Lecture Notes

Managing and Mining Multiplayer Online Games

Summer Term 2018

Chapter 4: DataPersistence

http://www.dbs.ifi.lmu.de/cms/VO_Managing_Massive_Multiplayer_Online_Games

Overview

- requirements
- save games and replays
    - state logs
    - transition logs
    - action logs
- persistence in MMOs
- check-point-recovery methods
    - Naive Snapshot
    - Copy-on-Update
    - Wait-Free Zigzag
    - Wait-Free Ping-Pong

Need for Persistence

1. **saving a part ($gs \in GS$) of the current game state**
   - allows resuming the game at another time (save game)
   - create a consistent game state, in case of a system crash
   - saving is only possible at certain locations
     (e.g. Resident Evil, Diablo III, …)
   - certain parts are not saved
     (NPC position/Monster/Enemies, Random maps, …)

2. **saving a replay of a game ($gs_1, \ldots, gs_{end}$)**
   - allows for retracing and analyzing the course of the game
   - usually saved on the clients
   - replays can grow quite large, depending on the format of stored data
   - since the last GS is also part of the replay, replays could be used as save games as well

Persistence Layer Requirements

- saving should not slow the game down
  => tick duration must not exceed the time limit
- save games should be as up-to-date as possible
  => if possible GS should be saved every tick

- loading a save game is supposed to create a consistent state
  => all GE contained in the save game should be equally up-to-date
  => minimum requirement: game state must be consistent (every GE appears only once etc.)

Important Impact Factors:

- size of the game state
- requirements to actuality and tick frequency
- impact of loading time on recovery
- part of the game state/ history of the game to be saved

Methods for Replays and Save games

Save-Game/Replay: local file containing the game state/ course of play

State-Log:

every game entity is saved every x ticks

⇒ sequential file containing a series of game states

example: demo-files of Quake/Half-life/Counterstrike
(parsed and transformed into XML) (Bachelor Thesis: J. Rummel 2011)

```
<replay path=" c:\data ncsdemos n dus t210 .dem“ duration=" 3379,459 " noOfRounds="39”
   mapname="dedust2 " maxCl ients="16" serverName="HLTV.org/VeryGames .net">
 <rounds>
<roundnumber="1" roundBegin="0" roundEnd=" 40 ,496184 “  endingReason="Bombing" winner=" Terrorists">
<teamScore ct="2" t="1" />
 <ticks>
<ticktime="1"> . . . </tick>
<ticktime="2"> . . . </tick>
<ticktime="3">
<players>
<playerid=" 765611887383 " localName="q“ 15 team="Terrorist" kills="3" deaths="7“x=“680" y=“819" z="164“
 angle0="2" angle1="60" moveType=“" weaponModel="172„  modelIndex="149“  isHi t="Helmet" outOfAmmo="
Rifle" />
....
```

State-Log Discussion

Advantages:

- documents a genuine series of game states
- random access to every point in time
- loading process is very simple and fast

Disadvantages:

- high redundancy for small change rates
- large data volume, due to high temporal resolution (every Tick)
- maximum writing load => possibly not feasible for large game states

Transition-Log

Log all changes to the game states via:

- time-stamp
- ID of the GameEntity
- Attribute
- New value

Advantage:

- more compact than a snap-shot
- less volume means less computation effort

Disadvantage:

- reconstruction of game state is more complex
- changes must be registered with the persistence layer

Action-Log

- contains the sequence of all user inputs
- the game is needed to “re-play” the game based on the user input
- random events must be saved
  (seeding or random numbers)

example: Starcraft II (*.sc2replays file) after parsing by sc2gears
(http://sites.google.com/site/sc2gears/)

```
0:00  TSLHyuN       Select Hatchery (10230)
0:00  TSLHyuN       Select Larva x3 (1027c,10280,10284), Deselect all
0:00  TSLHyuN       Train Drone
0:01  TSLHyuN       Train Drone
0:01  roxkisSlivko  Select Hatchery (10250)
0:01  roxkisSlivko  Select Larva x3 (10270,10274,10278), Deselect all
0:01  TSLHyuN       Select Drone x6 (10234,10238,1023c,10240,10244,10248), Deselect all
0:01  roxkisSlivko  Train Drone
0:01  TSLHyuN       Right click; target: Mineral Field (10114)
0:01  roxkisSlivko  Select Egg (10270), Deselect 1 unit
0:01  roxkisSlivko  Select Drone x6 (10254,10258,1025c,10260,10264,10268), Deselect all
0:01  roxkisSlivko  Right click; target: Mineral Field (10164)
0:01  TSLHyuN       Deselect 6 units
0:01  roxkisSlivko  Right click; target: Mineral Field (10164)
0:02  TSLHyuN       Right click; target: Mineral Field (10170)
0:02  roxkisSlivko  Deselect 6 units
….
```

