A SIMPLE CHARACTERIZATION OF DATABASE SERIALIZABILITY

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Abstract

An interleaved execution of transactions in a database system is serializable if the effect of the execution is equivalent to that of some serial execution of the transactions. We give a simple and intuitive characterization of serializability that brings out the inherent problem of serialization explicitly. We also give another characterization which extends naturally to multiversion serializability.

The class WRW is the largest known subclass of serializable executions having polynomial membership test. We give a new characterization for this class with the general class of serializable executions in a natural way.

1. Introduction

A database system is a collection of data items, read or written by transactions in a possibly interleaved fashion. The concurrency control mechanism ensures the correctness of the interleaved execution. A commonly accepted criterion of correctness is serializability, that is, the effect of the execution is equivalent to that of some serial execution of the transactions.

The theory of serializability has been extensively studied [BSW, EGLT, IKM1, P, SLR]. In this paper, we present a new characterization of serializability, using a new graph model to represent the execution. Our characterization is simple, intuitive, and it exhibits the inherent problem of serialization explicitly. We compare our characterization with the others in the literature in a later section.

We also give another characterization of serializability that extends naturally to multiversion case, where each value written by a transaction is kept as a separate version, and in a read operation one of the already created versions of a data item is read. Multiversion serializability has been studied in [BG, IK, PK].

The problem of deciding whether an execution is serializable is NP-complete. Hence serializability under some constraints have been
studied [BSW, IKM1, P]. Some of these constraints give rise to sub-classes of serializable executions that have polynomial membership test. The largest known polynomial class is WRW, defined in [IKM1]. We give another characterization for this class, that relates this class with the general class of serializable executions in a natural way.

In section 2, we give the basic terminology and definitions. In section 3, we define H and TP graphs, and give the main characterization. The comparison with other characterizations is given in section 4. In section 5 we give a stronger characterization of serializability and extend the result to multiversion case. The class WRW is discussed in section 6. Section 7 concludes the paper.

2. Basic Terminology and Definitions

A database system consists of a set $D$ of data items and a set $T = \{T_0, T_1, \ldots, T_n, T_f\}$ of transactions. A transaction is a finite partially ordered set of steps. Each step is either a read step reading (exactly) one data item, or a write step writing (exactly) one data item. We assume each data item is accessed by at most one read step and at most one write step in a transaction; and if both steps do occur, then the read step precedes the write step in the partial order. A transaction is a write-only transaction if it does not have any read steps. It is a read-only transaction if it does not have any write steps. The transaction $T_0$ is a fictitious write-only initial transaction which writes the initial values of all the data items, and $T_f$ is a fictitious read-only final transaction that reads the values of all data items after all transactions have completed.

A read step (write step) of Transaction $T_i$ reading (writing) the data item $X$ is denoted $R_i[X](W_i[X])$. A set of read steps of $T_i$, unrelated by the partial order, reading a subset $C$ of $D$ and occurring together, is denoted $R_i[C]$. For example, $R_i[\{X,Y\}]$ denotes the unrelated read steps $R_i[X]$ and $R_i[Y]$ occurring together in any order; for simplicity, we write this as $R_i[X,Y]$. Similar notation is followed for the write steps. A history $h$ of $T$ is a sequence of the steps of $T$ representing the execution of the transactions in a possibly interleaved fashion, starting with $W_0[D]$ and ending with $R_f[D]$. Note that the steps of each transaction in $h$ must satisfy the partial order. A history is serial if there is no interleaving, that is once a transaction starts executing, it finishes without any other transaction executing some