UNIVERSITY OF DUBLIN CS4B1A1

TRINITY COLLEGE

FACULTY OF ENGINEERING & SYSTEMS SCIENCES

DEPARTMENT OF COMPUTER SCIENCE

B.A. (Mod.) Computer Science **Trinity Term 2003**

Degree Examination

4BA1 INFORMATION SYSTEMS

Friday, 6th June 2003 Samuel Beckett Room 9.30 – 12.30

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Attempt **five** questions, at least **two** from each section.

Students may avail of the HANDBOOK OF MATHEMATICS of Computer Science.

The partition of marks is noted in the margin and correlated with effort.

Please use separate answer books for each section.

SECTION A

1. An Architectural firm has many clients for which it designs buildings. Each architect in the firm has a name (non unique) and may be involved in the design of several buildings. Each architect also has one or more competences drawn from the following areas: domestic housing, office blocks, public spaces and follies. Each time the firm is hired, it is designated as a new project and may involve the design of several buildings, be worked on by more than one architect and perhaps even have more than one client associated with the hiring (i.e. where the firm is jointly hired by a consortium). Each project is also associated with one or more specific competences required to complete the project — these competences are drawn from the same four areas indicated earlier. Each project has an estimated cost associated with it, a proposed start date and the number of working days estimated to complete the project.

Based on the above information, the architectural firm requires the development of a database to manage projects in the firm.

\ . . . continued over.

(a) Develop a Functional Dependency diagram for the firm's information given above, listing any enterprise rules you are assuming. [4/20]

(b) Give the Boyce-Codd normal form for the relations indicating foreign and primary keys. [3/20]

(c) Specify the SQL commands to create the appropriate schema. In your answer consider reasonable constraints which may be required by the firm. [4/20]

(d) Give the SQL for the following operations:

(i) Retrieve the possible architects with the appropriate competences for projects where the client's name is 'JONES'.

(ii) The firm has decided to amend the way it calculates the cost of a project. The new algorithm is calculated as the number of days taken for the job multiplied by 4,000 Euro. For every competence required to fulfil for the project, a surcharge of 20,000 Euro is added. Give the SQL statements required to increase the existing project costs. For example, to complete a project lasting 8 days and involving three of the four competences, the estimated cost would be 92,000 Euro.

(iii) Give the SQL command to grant retrieval access to users 'BLACK' and 'WHITE' on a table of your choice in the Database.

[9/20]

2. Patients in the Dublin area have a series of appointments with various consultants in various out-patient clinics at hospitals in the region and a relational database is to be set up to store this information. The following rules apply:

- On a given day, a consultant attends at just one hospital.
- At most one patient has an appointment with a given consultant at a given time.
- Consultant names are unique.

The following information is stored:

For each patient: a unique patient number, their name and their G.P. number (also unique) and their G.P.'s name and address.
For each appointment: the date and time of the appointment, the consultant's name, the consultant's phone number, the hospital's name and the hospital's address in which the clinic is being held.

The figure below shows a sample of the data.

PAT. NO.	PAT. NAME	G.P. NO.	G.P. NAME	G.P. ADDR.	APP. DATE	APP. TIME	CON. NAME	PH. NO.	HOSP.	HOSP. ADDR.
1234	Murphy	897	Watson	Malahide	12.6.87	13:10	Johnson	682115	Adelaide	Peter St.
					15.6.87	14:00	Moore	972810	Meath	Heytesbury St.
					2.4.87	10:20	Cox	669811	St. Vincents	Elm Park
1432	Ryan	304	Flaherty	Foxrock	2.4.87	10:20	Johnson	682115	Mater	Eccles St.
					15.6.87	13:30	Moore	972810	Meath	Heytesbury St.
2342	O'Toole	401	Casey	Beaumont	5.4.87	10:00	Moore	972810	St. Vincents	Elm Park
					10.4.87	16:00	Johnson	682115	Mater	Eccles St.
5971	Farrell	304	Flaherty	Foxrock	12.6.87	12:00	Johnson	682115	Adelaide	Peter St.
6347	O'Sullivan	897	Watson	Malahide	14.5.87	13:00	Cox	669811	Meath	Heytesbury St.
					14.6.87	14:00	Cox	669811	Meath	Heytesbury St.

