Benchmark Queries for Temporal Databases

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Abstract

This paper is intended to facilitate the development and evaluation of temporal database models by presenting semantic benchmarks with a large time component. It presents several temporal queries drawn from three application areas, and the results of some of these queries on the example relation instances. The schemas used in this paper are not based on any particular model but can be translated into most of the available temporal data models. With this in mind, it is our hope that other researchers will be able to use some of these queries as *benchmarks* to test their models *and* also as a basis for comparing different language proposals.

1 Introduction

Numerous temporal data models and their associated query languages have been proposed or developed over the past fifteen years. In these models researchers have used different approaches based on the type of time supported and the type of time-stamps used. In this paper, we present several temporal queries based on three schemas, each consisting of two or more relations, and the results of some of these queries on the example relation instances. We have already tested most of these queries in our implementation prototype of a historical database based on the nested relational model [9,10,8] and some of them have also been used elsewhere [15]. It is our hope that other researchers will use these queries as *benchmarks* to test their models *and* also as a basis for comparing different language proposals. This work is an expanded version of our earlier work [11]. The number of queries has gone up by about twenty and we have also provided solutions to over fifty queries.

1.1 The Need for Benchmarks

There are two major motivations for establishing benchmarks. When the database model is well-defined and the goal is to compare different implementations, a *performance* benchmark can be used to stress-test implementations under load [4]. When there are several proposed models and the goal is to compare the descriptive and operational characteristics and capabilities of the various models, a *semantic* benchmark facilitates this comparison. Our benchmarks fall into the semantic category. They are intended to demonstrate how temporal representation decisions constrain the ways we structure and retrieve information. They are not presented with large enough instances to stress an implementation.

A performance benchmark could be based on a meaningless schema with arbitrarily generated data, but a semantic benchmark must reflect a recognizable, comprehensible real-world situation. We have chosen to present three different schemas based on human behavior, from the realms of social science, administration, and medicine. These areas provide interesting temporal behavior and familiar situations (although our schemas are far from realistic data models of the associated scenarios). In two of the three areas we are aided by the fact that researchers in those areas have thought about their needs for temporal information [1,2,3,12,13,14,17].

1.2 Terminology

Snodgrass and Ahn [16] distinguish between two measures of time, called *transaction time*, the time when information is stored into the database and *valid time*, the time when the stored information models reality. Temporal databases are commonly categorized in two ways. One criterion is based on their ability to represent temporal information [16,7] :

- *Rollback* or *Transaction-Time* - if they have exactly one system-supported transaction time.
- *Historical* or *Valid-Time* - if they have exactly one system-supported valid time.
- *Temporal* or *Bitemporal* - if they have exactly one system-supported valid time and exactly one system-supported transaction time.

Name	*DOB*	*Rank*	*valid time*		*transaction time*	
			(from)	(to)	(start)	(stop)
Matthew	12/17/1960	Ass. Manager	12/01/1985	∞	11/25/1985	01/03/1989
Matthew	12/17/1960	Ass. Manager	12/01/1985	12/31/1988	02/03/1989	-
Matthew	12/17/1960	Manager	12/31/1988	∞	02/03/1989	-
Bruce	01/08/1955	Machinist	01/01/1987	∞	01/16/1987	08/28/1987
Bruce	01/08/1955	Machinist	01/01/1987	08/31/1987	08/28/1987	-
Ellen	06/25/1971	Secretary	07/01/1986	∞	07/01/1986	07/03/1986
Ellen	06/25/1971	Copy typist	07/01/1986	02/01/1988	07/03/1986	02/10/1988
Ellen	06/25/1971	Secretary	02/01/1988	∞	02/10/1988	-

Figure 1: An example of a 1NF Bitemporal relation

The other major criterion used for categorizing temporal databases is by the type of temporal binding that they provide. In other words, what units of information receive time-stamps : tuples or individual attributes ?

- *Temporally ungrouped* [6] or *First Normal Form* (1NF) - each tuple is augmented with some appropriate time attributes.
- *Temporally grouped* or *Non-First Normal Form* (N1NF) - a single (nested) tuple exists with time versions for each attribute value within the tuple.

In both 1NF and N1NF models, a time-stamp may consist of an *interval* represented by two time points marking the beginning and the end of some event or it may simply be a single *time point* marking either the beginning or the end of some event.

2 Example Schemas

The schemas used in this paper use a mixture of temporal representations. We have used *valid time* interval time-stamps on time-varying attributes such as "salary" and no time-stamps on

NAME	SALARY
12/85, Matthew	12/85, 30000
	01/88, 35000
	06/91, 42000
01/87, Bruce	01/87, 15000
07/86, Ellen	07/86, 11000
	08/89, 16000

NAME	SALARY
<[12/85,Now], Matthew>	<[12/85, 01/88), 30000>
	<[01/88,06/91), 35000>
	<[06/91,Now], 42000>
<[01/87,09/87), Bruce>	<[01/87,09/87), 15000>
<[07/86,Now], Ellen>	<[07/86,08/89), 11000>
	<[08/89,Now], 16000>

Figure 2: A N1NF relation (a) Point representation (b) Interval representation

time-invariant attributes such as "sex". And the queries are presented in simple English prose. Other researchers are free to translate them into the models and languages of their choice. And to make it easier for those people who may wish to translate these schemas into temporally ungrouped (1NF) models, an attribute may not have multiple values at the same time. For example, a faculty member may not have teaching appointments in more than one department at the same time or a patient may not have multiple therapies at the same time. We call such information "*serially single-valued*".

Most temporal queries involve the "state" of an object over some interval of time or the actual "transition", triggered by some event, from one state to another. For those queries that involve state transitions, one usually wants to know something about both the "old" state(s) and the "new" state(s) and some other "supporting information". Since the majority of our queries involve state transitions, our solutions also retrieve some relevant supporting information. For example, to the query *"list the secretaries who worked under the same boss in the same department at two or more different time periods"*, we would not only list the secretaries' names, but also the department's name, the boss's name and the times of employment. We have also tried to give a "loose" characterization of the queries by *selection condition* or *output*.

Our example schemas and queries are drawn from three different application areas. The first database is an event history database based on an employment survey ; the second one is a typical university administrative database for faculty ; and the last one is a clinical database for manic-depressive patients. To avoid clustering and improve readability, we have :

- used just a few attributes for each database,
- used a "mm/yy" representation for time-stamps instead of "mm/dd/yy" (with the exception of the clinical database),
- left out time-stamps on most time-invariant attributes, and
- presented some relations decomposed into two or more views.