Action-Log Discussion

Advantages:

- replays can be more compact
  (actions per minute APM vs. ticks per second)
- no redundancy
- may contain more information than the game state
  => User inputs that had no influence on the game state
  (e.g. mouse-movement, points of view, …)

Disadvantage:

- restoring the last state is very expensive, due to rerunning the game
- hard for large numbers of random elements
- computer controlled players/objects:
  - requires deterministic behavior
    (NPC behavior is part of the game and can be simulated as well)
  - AI should be controlled by the same rudimentary commands as human players

Save games in MMOs

Normal games: „small“ game states with decentralized replays/save games

⇒ local clients write peripheral game states into files

For MMO Games:

- complete and consistent game state is only on the server
  => persistence has to be implemented centrally on the server
  => on loss of connection the state on the server counts
- game state is substantially more extensive
  => performance of write operations may slow down the game loop
  => unstructured files are impractical
  (selective loading of players after login)
  => historical information about the course of play would sometimes cause large data volumes

MMOGs and relational databases

Managing large amounts of strictly structured objects

=> Use of a relational database

Advantages of a relational database:

- databases provide certain consistency checks (no duplicates, ...)
- databases support selective requests with efficient indexes
- current game state is immediately available
- databases possess innate recovery mechanisms (protection against system and hardware failures)

Disadvantages:

- structured saving and anomaly avoidance increases processing times of change operations

Persistence via Log-files

all changes in game state are quickly saved

⇒ logging with sequential files

Advantage:

- system has almost no overhead
- writing at the end of a sequential file

  ⇒ minimal waiting time

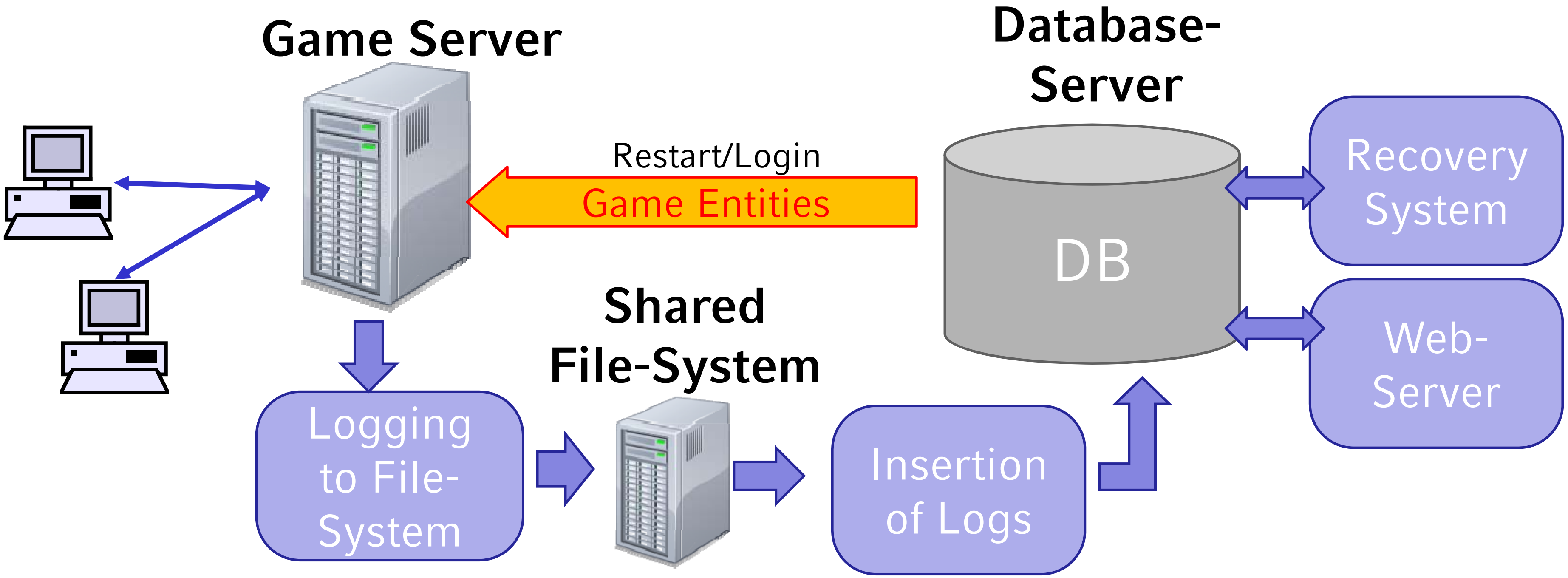
Disadvantages:

- no protection from hard-drive or system errors
- selective requests are not supported
- loading the last consistent game state may require extensive reconstructions by reapplying changes beginning with the last checkpoint

Example for a Hybrid Architecture

- writing data from game server to persistence layer via logging process

  => minimum impact on tick length
- at persistence-server: insertion of log-files into a database server
  - game states are saved durably and secure
    - game state is consistent and redundancy-free
    - includes recovery mechanisms (possible remote storage)
  - information is decoupled from the game for inquiry services (e.g. Armory, …)



Open Issues

- Which logging method is most suitable for volatile systems?
  - change rate for objects
    (How many objects change during a tick?)
  - change complexity
    (are actions more compact than resulting attribute changes?)
  - burstiness of changes
    (Do changes happen periodically in large numbers?)
- Which part of the game state needs to be saved?
  - all moving objects
  - states of all players
  - spatial positions of players and objects
- Concurrency and backlog
  - How fast must different actions be saved?
  - (running vs looting)

Check-Point Recovery Method for Games

- **Check-Point**: consistent image of the game state
- **Check-Point Phase:** time needed to create a check-point.
- **Goal**: Saving the game state with a minimal overhead in the game loop
  => minimal influence on latency
- **Idea**: information is not saved directly, instead all information is copied to a shadow copy
  - data in shadow copy is not affected by actions
  - game loop does not need to wait for the I/O-system
    (uses an asynchronous write-thread)
  - writing may take several ticks, persistence layer lags slightly behind
- **Classification of strategies based on** :
  - bulk-copies vs. selectively copying
  - locking single objects
  - resetting dirty-bits
  - memory usage

Naive-Snapshot

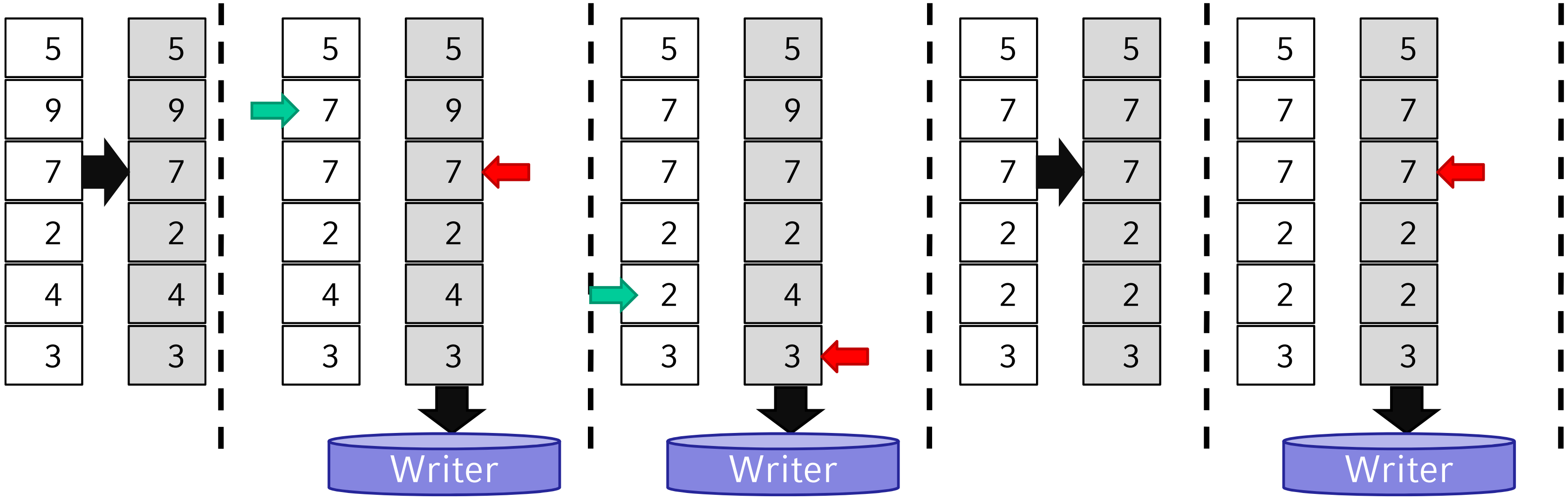
- If write-thread is finished with the last check-point, copy the whole game state into shadow memory.
- After finishing copying and at the start of the next tick, the write-thread writes the copied game state from shadow memory.