Figure 1.

(a) Give the relational schema in Boyce-Codd Normal form appropriate for this database. [6/20]

(b) How can Triggers be used to support active databases? Illustrate your answer with example assertions and triggers using the hospital database above as a basis. State any assumptions or additions you make to the schema in order to give these illustrations. [14/20]

3. Compare and contrast lock based concurrency (wound wait & wait die algorithms) and pure timestamping concurrency control algorithms. In your answer give the relevant algorithms and illustrate, with example schedule(s), how these algorithms provide their concurrency control. Indicate, giving reasons, what transaction mixes would favour the selection of these algorithms. [20/20]

4. (a) What is serialisability in terms of transaction scheduling and what can it be used to prove? [2/20]

(b) Listed below are three transaction schedules, each involving read and write operations for three transactions T_1, T_2, T_3. Indicate which of the following schedules are serialisable, and if so, give the equivalent serial schedule:

$$S_1 = \{r_3(a), r_1(a), r_1(b), r_3(c), r_1(c), w_1(b), r_2(b), w_1(d), r_1(d), r_2(b), r_2(d), r_3(d), w_3(d)\}$$
$$S_2 = \{r_2(a), r_3(d), r_2(b), r_1(a), r_1(b), r_3(b), w_1(a), w_3(d), r_2(d), r_2(c), w_2(c), r_3(c), r_1(d), w_1(d)\}$$
$$S_3 = \{r_3(v), r_2(y), w_3(v), r_2(x), w_2(x), r_1(v), r_1(x), w_1(x), r_1(y), w_1(v), r_3(y), r_3(z), w_3(z), r_1(z)\}$$

[9/20]

(c) Identify and explain the mechanisms used by relational databases to support data integrity and security. [9/20]

SECTION B

5. Refugee camps set up by the Red Cross Red Crescent are distributed among a set of disjoint physical regions outside of the war zone(s). Each camp is uniquely labelled and furnished with global positioning devices. To capture these notions let us introduce

$$\lambda \in \mathit{REF\_CAMPS} = \mathit{LABEL} \longrightarrow \mathit{REF\_CAMP}$$
$$\kappa \in \mathit{SAFE\_ZONES} = \mathit{REGION} \longrightarrow (\mathit{LABEL} \longrightarrow \mathit{REF\_CAMP})$$

Associated with each refugee camp there is a corresponding information base, which contains its name, global positioning coordinates, number of live refugees, number of dead refugees, etc. We model this abstractly by

$$\gamma \in \mathit{INFOBASE} = \mathit{LABEL} \longrightarrow \mathit{INFO}$$

(a) Write precise mathematical expressions for each of the following:

(i) "the labels of the *REF_CAMPS* are the same as those used in the *SAFE_ZONES* and in the *INFOBASE*";

(ii) "a new refugee camp c labelled l is sited in the region r and the associated information i recorded".

(iii) a major nuclear explosion destroyed all refugee camps $S = \{c_1, c_2, \ldots, c_j\}$. [8/20]

(b) At times safe zones become unusable and it may be necessary to move refugee camps from one region to another. In the specification of such a move operation the concept of "system of refugee camps" is introduced and modelled by the Cartesian product $\mathit{SYSTEM} = \mathit{REF\_CAMPS} \times \mathit{SAFE\_ZONES} \times \mathit{INFOBASE}$. Using this definition the moving of a refugee camp c labelled l from region r to region s may be specified by an operation of the form

$$\mathit{Move}\colon \mathit{LABEL} \times \mathit{REGION} \times \mathit{REGION} \times \mathit{INFO} \longrightarrow (\mathit{SYSTEM} \longrightarrow \mathit{SYSTEM})$$
$$\mathit{Move}[l, r, s, i]\langle \lambda, \kappa, \gamma \rangle := \langle \ldots \rangle$$

where i denotes the new information. Fill in the details. Assume any pre-conditions that you feel are necessary. [6/20]