And because of the rather large size of the data tables, we have opted to display them at the end of the paper (where they can easily be pulled out) rather than in the body of the paper.

2.1 The Event History Database

Most statistical software in the social sciences has been developed to deal with two main kinds of data sources : *cross-sectional survey* data, which provides a snapshot description of characteristics of a set of individuals observed at a moment in time , and *time series* data which provides a series of observations of some aggregate unit at regular intervals [3]. However, an increasing number of demographic researchers have recently developed an interest in using the group of techniques often referred at as "event history analysis" [1]. Like cross-section data, event history data describes the attributes of individuals. But additionally, event history data includes the dates at which the attributes changed. It is these *transitions* between attribute values or statuses that are the primary innovation in event history data, and recent developments in statistics based on event histories provide new ways of describing the rates of transitions between statuses [1,2]. It is also worth noting here that in event history data, the intervals between transitions are not regular.

Most of our queries on the event history database are patterned after current literature in demographic research [1,2,3] *and* from the several discussions we have had with some historians and demographers at Indiana University who use event history data in their research and with whom we have been collaborating on our project [9]. Our example event history database is constructed using *spells* from data obtained in an employment survey of work histories of men and women[2]. The data for each individual is valid from that person's eighteenth birthday up to January 1988, thus providing a variable but well-defined lower bound and a fixed upper bound. Example data for one individual looks like :

- Initial declaration

  Name : Jenny Aris

  Date of birth : December 1, 1959

  Sex : Female

- Time_Varying characteristics at origin

  Employment : unemployed

[2] A spell is an interval of time from the point at which an individual becomes at risk of experiencing a certain kind of transition until this risk ends.

Residence : with parents

- Events (in chronological order)

  01/01/1978 : began employment as a cook

  12/01/1979 : dismissed from her job as a cook

  04/05/1979 : picked up another job as a waitress

  05/01/1980 : moved to own apartment

  02/01/1981 : married

  12/01/1984 : divorced

  08/01/1987 : married again

From this kind of data, we construct the relation :

Employment(NAME,DOB,SEX,MSTATUS,OCCUPATION,RESIDENCE) which will be represented as two views:

Employ_View1(NAME,DOB,SEX,RESIDENCE), and

Employ_View2(NAME,MSTATUS,OCCUPATION)

2.1.1 Queries On the Event History Database

Remarks

Queries **QA1** through **QA7** are non-temporal selections on one attribute. The selection condition does not involve any time component. However, output may require temporal intersection, including relatively complex operations such as the temporal intersection necessary for **QA1**. For all of these queries, we have projected temporal outputs even though some queries such as **QA7** do not specifically ask for temporal outputs.

QA1 What were the names and marital statuses of managers during the periods when they were managers?

NAME	MSTATUS
[12/86,01/88], Sean Rose	[12/86,01/88], Married
[03/87,01/88], Ken Witts	[03/87,01/88], Divorced

Figure 3: Output for QA1

QA2 What were the marital statuses of those who lived with their parents?

NAME	MSTATUS
Jenny Aris	[12/77,05/78), Single
Bill Nee	[01/74,11/76), Single
Ken Witts	[01/80,01/82), Single [04/86,06/86), Divorced

Figure 4: Output for QA2

QA3 List the names and sex of all employees who have ever been divorced.

NAME	SEX
Jenny Aris	F
Kim Bruce	F
Bill Nee	M
Ken Witts	M

Figure 5: Output for QA3

QA4 List the names, marital status histories and residence histories of all managers before they became managers?

NAME	MSTATUS	RESIDENCE
[12/86,01/88], Sean Rose	[08/77,03/85), Widowed [03/85,12/86), Married	[08/77,03/85), Own Apart [03/85,12/86), With Wife
[03/87,01/88], Ken Witts	[01/80,06/82), Single [06/82,04/86), Married [04/86,03/87), Divorced	[01/80,01/82), With Parents [01/82,04/86), Own Apart [04/86,06/86), with Parents [06/86,03/87), Own Apart

Figure 6: Output for QA4

QA5 List all people who lived with their parents along with their jobs during those periods.

NAME	OCCUPATION
Jenny Aris	[12/77,01/78), None [01/78,02/79), Cook [02/79,04/79), None [04/79,05/80), Waitress
Bill Nee	[01/74,11/76), Bartender
Ken Witts	[01/80,01/82), Driver [04/86,06/86), Mechanic

Figure 7: Output for QA5

QA6 List all people who never lived with their parents along with their sex and their residence histories.

NAME	SEX	RESIDENCE
Kim Bruce	F	[04/80,06/82), Own Apart [06/82,12/86), With Husband [12/86,01/88], Own Apart
Wyn Bruce	M	[05/79,01/88], Own Apart
Sy Rhodes	M	[10/86,01/88], Own Apart
Sean Rose	M	[08/77,03/85), Own Apart [03/85,01/88], With Wife

Figure 8: Output for QA6

QA7 What jobs did the widows do?

WIDOWS	OCCUPATION
Wyn Bruce	[11/85,01/88], Machinist
Sean Rose	[08/77,12/81), Programmer [12/81,03/85), Analyst

Figure 9: Output for QA7

Remarks

Query **QA8** is non-temporal selection on intersection between two attributes. The selection condition is a non-temporal intersection. While it may seem irrelevant to pose a query which appears to be the conjunction of non-temporal selections, implementation of this query on a tuple time-stamped database requires joining the relation with itself.

QA8 List all people who ever worked as programmers and who lived with their parents at some time, along with their employment and residence histories.

NAME	OCCUPATION	RESIDENCE
Bill Nee	[01/74,11/78), Bartender	[01/74,11/76), With Parents
	[11/78,08/81), Data Coder	[11/76,07/82), Own Apart
	[08/81,12/86), Programmer	[07/82,06/86), With Wife
	[12/86,01/88], Analyst	[06/86,01/88], Own Apart

Figure 10: Output for QA8

Remarks

The selection condition in query **QA9** is an intersection between one non-temporal attribute (SEX) and a temporal one, but the non-temporal nature of SEX means this query is infact non-temporal.

QA9 What jobs did the divorced men do?

DIVORCED_MEN	OCCUPATION
Bill Nee	[06/86,12/86), Programmer
	[12/86,10/87), Analyst
Ken Witts	[04/86,03/87), Mechanic
	[03/87,01/88], Manager

Figure 11: Output for QA9

Remarks

The selection condition in query **QA10** involves time-intersection between RESIDENCE and MSTATUS.

