobale*  **\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**/\* indique la limite quotidienne du système \*/

  *limiteParTransaction*  *\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_* /\* indique la limite d'une transaction d'un courtier \*/

  *transaction*  *\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_* /\* ensemble des transactions \*/

  *montant*  *\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_* /\* montant d'une transaction\*/

  *auteur*  *\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_* /\* indique le courtier qui a effectué la transaction \*/

  *transactionEnAttente*  *\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_* /\* transactions qui doivent être approuvées \*/

  *approbation*  *\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_* /\* indique le superviseur qui a approuvé une transaction \*/

  *refus*  *\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_* /\* indique le superviseur qui a refusé une transaction \*/

 /\* La somme des transactions ne dépasse pas la limite du courtier \*/

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 /\* La limite quotidienne d'un courtier ne dépasse pas la limite de la firme \*/

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 /\* Les transactions en attente ont besoin d'être approuvées \*/

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 /\* Les transaction complétées sont approuvées si nécessaire \*/

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 /\* Une transaction est soit en attente, soit approuvée ou refusée \*/

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**INITIALISATION**

 *… rien à compléter ici …*

**OPERATIONS**

/\* Cette opération effectue une transaction par le courtier *c* pour le montant *m*. Le no de la transaction est choisi de manière aléatoire par le système. \*/

 **transiger**(*c*,*m*) =

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/\* Cette opération permet à un superviseur *s* d'approuver la transaction *t*. \*/

 **approuver**(*s*,*t*) =

 **PRE**

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**END**

**5.** (10 pts) Pour chaque question suivante, indiquez si l'opération abstraite Op1 est raffinée par l'opération concrète Op2, avec l'invariant de collage x = x' (l'invariant de collage est l'invariant *J* du REFINEMENT, c'est-à-dire la machine concrète). L'invariant *I* de la machine abstraite est x  -1 .. 1. Notez qu'il n'y a pas de variable de sortie ici et pas de précondition, donc l'obligation de preuve devient simplement

*I*  *J* => [op2] ¬ [op1] ¬*J*

a)

Op1 = ANY z WHERE z 

Op2 = CHOICE x' := 1 OR x' := -1 END

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

Op1 = CHOICE x' := 1 OR x' := -1 END

Op2 = ANY z WHERE z 

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