Using time-space diagrams for testing real OT systems

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The Transparent Adaptation (TA) technology

OT is the cornerstone of the GCE.
Comprehensive testing is crucial in validating a real OT system

Testing is difficult due to:

- Involvement of multiple users and computers
- Coordination of operation generation (concurrency and causality)
- Control of operation propagation (communication latency)
- Mixture of SA, CA and GCE (OT) issues (difficult to differentiate)
Independent testing of the OT-based GCE

- Separate GCE issues from the rest of the system
- Easy to generate operations with arbitrary relationships

GCE-specific testing programs

Generic Collaborative Engine (GCE)

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An example GCE testing program

```c
Void main( ) {// a GCE test program
    // initialize document state and engines
    char* initDoc = "abc";
    tengines = createEngines(3);
    createDocStates(sites, initDoc, 3);

    // create and do local operations
    OP O1 = createOp(OP_INSERT, 1, 0, "1", "1");
    OP O2 = createOp(OP_INSERT, 2, 1, "2", "2");
    OP O3 = createOp(OP_INSERT, 3, 2, "3", "3");
    sites[0].docDO(O1, islocal);  tengines[0].localOP(O1);
    sites[1].docDO(O2, islocal);  tengines[1].localOP(O2);
    sites[2].docDO(O3, islocal);  tengines[2].localOP(O3);

    // do remote operations
    sites[0].docDo(tengines[0].doOT(O3));
    sites[1].docDo(tengines[1].doOT(O1));
    sites[2].docDo(tengines[2].doOT(O2));
    sites[0].docDo(tengines[0].doOT(O2));
    sites[1].docDo(tengines[1].doOT(O3));
    sites[2].docDo(tengines[2].doOT(O1));
}
```

Drawbacks:
- hand-coded,
- GCE-specific,
- non-intuitive.
Time-Space Diagrams (TSD)

1. TSD is an effective tool for describing operations with arbitrary dependency and independency relationships.

2. TSD is commonly used to describe representative scenarios for illustrating the correctness or potential problems of an OT system.

3. All known OT-puzzle scenarios have been expressed in TSD, which can be utilized as a comprehensive testing suite for OT systems.
A TSD-OT testing system architecture

1. TSD-GUI provides a graphic user interface for describing OT testing scenarios and for displaying OT system outputs.

2. TSD-OT adaptor provides conversion between the generic TSD description and the OT-system-specific testing code and outputs.

3. OT-based system (e.g. GCE) implements the OT algorithms to be tested.
Design issues
(1) Validating TSD

Invalidate TSD

Validate TSD

Event Properties
Validation Result

Local Operation 03 at Site 3 is trying to undo an operation that has not arrived. Operation 02's remote operation at site 3 resides higher than the local operation. Operations 04's and 01's remote operations at site 3 violate their local operation's causality.
(2) Deriving causal relationships from TSD
(3) Converting TSD into TSD-script

<doc>
  abc
</doc>

<site>
  <siteid>1</siteid>
  <event>
    <eventid>1</eventid>
    <local>true</local>
    <op>insert</op>
    <pos>1</pos>
    <char>1</char>
    <statevector>{1,0,0}</statevector>
  </event>
  <event>
    <eventid>2</eventid>
    <local>false</local>
    <statevector>{1,1,0}</statevector>
  </event>
  <event>
    <eventid>3</eventid>
    <local>false</local>
    <statevector>{1,1,1}</statevector>
  </event>
  <event>
    <eventid>4</eventid>
    <local>false</local>
    <statevector>{1,2,1}</statevector>
  </event>
</site>

<site>
  <siteid>2</siteid>
  <event>
    <eventid>2</eventid>
    <local>true</local>
    <op>insert</op>
    <pos>2</pos>
    <char>2</char>
    <statevector>{0,1,0}</statevector>
  </event>
  <event>
    <eventid>1</eventid>
    <local>false</local>
    <statevector>{1,1,0}</statevector>
  </event>
  <event>
    <eventid>4</eventid>
    <local>true</local>
    <op>delete</op>
    <pos>0</pos>
    <char>a</char>
    <statevector>{1,2,0}</statevector>
  </event>
  <event>
    <eventid>3</eventid>
    <local>false</local>
    <statevector>{1,2,1}</statevector>
  </event>
</site>

<site>
  <siteid>3</siteid>
  <event>
    <eventid>2</eventid>
    <local>false</local>
    <statevector>{0,1,0}</statevector>
  </event>
  <event>
    <eventid>1</eventid>
    <local>false</local>
    <statevector>{1,1,0}</statevector>
  </event>
  <event>
    <eventid>3</eventid>
    <local>true</local>
    <op>undo</op>
    <undoid>1</undoid>
    <statevector>{1,1,1}</statevector>
  </event>
  <event>
    <eventid>4</eventid>
    <local>false</local>
    <statevector>{1,2,1}</statevector>
  </event>
</site>
void Example() {
    vector<DocState> sites;
    char* initDoc = "abc";
    vector<TE> tengines = createEngines(3);
    createDocStates(sites, initDoc, 3);

    OP O1 = createOp(OP_INSERT, 1, 0, "1", "1");
    OP O2 = createOp(OP_INSERT, 2, 1, "2", "2");
    OP O4 = createOp(OP_DELETE, 0, 1, "a", "4");

    //local do
    sites[0].docDO(O1, islocal);
    tengines[0].localOP(O1);
    sites[1].docDO(O2, islocal);
    tengines[1].localOP(O2);

    //remote do
    sites[2].docDO(tengines[2].doOT(O2));
    sites[0].docDO(tengines[0].doOT(O2));
    sites[1].docDO(tengines[1].doOT(O1));
    sites[2].docDO(tengines[2].doOT(O1));

    //local undo
    OP O1U = O1;
    tengines[2].makeUndoCmd(O1U);
    sites[2].docDO(tengines[2].undoOT(O1U));

    //remote undo
    O1U = O1;
    tengines[0].makeUndoCmd(O1U);
    sites[0].docDO(tengines[0].undoOT(O1U));

    //remote do
    sites[0].docDO(tengines[0].doOT(O4));

    //remote undo
    O1U = O1;
    tengines[1].makeUndoCmd(O1U);
    sites[1].docDO(tengines[1].undoOT(O1U));

    //remote do
    sites[2].docDO(tengines[2].doOT(O4));
}
TSD-serialization underlying the GCE code generation

Normal TSD

Serialized TSD
(5) Executing TSD-generated code and displaying GCE-generated results
Concluding remarks

1. The TSD-based OT testing tool has helped us to test the GCE used in CoWord and other follow-up TA-based applications.

2. The TSD-based testing suite are independent of the OT system being tested, and can be used as general validation benchmark for OT systems.

3. We continue to improve and enhance the functionality the TSD-based OT testing tool, and to produce a polished API, which can be used to adapt this tool to other OT systems.