QA10 List all people who lived with their parents while married or divorced, giving the times when this occured.

NAME	MSTATUS	RESIDENCE
Ken Witts	[04/86,01/88), Divorced	[04/86,06/86), With Parents

Figure 12: Output for QA10

Remarks

The selection condition in query **QA11** is non-temporal and involves only one attribute (NAME). However, we have included it as it illustrates the notion of a "*spell*".

QA11 Retrieve all spells defined by Marital Status and Residence for Kim Bruce and Ken Witts.

NAME	SPELL	MSTATUS	RESIDENCE
Kim Bruce	[04/83,06/85)	Single	Own Apart
	[06/85,12/86)	Married	With Husband
	[12/86,01/88]	Divorced	Own Apart
Ken Witts	[01/80,01/82)	Single	With Parents
	[01/82,06/82)	Single	Own Apart
	[06/82,04/86)	Married	Own Apart
	[04/86,06/86)	Divorced	With Parents
	[06/86,01/88]	Divorced	Own Apart

Figure 13: Output for QA11

Remarks

Query **QA12** is a non-temporal selection on one attribute, with output which is a temporal complement.

QA12 List the names and sex of all those who ever lived with their parents during the period of

survey, along with their residence histories during the periods that they did not live with their parents.

NAME	SEX	RESIDENCE
Jenny Aris	F	[05/80,01/88], Own Apart
Bill Nee	M	[11/76,07/82), Own Apart [07/82,06/86), With Wife [06/86,01/88], Own Apart
Ken Witts	M	[01/82,04/86), Own Apart [06/86,01/88], Own Apart

Figure 14: Output for QA12

Remarks

Queries **QA13** and **QA14** are temporal sequence selections on one attribute.

QA13 List all women who re-married within a year after a divorce, along with their marital histories.

NAME	MSTATUS
Jenny Aris	[12/77,02/81), Single [02/81,12/84), Married [12/84,08/85), Divorced [08/85,01/88], Married

Figure 15: Output for QA13

QA14 List all people who re-married after they were divorced, along with their marital histories.

NAME	MSTATUS
Jenny Aris	[12/77,07/86), Single [02/81,12/84), Married [12/84,08/85), Divorced [08/85,01/88], Married
Bill Nee	[01/74,07/82), Single [07/82,06/86), Married [06/86,10/87), Divorced [10/87,01/88], Married

Figure 16: Output for QA14

Remarks

Query **QA15** is a temporal sequence selection on two attributes.

QA15 List all people who changed jobs within a year after divorcing, along with their new jobs.

NAME	MSTATUS	OCCUPATION
Bill Nee	[06/86,10/87), Divorced	[12/86,10/87], Analyst
Ken Witts	[04/86,10/87), Divorced	[03/87,01/88], Manager

Figure 17: Output for QA15

Remarks

Query **QA16** aggregates by count of the number of occurences of the divorce event over a given time period.

QA16 Calculate the number of divorces per year for the four years preceeding January 1988.

YEAR	DIVORCED
1984	1
1985	0
1986	3
1987	0

Figure 18: Output for QA16

Remarks

Unlike in **QA16** above where the actual events are aggregated, it is the time periods (the spells) which are aggregated in **QA17** and **QA18**. **QA17** also involves a non-temporal selection. In a typical relational database, queries involving simple negations or opposites are not distinct. For example "count the men" and "count the women" are identical for benchmark purposes. However, this difference can be significant if spells are involved because of the semantics of null values. In **QA18**, should Kim Bruce be counted as unemployed during 1982?

QA17 Calculate the total work-months of employment per calendar year for men from 1982 through 1984.

QA18 Calculate the total work-months of unemployment per calendar year from 1982 through 1984.

YEAR	MEN_EMP_MONTHS
1982	42
1983	37
1984	43

YEAR	UNEMP_MONTHS
1982	6
1983	11
1984	5

Figure 19: (a) Output for QA17(b) Output for QA18

2.2 The University Database

This database keeps personal and professional data for faculty members and the departments they work for. It consists of four relations :

Departments(FDEPT,SECRETARY, HEAD),

Pers_Data(FNAME,FSEX, MSTATUS, NO_DEPENDENTS),

Professional(FNAME,FDEPT,RANK,SALARY), and

Publications(FNAME,JOUNAL,ISSUE,EFFECTIVE_TIME)

The Publications table is intended to be an example where used-defined tuple time-stamps may be more suitable than the attribute time-stamps that we have used in all other tables. Thus we are able to experiment with interactions between valid time and user-defined time. It is also worth noting here that we have not bothered with referential integrity for the department relation.

2.2.1 Queries On the University Database

Remarks

Queries **QB1** through **QB8** are non-temporal selections on one attribute. **QB1** and **QB2** project non-temporal information while the outputs of queries **QB3** through **QB8** have some temporal components.

QB1 List all faculty who have ever earned a salary of at least 50000.

FNAME	SALARY
Bob Gross	[08/91, NOW], 51000
Don Irsay	[08/89,01/91), 51000 [01/91, NOW], 56000

Figure 20: Output for QB1

QB2 Which secretaries have worked in more than one department, where and when?

SECRETARY	DEPT
Cheri Best	[12/84,06/87), Cogn Sc [06/87,08/92), Comp Sc [08/92, NOW], Ling

Figure 21: Output for QB2

QB3 What departments were headed by Dick Bond and Tim Young and who were their secretaries?

NAME	DEPT	SECRETARY
Dick Bond	[08/75,08/83), Comp Sc [06/78,08/83), Joan King	[08/75,06/78), Cindy Jones
Tim Young	[08/84, NOW], Maths [06/87,08/91), Joan King [08/91,01/93), Ann Treece [01/93, NOW], Betty Hills	[08/84,06/87), Betty Hills

Figure 22: (a) Output for QB3

QB4 Which departments have been headed by the same person during two or more distinct periods, who and when ?

FDEPT	HEAD
Ling	[06/86,08/91), Ann Byron [08/92, NOW], Ann Byron

Figure 23: Output for QB4

QB5 When, and of which department was Ann Byron head?

HEAD	DEPT
Ann Byron	[06/86,08/91), Ling [08/92, NOW], Ling

Figure 24: Output for QB5

QB6 Which secretaries have worked in the same department during two or more distinct periods? Where, when and under whom?

