**Exercise (Recovery algorithm)**

Apply the recovery algorithm executed by the system when recovers from a crash.
Assume the following log:

<start, T1> <start, T2> <T2, O1, V1, V1'> <T1, O2, -, V2'> <start, T3> <commit, T1> <start, T4> <T3, O2, V3, V3'> <T4, O3, V4, V4'> checkpoint (L) <commit, T4> <start, T5> <T3, O3, V5, V5'> <T5, O4, V6, V6'> <T3, O5, V7, -> <abort, T3> <commit, T5> <T2, O6, -, V8'> CRASH

with
<T, O1, V1, V1'> record for update operation : transaction T updates object O1;
V1 is the state of O1 before the update; V1' is the state of O1 after the update.
<T, O1, - , V1'> record for insert operation: transaction T inserts object O1 with V1'.
<T, O1, V1 , - > record for delete operation: transaction T deletes object O1 whose state is V1.

1) Shows the list L of transactions active at the checkpoint.
2) Show the undo-list and the redo-list.
3) Show the actions executed by the system in the correct order.

**Point 1**

L= {T2, T3, T4}

**Point 2**

- undo-list ={} redo-list ={}
- scan le log backward until the checkpoint record
  for each record <commit, Ti>, add Ti to redo_list
  for each record <start, Ti>, if Ti is not in redo_list, add Ti to undo_list
  for each Ti into the checkpoint list L, if Ti is not into redo_list, add Ti to undo_list

| | |
|---|---|
| undo-list ={} redo-list ={} | |
| undo-list ={} redo-list ={T5} | <commit, T5> |
| undo-list ={} redo-list ={T4, T5} | <commit, T4> |
| undo-list ={T2, T3} redo-list ={T4, T5} | ckeckpoint(T2, T3, T4) |

**Point 3**

3.1) Rescan the log backward and perform undo for each log record that belongs to Ti in undo_list. Log records that belong to transactions in redo_list are ignored. The scan stops when the <start, Ti> records have been found for every transaction in undo_list.

Undo actions:
T2: delete O6
T3: insert O5=V7
T3: O3=V5
T3: O2=V3
T2: O1=V1

3.2) Scan the log backward until the <start, Ti> records have been found for every transaction in redo_list. Scan the log forward. For each record of transactions in redo_list perform redo of the operation.

Redo actions:
T4: O3=V4'
T5: O4=V6'