Zen and the Art of Concurrency Control

An Exploration of TM Safety Property Space with Early Release in Mind

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Distributed Systems Group

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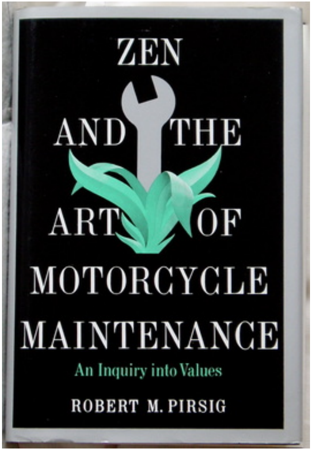

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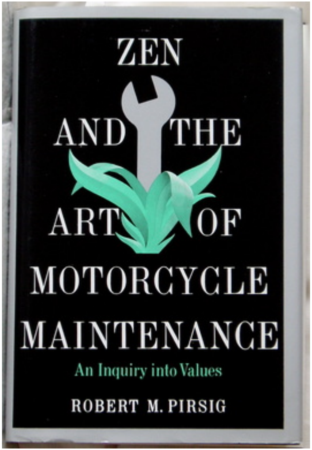

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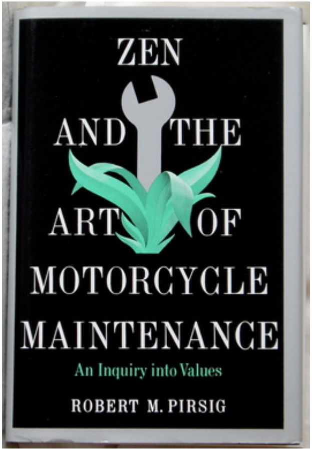
Quality is not absolutely applicable
$\rightarrow$depends on the situation



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Quality is not absolutely applicable

$\rightarrow$depends on the situation

quality = TM safety
situation = high contention

High contention

$T_1 \llbracket\ r(x)0, w(x)1\ \rrbracket$

$T_2\ \llbracket\ r(x)0, w(x)1 \circlearrowleft \llbracket\ r(x)1, w(x)2\ \rrbracket$

$T_3\ \ \llbracket\ r(x)0, w(x)1 \circlearrowleft \llbracket\ r(x)1, w(x)2 \circlearrowleft \llbracket\ r(x)2, w(x)3\ \rrbracket$

$T_4\ \ \ \llbracket\ r(x)0, w(x)1 \circlearrowleft \llbracket\ r(x)1, w(x)2 \circlearrowleft \llbracket\ r(x)2, w(x)3 \circlearrowleft \llbracket\ r(x)3, w(x)4\ \rrbracket$

High contention

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\begin{array}{ll}
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\end{array}
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\begin{array}{lllll}
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Early release

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\begin{array}{ll}
T_1 \llbracket\ \mathrm{r}(x)0,\ \mathrm{w}(x)1,\ \mathrm{r}(y)0,\ \mathrm{w}(y)1\ \rrbracket & \\
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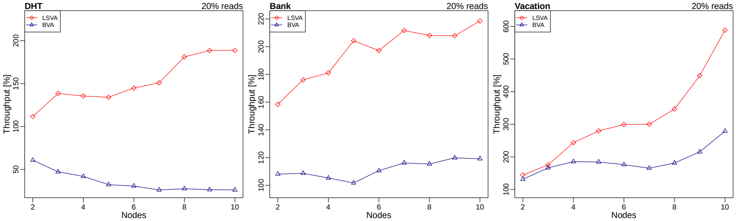

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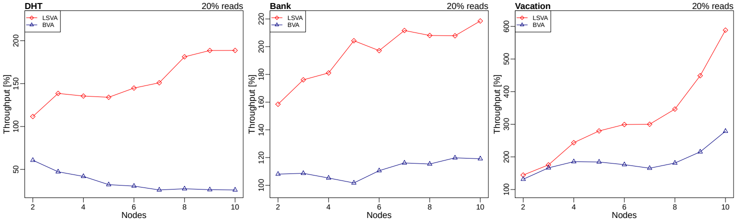

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Which TM safety properties can be used for early release?

Early release

Definition

Transaction T_i releases x early in H iff there is some prefix H' of H, such that T_i **is live** in H' and there exists T_j in H' such that there is a non-local **read operation** op_j **in** $H'|T_j$ reading v from x and a **preceding write operation** op_i **in** $H'|T_i$ writing x to v.

Example:

$$\begin{array}{ll} T_1 & [\![\ \mathrm{r}(x)0,\ \mathrm{w}(x)1,\ \mathrm{r}(y)0,\ \mathrm{w}(y)1\ ]\!] \\ T_2 & \qquad\qquad [\![\ \searrow\mathrm{r}(x)1,\ \mathrm{w}(x)2,\ \searrow\mathrm{r}(y)1,\ \mathrm{w}(y)2\ ]\!] \end{array}$$

Serializability

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Components of opacity:

- Serializability
- Real-time order
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An opaque history cannot contain early release.

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An elastic opaque history can contain early release. However...