SECRETARY	DEPT	HEAD
Ann Treece	Cogn Sc	[08/80,12/84), Don Gibbs [01/93, NOW], Sue Harris
Betty Hills	Maths	[08/79,08/80), Jeff Casey [08/80,08/84), Peter Liu [08/84,06/87), Tim Young [01/93, NOW], Tim Young
Laura Huff	Philo	[08/80,06/87), Randy Wells [08/91, NOW], Larry Bates

Figure 25: Output for QB6

QB7 List all faculty who published in the same journal at least twice, along with the journal issues and publication dates.

FNAME	JOURNAL	ISSUE	EFFECTIVE _TIME
Ron Ely	Cogn Sc	9:3 14:3	[09/87,09/87] [09/92,09/92]
Reid Fox	Graphics	7:2 9:2	[07/89,07/89] [07/91,07/91]
Bob Gross	SIGPLAN	12th 16th	[03/81,03/81] [03/85,03/85]
Carol Nee	Proc JELIA	13:2 15:2	[06/90,06/90] [06/92,06/92]
Peter Liu	Trans AMS	21 23	[10/80,10/80] [10/82,10/82]
Mike Wall	Physica	8:3 9:3	[08/85,08/85] [08/86,08/86]

Figure 26: Output for QB7

QB8 When did the associate professors attain this rank?

ASSOC_NAME	DATE_PROMOTED
Ann Byron	01/86
Ron Ely	05/92
Reid Fox	08/92
Bob Gross	01/80
Carol Nee	08/92
Peter Liu	08/86
Mike Wall	08/84

Figure 27: Output for QB8

Remarks

Queries **QB9** through **QB16** are temporal selections on one attribute. Queries **QB9** and **QB10** project non-temporal information while the outputs of queries **QB11** through **QB16** have some temporal components.

QB9 List all assistant professors who got promoted in the last three years, along with their department and salary immediately before their promotion.

PROMOTED_ASSIST	DATE_OF_PROMOTION	DEPT	SALARY
Ron Ely	05/92	Ling	34000
Reid Fox	08/92	Cogn Sc	32000
Carol Nee	08/92	Philo	29000

Figure 28: Output for QB9

QB10 List the names, departments and salaries of all associate professors at the time Bob Gross got promoted from associate to full.

QB11 List all faculty who were promoted after being in a department for less than 3 years, along with their department and rank while in that department.

ASSOC_NAME	DEPT	SALARY
Ann Byron	Ling	37000
Peter Liu	Comp Sc	38000

Figure 29: Output for QB10

FNAME	FDEPT	RANK
Ron Ely	[08/91, NOW], Ling	[08/91,05/92), Assist [05/92, NOW], Assoc
Reid Fox	[08/90, NOW], Cogn Sc	[08/90,08/92), Assist [08/92, NOW], Assoc
Carol Nee	[12/89, NOW], Philo	[12/89,08/92), Assist [08/92, NOW], Assoc
Pete Liu	[08/84,04/91), Comp Sc	[08/84,08/86), Assist [08/86,04/91), Assoc

Figure 30: Output for QB11

QB12 Which faculty stayed at the associate rank for at least six years?

SIX_YEAR_ASSOCS
[01/86, NOW], Ann Byron
[01/80,08/90), Bob Gross

Figure 31: Output for QB12

Note : In the solution to query **QB12** above, "NOW" represents the date on which the query was paused, in this case, March 1993. Should Ann Byron get promoted at some future date, the interval would change to [01/86, mm/yy) where mm/yy is the date she gets promoted from associate professor.

QB13 Who have been full professors for the last four years? and what have been their department and salary histories during this period?

PROFS_LAST4YEARS	DEPT	SALARY
Don Irsay	[02/89,08/89), Ling [08/89, NOW], Comp Sc	[02/89,08/89), 48000 [08/89,01/91), 51000 [01/91, NOW], 56000

Figure 32: Output for QB13

QB14 For all current full professors, list their marital and salary histories since January 1990.

FNAME	MSTATUS	SALARY
Bob Gross	[01/90, NOW], Married	[01/90,08/90), 43000 [08/90,08/91), 48000 [08/91, NOW], 51000
Don Irsay	[01/90,06/90), Married [06/90, NOW], Divorced	[01/90,01/91), 51000 [01/91, NOW], 56000

Figure 33: Output for QB14

QB15 Who got promoted from assistant to full professor while at least one other faculty in the university remained at the associate rank? When did this happen and what departments were they in at the time?

STAR_ASSIST	FDEPT	RANK
Don Irsay	[07/76,08/84), Comp Sc	[07/76,01/83), Assist [01/83, NOW], Full

Figure 34: Output for QB15

QB16 Which faculty lost their spouses while still employed by the university and how long did they stay widowed?

WIDOWED_FACULTY	MOURNING_PERIOD
Ron Ely	16 months

Figure 35: Output for QB16

Remarks

Query **QB17** is a selection with conjunctions between two non-temporal conditions and projects temporal output.

QB17 Which faculty have ever served as associate professors and ever earned at least 40000, along with their rank and salary histories?

FNAME	RANK	SALARY
Ann Byron	[01/86, NOW], Assoc	[01/86,01/91), 37000 [01/91, NOW], 40000
Bob Gross	[01/80,08/90), Assoc [08/90, NOW], Full	[01/80,01/84), 36000 [01/84,08/86), 39000 [08/86,01/89), 41000 [01/89,08/90), 43000 [08/90,08/91), 48000 [08/91, NOW], 51000
Mike Wall	[08/84,07/88), Assoc	[08/84,08/86), 35000 [08/86,08/87), 37000 [08/87,07/88),42000

Figure 36: Output for QB17

Remarks

The selection condition in query **QB18** is a conjunction of two spell-intersections and it projects temporal output.

QB18 Which secretaries have worked under more than one head in the same department? Where, when and under whom?