(c) Ignoring the change to the *INFOBASE* prove that a simplied version of your *Move* operation satisfies the property that $(\mathit{Move}[l, s, r] \circ \mathit{Move}[l, r, s])\kappa = \kappa$. [6/20]

6. A spelling checker dictionary ($DICT_0$) may be modelled as a set of words. Implementation of *set* as *list* suggests the reification ($DICT_1$) subject to an appropriate invariant. A distributed spelling checker dictionary ($DICT_2$) may be modelled by the introduction of locations and it in turn may be elaborated ($DICT_3$) to include sets of definitions associated with each word.

$$DICT_0 = \mathcal{P}WORD \qquad\qquad DICT_2 = LOC \longrightarrow \mathcal{P}WORD$$

$$DICT_1 = WORD^\star \qquad\qquad DICT_3 = LOC \longrightarrow (WORD \longrightarrow \mathcal{P}DEF)$$

(a) Suggest suitable English text and give appropriate signatures for each of the following operations in the context of the indicated model:

(i) $[DICT_0]$: $\mathrm{Xop}[w]\delta := \delta \cup \{w\}$, $\quad \mathrm{Yop}[w]\delta := \neg(\{w\} \subseteq \delta)$

(ii) $[DICT_1]$: $\mathrm{Zop}(\delta) := (\sigma\delta = \delta) \wedge (|\delta| = |\,\mathsf{elems}\,\delta|)$

where $\sigma\colon WORD^\star \rightarrow WORD_{\leq}{}^\star$ is the usual sorting map.

(iii) $[DICT_2]$: $\mathrm{Aop}(\delta) := {}^{\cup}/\ \mathsf{rng}\ \delta$

(iv) $[DICT_3]$: $\mathrm{Bop}(\delta) := {}^{\cup}/\ \mathsf{rng}\ {}^{\cup}/\ \mathsf{rng}\ \delta$

[8/20]

(b) The retrieve map $\mathcal{R}\colon DICT_3 \longrightarrow DICT_2$ is given by $\mathbf{1}_{LOC} \longrightarrow \mathsf{dom}$. Show *in broad outline* that the following diagram commutes.

$$\begin{tikzcd} DICT_2 \arrow[r, "Ent_2{[l,w]}"] & DICT_2 \\ DICT_3 \arrow[u, "\mathcal{R}"] \arrow[r, "Ent_3{[l,w]}"'] & DICT_3 \arrow[u, "\mathcal{R}"'] \end{tikzcd}$$

where $Ent_2[l,w]$ and $Ent_3[l,w]$ denote the entering of a new word w into an existing location l with respect to the appropriate model. [6/20]

(c) Consider the spelling checker dictionary modelled as a poset category with objects dictionaries A, B and maps $A \longrightarrow B$ whenever $A \subseteq B$, read A is a part of or equal to B. Write a *complete* specification of the entering of a *new* word into an existing dictionary in terms of the poset category alone. [6/20]

7. Surprisingly, perhaps, the notion of *difference* can be primary! In the *Triangle of Thoughts*, Alain Connes remarks on its fundamental role in the Ritz-Rydberg principle whereby the spectrum of frequencies of the light emitted by a heated body transcends experimental precision of measurement. (American Mathematical Society, 2001, pp. 46–47). In computing, as in the experienced reality of directed time, the notion of state change is essentially a matter of difference. In computing, such state change (override) may be modelled by a pair of maps $\langle f, g \rangle$ where $X \underset{g}{\overset{f}{\rightrightarrows}} Y$ and which we read as "first f and then g". For definiteness let us consider a simple example such as

$$f = [p \mapsto x, q \mapsto x, r \mapsto y, s \mapsto z]$$
$$g = [p \mapsto z, q \mapsto y, r \mapsto y, s \mapsto z]$$

(a) (i) Illustrate the state change "first f and then g" by constructing the corresponding graph object in the topos of graphs $\mathcal{S}^{\bullet\downdownarrows\bullet}$.