Elastic opacity

Well-formed cut:

- A subhistory cannot start with a write (unless it is the first subhistory of a cut).
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TMS1 & TMS2

Definition (TMS1—Valid Response)

For operation op to return in some subhistory $H|T_i$, there must exist some set of transactions S that follow real-time order and justify the legality of op, and for any $T_j \in S$ it is true that,

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A TMS2 history cannot contain early release (TMS2 $\subset$ TMS1).

Virtual world consitency

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- If T_j eventually aborts, its causal past $C(T_j) = \langle T_i, T_j \rangle$ contains two aborted transactions, so it is illegal.

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Database properties

- Recoverability
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  History H is strict iff for any $T_i, T_j \in H$ and given any operation $op_i = \mathrm{r}(x)v$ or $\mathrm{w}(x)v'$ in $H|T_i$, and any operation $op_j = \mathrm{w}(x)v$ in $H|T_j$, if op_i follows op_j, then T_j commits or aborts before op_i.

- Rigorousness

  History H is rigorous if it is strict and for any $T_i, T_j \in H$ such that T_j writes to variable x, i.e., $op_j = \mathrm{w}(x)v \in H|T_j$ after T_i reads x, then T_i commits or aborts before op_j.

Database properties

- Recoverability ✓

  History H is recoverable iff for any $T_i, T_j \in H$ s.t. T_j reads from T_i, T_i commits in H before T_j.

- Avoiding Cascading Aborts ≈

  History H Avoids Cascading Aborts iff for any $T_i, T_j \in H$ s.t. T_j reads from T_i, T_i commits before the read.

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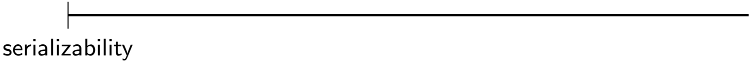
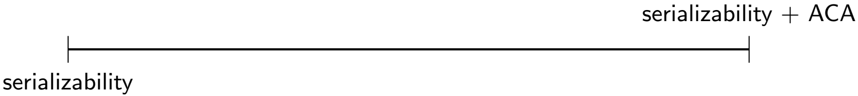
Serializability+ spectrum

Serializability+ spectrum



Serializability+ spectrum



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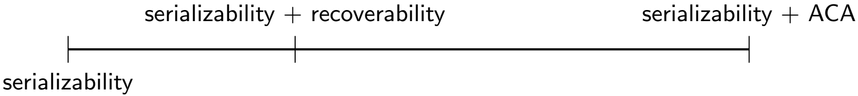
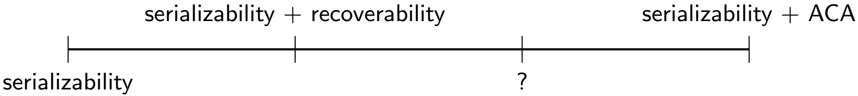


Serializability+ spectrum



Last-use

Definition (Commit-pending–equivalence)

A live transaction T_i in H is commit-pending–equivalent with respect to x iff it is finished executing all of its operations on x.

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    int v = read(x);
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        write(x,-v); // commit-pending--equivalent wrt x
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Definition (Early release after last use)

Transaction T_i releases x after last use in H iff T_i releases x early in H and T_i is commit-pending equivalent wrt x.

Last-use consistency

Definition

- Let $\mathbb{T}_{er}^{H}$ be a subset of all transactions in history H that release some variable early.
- Let $\mathbb{T}_{lu}^{H}$ be a subset of all transactions in history H that release some variable early only after last-use.

History H satisfies last-use consistency if $\mathbb{T}_{lu}^{H} = \mathbb{T}_{er}^{H}$.

Inconsistent views

Last-use consistency precludes overwriting:

$$\begin{array}{ll} T_i & [\![\ \mathrm{w}(x)0, \quad \mathrm{w}(x)1 \ ]\!] \\ T_j & \qquad [\![\ \searrow \mathrm{r}(x)0 \ \searrow \circlearrowleft T'_j \ [\![\ \mathrm{r}(x)1, \mathrm{w}(x)2 \ ]\!] \end{array}$$

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\end{array}
$$

Allowed inconsistent view:

$$
\begin{array}{ll}
T_i & \llbracket\ \mathrm{w}(x)0,\quad \mathrm{w}(x)1 \qquad\quad \circlearrowleft \\
T_j & \qquad\qquad\qquad\qquad \llbracket\ \searrow \mathrm{r}(x)0\ \ \searrow \circlearrowleft T'_j \llbracket\ \mathrm{r}(x)1, \mathrm{w}(x)2\ \rrbracket
\end{array}
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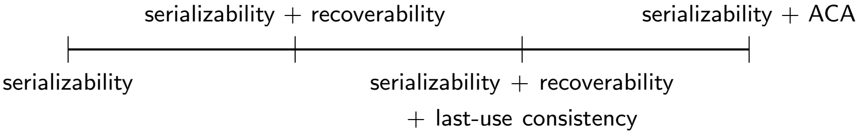
Serializability+ spectrum



Conclusions

- Current safety properties not enough for TM with early release
- Spectrum of database consistency properties
- Last-use consistency

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- Current safety properties not enough for TM with early release
- Spectrum of database consistency properties
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- Future work: last-use opacity

?