SECRETARY	DEPT	HEAD
Ann Treece	Cogn Sc	[08/80,12/84), Don Gibbs [01/93, NOW], Sue Harris
Jill Dole	Cogn Sc	[06/87,08/89), Don Gibbs [08/89,01/93), Sue Harris
Joan King	Comp Sc	[06/78,08/83), Dick Bond [08/83,08/86), Bob Gross [08/86,06/87), Mike Webb
Cheri Best	Comp Sc	[06/87,07/91), Mike Webb [07/91,08/92), Don Irsay
Pattie Moby	Ling	[08/85,06/86), Sonny Stubb [06/86,08/88), Ann Byron
Tasha Davis	Ling	[08/88,08/91), Ann Byron [08/91,08/92), Sue McCoy
Betty Hills	Maths	[08/79,08/80), Jeff Casey [08/80,08/84), Peter Liu [08/84,06/87), Tim Young [01/93, NOW], Tim Young
Laura Huff	Philo	[08/80,06/87), Randy Wells [08/91, NOW], Larry Bates

Figure 37: Output for QB18

Remarks

Queries **QB19** through **QB22** are temporal selections on intersection between two attributes and they all project temporal outputs. Queries **QB20** and **QB21** are variations of query **QB17**. All three select on conjunction (non-temporal for **QB17** and temporal for **QB20** and **QB21**). The rank and/or salary histories projected are for the whole time period (**QB17**), during the time of temporal intersection only (**QB20**), and for up to the time they cease to be associates (**QB21**).

QB19 Which secretaries have worked in the same department and under the same head during two or more distinct periods? Where, when and under whom?

SECRETARY	DEPT	HEAD
Betty Hills	Maths	[08/84,06/87), Tim Young [01/93, NOW], Tim Young

Figure 38: Output for QB19

QB20 Which faculty have earned at least 40000 while serving as an associate professor, along with their salaries during that period?

FNAME	SALARY
Ann Byron	[01/91, NOW], 40000
Bob Gross	[08/86,01/89), 41000 [01/89,08/90), 43000
Mike Wall	[08/87,07/88), 42000

Figure 39: Output for QB20

QB21 Which faculty have earned at least 40000 while serving as an associate professor, along with their rank and salary histories up to the time they ceased to be associate professors?

FNAME	RANK	SALARY
Ann Byron	[01/86, NOW], Assoc	[01/86,01/91), 37000 [01/91, NOW], 40000
Bob Gross	[01/80,08/90), Assoc	[01/80,01/84), 36000 [01/84,08/86), 39000 [08/86,01/89), 41000 [01/89,08/90), 43000
Mike Wall	[08/84,07/88), Assoc	[08/84,08/86), 35000 [08/86,08/87), 37000 [08/87,07/88),42000

Figure 40: Output for QB21

QB22 When and in which department did Cheri Best work under Mike Webb?

CHERI_MIKE_DEPT
[06/87,07/91), Comp Sc

Figure 41: Output for QB22

Remarks

Queries **QB23** through **QB27** project non-temporal information following temporal joins between two tables while queries **QB28** through **QB30** project temporal information following temporal joins.

QB23 Which departments have been headed by assistant professors at one point or another?

DEPT	ASSIST_PROF_HEAD
Ling	[08/91,08/92), Sue McCoy
Maths	[08/80,08/84, Peter Liu

Figure 42: Output for QB23

QB24 What were the salaries of assistant professors with exactly one dependent?

ONE_DEPEND_ASSISTS	SALARY
Barb Bork	[07/89,08/90), 29000 [08/90,06/91), 31000
Don Irsay	[11/80,01/83), 32000

Figure 43: Output for QB24

QB25 List all faculty who got promoted while single, along with their department,rank and salary immediately before their promotion.

FNAME	DATE_OF_PROMOTION	DEPT	RANK	SALARY
Carol Nee	08/92	Philo	Assist	29000

Figure 44: Output for QB25

QB26 What publication submissions were made by faculty while serving as full professors?
QB27 What were the salaries of the other faculty in Philosophy when Randy Wells was head of department?

FNAME	SALARY
Bob Gross	[08/86,01/89), 41000 [01/89,08/90), 43000 [08/90,08/91), 48000
Carol Nee	[12/89,08/91), 29000

Figure 45: Output for QB27

QB28 What is the publication record of current full professors?
QB29 Which female faculty changed their rank *and* marital status in the same year and what rank and marital status information supports this retrieval?

FNAME	MSTATUS	RANK
Carol Nee	[12/89,11/92), Single [11/92, NOW], Married	[12/89,08/92), Assist [08/92, NOW], Assoc

Figure 46: Output for QB29

QB30 Which faculty got promoted while they had fewer than three publications? And what were their ranks and publications through the time of their third publication?

FNAME	JOURNAL	RANK
Carol Nee	[06/90,06/90], Proc JELIA [06/92,06/92], Proc JELIA [11/92,11/92], Philo Studies	[12/89,08/92), Assist [08/92,11/92], Assoc

Figure 47: Output for QB30

Remarks

Query **QB31** tabulates the maximum salary paid by each department. Query **QB32** does the same thing but only for associate professors. Both queries require proper normalization in order to get the aggregation right.

QB31 What have been the highest salaries paid by each department? Who earned these, when and at what rank?

DEPT	FNAME	RANK	SALARY
Cogn Sci	Mike Wall	Assoc	[08/86,07/87), 37000
Cogn Sci	Reid Fox	Assoc	[08/92, NOW], 37000
Comp Sc	Don Irsay	Full	[01/91, NOW], 56000
Ling	Don Irsay	Full	[08/87,08/89), 48000
Maths	Don Irsay	Full	[08/84,08/87), 45000
Philo	Bob Gross	Full	[08/90,08/91), 48000

Figure 48: Output for QB31

QB32 What have been the highest salaries paid to associate professors by each department? Who earned these and when?

Remarks

Queries **QB33** through **QB35** are simple count aggregates. The selection condition for **QB33** a temporal join on the faculty identification attribute between the professional and publications tables while for **QB34**, it is a non-temporal join between the professional and personal tables.

QB33 Tabulate the total number of faculty publications by rank.
QB34 Tabulate the total number of faculty publications by gender.

DEPT	ASSOC_NAME	SALARY
Cogn Sci	Mike Wall	[08/86,07/87), 37000
Comp Sc	Mike Wall	[08/87,07/88), 42000
Ling	Ann Byron	[01/91, NOW], 40000
Maths	Don Irsay	[08/84,08/87), 45000
Philo	Bob Gross	[01/89,08/90), 43000

Figure 49: Output for QB32

RANK	NO_PUBS
Assist	20
Assoc	14
Full	5

SEX	NO_PUBS
MALE	29
FEMALE	10

Figure 50: Outputs for (a) QB33 and (b) QB34

QB35 What was the composition of Computer Science faculty by rank as of January 1992?