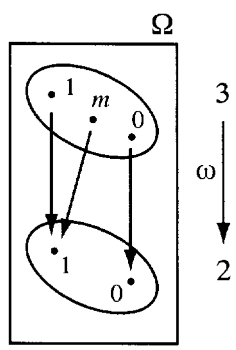
(ii) Let $E \xrightarrow{e} X$ and $D \xrightarrow{d} X$ denote the equalizer and the differencer of $\langle f, g \rangle$, respectively. Let φ_E and φ_D denote the corresponding subobject classifiers. With the aid of appropriate diagrams show the relationships between E and D and between φ_E and φ_D. [8/20]

(b) It is proposed that one define a binary operator " $-$ " on the product $\langle f, g \rangle$ to obtain the difference $g - f$ and then to define a restricted form of "override" such that

$$f \dagger (g - f) = g$$

Construct $g - f$ and the composite map gd where d is the differencer. What is the relationship between them? [6/20]

(c) Within the topos of sets $\mathcal{S}$ one finds that the analysis of state change (override) is seriously defective due to natural partiality of the maps in computing. Natural resolution is obtained in the topos of maps $\mathcal{S}^{\bullet\downarrow\bullet}$. The truth value object Ω in $\mathcal{S}^{\bullet\downarrow\bullet}$ is the map object shown opposite. Explain how the difference (and thus state change) between the map objects f and g is classified adequately. [6/20]



8. A deterministic finite state machine (fsm) $(Q, \Sigma, \delta, q_0, F)$ consists of a set of states Q, an input alphabet Σ of letters, a start state q_0, a set of final states F and state transitions are given by the action:

$$\delta \colon \Sigma \times Q \longrightarrow Q$$

There is a natural extension of the state transition map to the free monoid over Σ:

$$\delta^\star \colon \Sigma^\star \times Q \longrightarrow Q$$

(a) Consider the fsm with $Q = \{0, 1, 2\}$, $\Sigma = \{l, d, u\}$, $q_0 = 0$, $F = \{1\}$ which captures something of the syntactic structure of a program variable. The action is

$$\delta = \begin{bmatrix} \langle l, 0 \rangle & \mapsto & 1, & & & & & & \\ \langle l, 1 \rangle & \mapsto & 1, & \langle d, 1 \rangle & \mapsto & 1 & \langle u, 1 \rangle & \mapsto & 2 \\ \langle l, 2 \rangle & \mapsto & 1, & \langle d, 2 \rangle & \mapsto & 1 & & & \end{bmatrix}$$

(i) Give the state transition table for the action δ and draw the corresponding state transition diagram.

(ii) Considering an input letter as the name of a map $Q \longrightarrow Q$, it is clear that the action consists of three maps two of which are partial. There are two classical techniques by which such partiality is removed. What are they? [8/20]

(b) Words in $\Sigma^\star$ may also be considered as maps $Q \longrightarrow Q$ which together give the action $\delta^\star$. There are only a finite number of such maps which may be determined by computing the syntactic transformation monoid. Demonstrate this by completing the table

$\star$	l	d	$\ldots$
l	$\ldots$	$\ldots$	$\ldots$
d	$\ldots$	$\ldots$	$\ldots$
$\vdots$	$\ldots$	$\ldots$	$\ldots$

where $x \star y = xy$ denotes the map composition $y \circ x$. [6/20]

(c) Forgetting start and final states, the state transition diagram δ may be regarded as an object in the topos of graphs $\mathcal{S}^{\overset{\bullet}{\downdownarrows}\bullet}$. Let $\gamma = [\langle l, 0 \rangle, \mapsto 1, \langle l, 1 \rangle \mapsto 1, \langle d, 1 \rangle \mapsto 1]$ denote a part of δ. Construct the corresponding subobject classifier $\delta \xrightarrow{\varphi_\gamma} \Omega$. [6/20]