RANK	NO_FACULTY
Assist	1
Assoc	0
Full	2

Figure 51: Output for QB35

2.3 The Clinical Database

The medical field has been in the forefront on the use of time in databases. One of the first and most recognized clinical database systems with time support is Time Oriented Databank (TOD), a historical database management system developed by Weyl, Fries and Wiederhold [17] at Stanford University School of Medicine in the early seventies to support clinical research on chronic diseases. Over the years, a number of medical data base management systems have incorporated TOD's model. One such system is MEDLOG, an interactive, microcomputer-based, time-oriented database system used to store and analyze longitudinal clinical data [13]. The TOD (and MEDLOG) databases are structured to store patient information that has been collected over the course of multiple clinic visits. The CLINFO+ system, developed by the Rand Corporation under the sponsorship of the National Institutes of Health (NIH), is yet another clinical research system that supports the storage and retrieval of time-oriented data [12].

There have been several longitudinal studies on recurrent affective illness [14]. Our sample database records diagnostic symptoms and selective experimental pharmacologic treatments on a series of largely treatment-resistant manic-depressive patients consecutively admitted over a six-month period to the clinical research ward at some hospital. These patients go through the different phases of mania, depression, or both, in the case of *bipolar* patients. During the six-month period of observation, each patient receives medication for a total of three months, not necessarily consecutive. Using *spells* created by transitions between distinct episodes of sickness and transitions between different pharmacologic treatments and leaving out most of the attributes, we construct the relation :

Manic_Depressive(PATIENT,SEX,EPISODE_PHASE,TREATMENT)

2.3.1 Queries On the Clinical Database

Remarks

Queries **QC1** through **QC3** are temporal selections on one attribute.

QC1 List all bipolar patients who experienced some form of mania as well as depression within a month of each other, along with any supporting information.

QC2 List all patients who had the same episode of mania or depression recur within a month after the last one.

QC3 For those patients who experienced severe mania, what treatment were they on at the time? And when did they experience this?

PATIENT	EPISODE
P0207	[01/30/82,02/20/82), Moderate Mania [02/20/82,03/07/82), Moderate Depression
P0302	[04/11/82,04/25/82), Moderate Depression [04/25/82,05/19/82), Moderate Mania
P0310	[05/30/82,06/20/82), Mild Mania [06/30/82,07/08/82), Mild Depression
P0127	[04/28/82,05/14/82), Moderate Mania [05/24/82,06/07/82), Moderate Depression

Figure 52: Output for QC1

PATIENT	EPISODE
P0302	[01/30/82,02/19/82), Severe Depression [03/12/82,04/11/82), Severe Depression
P0127	[03/08/82,04/04/82), Moderate Mania [04/28/82,05/14/82), Moderate Mania

Figure 53: Output for QC2

PATIENT	TREATMENT
[07/15/82,07/30/82), P0207	None
[04/17/82,05/02/82), P0310	None
[04/04/82,04/28/82), P0127	None

Figure 54: Output for QC3

Remarks

Queries **QC4** is a temporal selection on temporal intersection between two atributes.

QC4 Who experienced *new* bouts of mania or depression while on lithium treatment?

P_ID	NEW_ EPISODE	TREATMENT
P0207	[04/12/82,04/22/82), Moderate Mania	[02/28/82,05/30/82), Lithium
P0310	[06/30/82,07/08/82), Mild Depression	[06/15/82,07/30/82), Lithium

Figure 55: Output for QC4

Remarks

Queries **QC5** and **QC6** aggregate by count of the number of occurences of the states "mania" and "depression". While query **QC5** aggregates by patient, **QC6** aggregates by treatment type.

QC5 For each patient, tabulate the total number of bouts of mania and the total number of bouts of depression.

PATIENT	NO_BOUTS_MANIC	NO_BOUTS_DEPRESSIVE
P0207	4	1
P0302	1	5
P0310	5	1
P0127	4	2

Figure 56: Output for QC5

QC6 Tabulate the combined number of *new* bouts of mania or depression by treatment type.

TREATMENT	NO_NEW_BOUTS
None	17
Lithium	2
Placebo	4

Figure 57: Output for QC6

Remarks

Unlike in **QC5** above where the actual events are aggregated, it is the time periods (the spells) which are aggregated in queries **QC7** through **QC9**.

QC7 Tabulate the combined total number of days when the patients had bouts of mania or depression of any degree by treatment type.

TREATMENT	DAYS_MD_BOUTS
None	323
Lithium	30
Placebo	66

Figure 58: Output for QC7

QC8 What was the total number of days that each patient was "normal" during the six-month period?

PATIENT	TOTAL_DAYS_NORMAL
P0207	87
P0302	63
P0310	75
P0127	83

Figure 59: Output for QC8

QC9 For each patient, tabulate the total number of days when they were manic and the total number of days when they were depressive during the six-month period.

Remarks

Query **QC10** finds maximum and minimum spells of the attribute value "normal".

QC10 What were the longest and shortest periods of "normality" in days for each patient?

PATIENT	TOTDAYS_MANIC	TOTDAYS_DEPRESSIVE
P0207	79	15
P0302	24	94
P0310	99	08
P0127	74	24

Figure 60: Output for QC9

PATIENT	MAX_NORMAL_PERIOD	MIN_NORMAL_PERIOD
P0207	51	36
P0302	39	24
P0310	42	10
P0127	33	10

Figure 61: Output for QC10

3 Conclusion

We have presented several temporal queries based on time-dependent data from three application areas. We have also provided results of some of the queries on the relation instances. Even though the schemas used in this paper are not based on any particular model, they can be easily translated into most of the available temporal data models. We hope that other researchers will find these useful when testing their models *and* also when comparing and evaluating different temporal language proposals. We are currently analysing temporal queries through the semantics of their *selection conditions* and their *outputs* and then classifying them into different types using these two dimensions.

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5 Example Schemas

5.1 The Event History Database

Employ_View1(NAME,DOB,SEX,RESIDENCE), and

Employ_View2(NAME,MSTATUS,OCCUPATION)

NAME	DOB	SEX	RESIDENCE
Jenny Aris	12/59	F	[12/77,05/80), With Parents [05/80,01/88), Own Apart
Kim Bruce	04/65	F	[04/83,06/85), Own Apart [06/85,12/86), With Husband [12/86,01/88), Own Apart
Wyn Bruce	05/61	M	[05/79,01/88), Own Apart
Bill Nee	05/56	M	[01/74,11/76), With Parents [11/76,07/82), Own Apart [07/82,06/86), With Wife [06/86,01/88), Own Apart
Sy Rhodes	10/68	M	[10/86,01/88), Own Apart
Sean Rose	08/59	M	[08/77,03/85), Own Apart [03/85,01/88), With Wife
Ken Witts	01/62	M	[01/80,01/82), With Parents [01/82,04/86), Own Apart [04/86,06/86), With Parents [06/86,01/88), Own Apart

Figure 62: The Employ_View1 Relation

NAME	MSTATUS	OCCUPATION
Jenny Aris	[12/77,02/81), Single [02/81,12/84), Married [12/84,08/85), Divorced [08/85,01/88), Married	[12/77,01/78), None [01/78,02/79), Cook [02/79,04/79), None [04/79,01/88), Waitress
Kim Bruce	[04/83,06/85), Single [06/85,12/86), Married [12/86,01/88), Divorced	[04/83,12/84), Typist [12/84,01/88), Secretary
Wyn Bruce	[05/79,11/85), Married [11/85,01/88), Widowed	[05/79,12/83), Handy Man [12/83,06/84), None [06/84,01/88), Machinist
Bill Nee	[01/74,07/82), Single [07/82,06/86), Married [06/86,10/87), Divorced [10/87,01/88), Married	[01/74,11/78), Bartender [11/78,08/81), Data Coder [08/81,12/86), Programmer [12/86,01/88), Analyst
Sy Rhodes	[10/86,91/88), Married	[10/86,01/88), Programmer
Sean Rose	[08/77,03/85), Widowed [03/85,01/88), Married	[08/77,12/81), Programmer [12/81,12/86), Analyst [12/86,01/88), Manager
Ken Witts	[01/80,06/82), Single [06/82,04/86), Married [04/86,01/88), Divorced	[01/80,07/82), Driver [07/82,11/83), None [11/83,03/87), Mechanic [03/87,01/88), Manager

Figure 63: The Employ_View2 Relation

5.2 The University Database

Departments(FDEPT,SECRETARY, HEAD)

Pers_Data(FNAME,FSEX, MSTATUS, NO_DEPENDENTS)

Professional(FNAME,FDEPT,RANK,SALARY)

Publications(FNAME,JOURNAL,ISSUE,EFFECTIVE_TIME)

DEPT	SECRETARY	HEAD
Cogn Sc	[08/80,12/84), Ann Treece [12/84,06/87), Cheri Best [06/87,01/93), Jill Dole [01/93, NOW], Ann Treece	[08/80,08/89), Don Gibbs [08/89, NOW], Sue Harris
Comp Sci	[08/75,06/78), Cindy Jones [06/78,06/87), Joan King [06/87,08/92), Cheri Best [08/92, NOW], Bill Rose	[08/75,08/83), Dick Bond [08/83,08/86), Bob Gross [08/86,07/91), Mike Webb [07/91, NOW], Don Irsay
Ling	[08/85,08/88), Pattie Moby [08/88,08/92), Tasha Davis [08/92, NOW], Cheri Best	[08/85,06/86), Sonny Stubb [06/86,08/91), Ann Byron [08/91,08/92), Sue McCoy [08/92, NOW], Ann Byron
Maths	[08/75,08/79), Linda Kahn [08/79,06/87), Betty Hills [06/87,08/91), Joan King [08/91,01/93), Ann Treece [01/93, NOW], Betty Hills	[08/75,08/80), Jeff Casey [08/80,08/84), Peter Liu [08/84, NOW], Tim Young
Philo	[08/80,06/87), Laura Huff [06/87,08/91), Tony Lee [08/91, NOW], Laura Huff	[08/80,08/91), Randy Wells [08/91, NOW], Larry Bates

Figure 64: The Departments Relation

FNAME	FSEX	MSTATUS	DEPENDENTS
Barb Bork	F	[06/88,07/89), Single [07/89,06/91), Married [06/91,12/92), Divorced	[06/88,07/89), 0 [07/89,06/91), 1 [06/91,12/92), 0
Ann Byron	F	[01/86,06/90), Single [06/90, NOW], Married	[01/86,06/90), 0 [06/90, NOW], 1
Ron Ely	M	[12/85,05/90), Married [05/90,09/91), Widowed [09/91, NOW], Married	[12/87,02/89), 3 [02/89,05/90), 4 [05/90,09/91), 3 [09/91, NOW], 4
Reid Fox	M	[01/87,10/90), Married [10/90,07/92), Divorced [07/92, NOW], Married	[01/87,10/90), 4 [10/90,07/92), 3 [07/92, NOW], 5
Bob Gross	M	[01/80, NOW], Married	[05/82,04/86), 2 [04/86, NOW], 3
Carol Nee	F	[12/89,11/92), Single [11/92, NOW], Married	[12/89,11/92), 0 [11/92, NOW], 1
Don Irsay	M	[07/76,11/80), Divorced [11/80,06/90), Married [06/90, NOW], Divorced	[07/76,11/80), 0 [11/80,11/88), 1 [11/88,06/90), 2 [06/90, NOW], 1
Sue McCoy	F	[08/90, NOW], Single	[08/90, NOW], 0
Peter Liu	M	[12/79,09/84), Divorced [09/84,04/91), Married	[12/79,09/84), 2 [09/84,02/86), 3 [02/86,10/89), 4 [10/89,04/91), 5
Mike Wall	M	[08/84,07/88), Single	[08/84,07/88), 0

Figure 65: The Pers_Data Relation

FNAME	FDEPT	RANK	SALARY
Barb Bork	[06/88,12/92), Comp Sc	[06/88,12/92), Assist	[06/88,08/90), 29000 [08/90,12/92), 31000
Ann Byron	[01/86, NOW], Ling	[01/86, NOW], Assoc	[01/86,01/91), 37000 [01/91, NOW], 40000
Ron Ely	[12/85,08/91), Cogn Sc [08/91, NOW], Ling	[12/85,05/92), Assist [05/92, NOW], Assoc	[12/85,01/88), 28000 [01/88,08/91), 31000 [08/91,05/92), 34000 [05/92, NOW], 39000
Reid Fox	[01/87,08/90), Comp Sc [08/90, NOW], Cogn Sc	[01/87,08/92), Assist [08/92, NOW], Assoc	[01/87,08/90), 28000 [08/90,08/92), 32000 [08/92, NOW], 37000
Bob Gross	[01/80,08/86), Comp Sc [08/86,08/91), Philo [08/91, NOW], Comp Sc	[01/80,08/90), Assoc [08/90, NOW], Full	[01/80,01/84), 36000 [01/84,08/86), 39000 [08/86,01/89), 41000 [01/89,08/90), 43000 [08/90,08/91), 48000 [08/91, NOW], 51000
Carol Nee	[12/89, NOW], Philo	[12/89,08/92), Assist [08/92, NOW], Assoc	[12/89,08/92), 29000 [08/92, NOW], 34000
Don Irsay	[07/76,08/84), Comp Sc [08/84,08/87), Maths [08/87,08/89, Ling [08/89, NOW], Comp Sc	[07/76,01/83), Assist [01/83, NOW], Full	[07/76,08/80), 29000 [08/80,01/83), 32000 [01/83,08/84), 42000 [08/84,08/87), 45000 [08/87,08/89), 48000 [08/89,01/91), 51000 [01/91, NOW], 56000
Sue McCoy	[08/90,08/92), Ling [08/92, NOW], Comp Sc	[08/90, NOW], Assist	[08/90,08/92), 26000 [08/92, NOW], 31000
Pete Liu	[12/79,08/84), Maths [08/84,04/91), Comp Sc	[12/79,08/86), Assist [08/86,04/91), Assoc	[12/79,08/84), 30000 [08/84,08/86), 33000 [08/86,04/91), 38000
Mike Wall	[08/84,07/87), Cogn Sc [07/87,07/88), Comp Sc	[08/84,07/88), Assoc	[08/84,08/86), 35000 [08/86,08/87), 37000 [08/87,07/88), 42000

Figure 66: Professional

FNAME	JOURNAL	ISSUE	EFFECTIVE TIME
Barb Bork	SIG RECORD	12:1	[02/90,NOW]
Barb Bork	Proc VLDB	17th	[08/91,NOW]
Ann Byron	Phonetics	6	[05,87,NOW]
Ann Byron	AI & Music	7:3	[10,88,NOW]
Ron Ely	Cogn Sc	9:3	[09/87,NOW]
Ron Ely	Humor	15:1	[02/88,NOW]
Ron Ely	Cogn Sc	14:3	[09/92,NOW]
Ron Ely	Brain Sc	19:1	[01/93,NOW]
Reid Fox	SIGGRAPH	13th	[03/87,NOW]
Reid Fox	Graphics	7:2	[07/89,NOW]
Reid Fox	Graphics	9:2	[07/91,NOW]
Reid Fox	Visualisation	11:4	[11/91,NOW]
Bob Gross	Comp Lang	6th	[11/80,NOW]
Bob Gross	SIGPLAN	12th	[03/81,NOW]
Bob Gross	Prog Lang	3rd	[07/83,NOW]
Bob Gross	SIGPLAN	16th	[03/85,NOW]
Bob Gross	Philo Studies	10:2	[06/88,NOW]
Carol Nee	Proc JELIA	13:2	[06/90,NOW]
Carol Nee	Proc JELIA	15:2	[06/92,NOW]
Carol Nee	Philo Studies	14:4	[11/92,NOW]
Don Irsay	Proc PODS	13th	[04/77,NOW]
Don Irsay	Comm ACM	22:3	[11/78,NOW]
Don Irsay	SIG. RECORD	13:2	[08/85,NOW]
Don Irsay	J of Algebra	16:3	[11/85,NOW]
Don Irsay	Connection	11:2	[06/88,NOW]
Don Irsay	Proc VLDB	16th	[08/90,NOW]
Don Irsay	Proc EER	5th	[08/92,NOW]
Sue McCoy	Brain Sc	17:1	[01/91,NOW]
Sue McCoy	Phonetics	11	[05/92,NOW]
Sue McCoy	Connection	15:2	[06/92,NOW]
Peter Liu	Trans AMS	21	[10/80,NOW]
Peter Liu	Trans AMS	23	[10/82,NOW]
Peter Liu	J of Algebra	14:3	[11/83,NOW]
Peter Liu	SIAM	11:2	[06/86,NOW]
Peter Liu	Software	5:3	[11/89,NOW]
Mike Wall	Humour	12:1	[02/85,NOW]
Mike Wall	Physica	8:3	[08/85,NOW]
Mike Wall	Physica	9:3	[08/86,NOW]
Mike Wall	Info Systems	14:1	[03/88,NOW]

Figure 67: Publications (with tuple time-stamping)

5.3 The Clinical Database

P_ID	SEX	EPISODE_PHASE	TREATMENT
P0207	F	[01/30/82,02/20/82), Moderate Mania [02/20/82,03/07/82), Moderate Depression [03/07/82,04/12/82), Normal [04/12/82,04/22/82), Moderate Mania [04/22/82,06/12/82), Normal [06/12/82,07/15/82), Moderate Mania [07/15/82,07/30/82), Severe Mania	[01/30/82,02/28/82), None [02/28/82,05/30/82), Lithium [05/30/82,07/30/82), None
P0302	M	[01/30/82,02/19/82), Severe Depression [02/19/82,03/12/82), Moderate Depression [03/12/82,04/11/82), Severe Depression [04/11/82,04/25/82), Moderate Depression [04/25/82,05/19/82), Moderate Mania [05/19/82,06/12/82), Normal [06/12/82,06/21/82), Mild Depression [06/21/82,07/30/82), Normal	[01/30/82,04/30/82), None [04/30/82,07/30/82), Placebo
P0310	M	[01/30/82,02/12/82), Moderate Mania [02/12/82,03/26/82), Normal [03/26/82,04/17/82), Mild Mania [04/17/82,05/02/82), Severe Mania [05/02/82,05/30/82), Moderate Mania [05/30/82,06/20/82), Mild Mania [06/20/82,06/30/82), Normal [06/30/82,07/08/82), Mild Depression [07/08/82,07/30/82), Normal	[01/30/82,03/15/82), Placebo [03/15/82,06/15/82), None [06/15/82,07/30/82), Lithium
P0127	F	[01/30/82,02/09/82), Mild Depression [02/09/82,03/08/82), Normal [03/08/82,04/04/82), Moderate Mania [04/04/82,04/28/82), Severe Mania [04/28/82,05/14/82), Moderate Mania [05/14/82,05/24/82), Normal [05/24/82,06/07/82), Moderate Depression [06/07/82,07/10/82), Normal [07/10/82,07/17/82), Mild Mania [07/17/82,07/30/82), Normal	[01/30/82,02/28/82), Placebo [02/28/82,05/30/82), None [05/30/82,07/30/82), Placebo

Figure 67 : The Manic_Depressive Relation