Advantages:

- no overhead from locking or bit-resets
- efficient for large numbers of changes

Disadvantages:

- for limited numbers of changes large overhead for copying and writing
- periodically expensive for ticks during where the game state is copied



Copy-On-Update

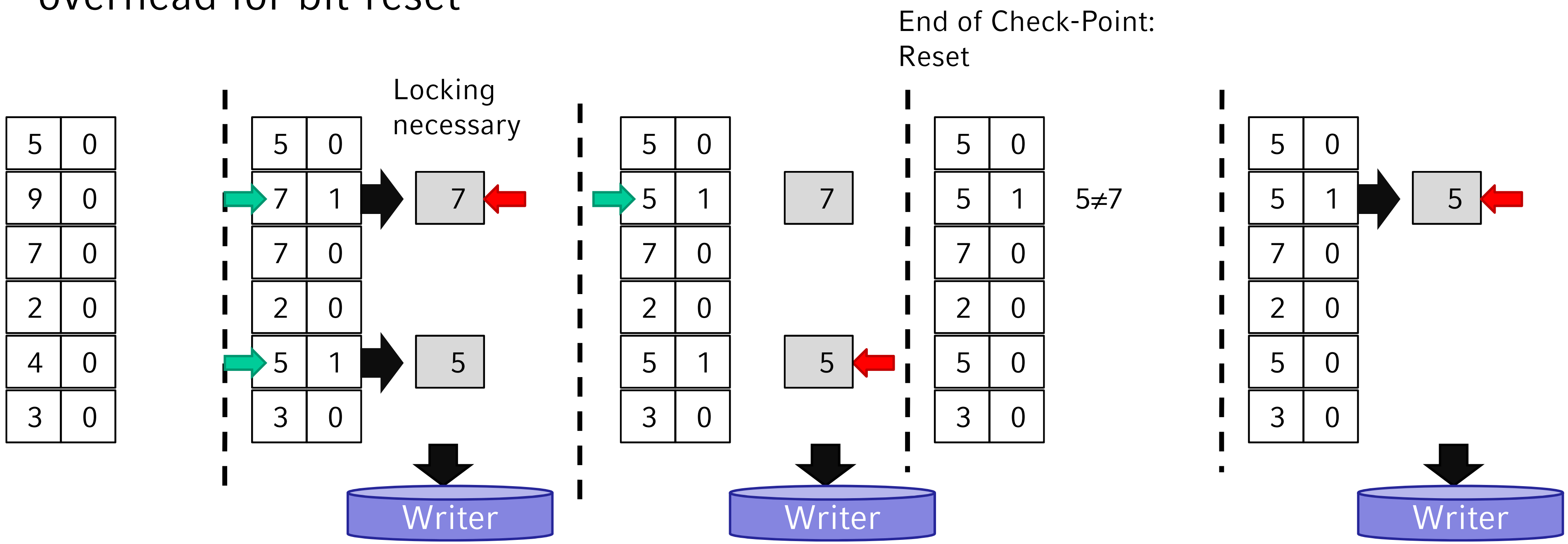
- on change, objects are copied to shadow memory and marked (dirty-bits)
- objects are copied only once per period
- after a check-point has been written markers are reset

Advantages:

- smaller change volume
- better distribution of copies over multiple ticks

Disadvantages:

- requires locking to avoid simultaneous change and copy operations
- overhead for bit-reset



Wait-Free Zigzag

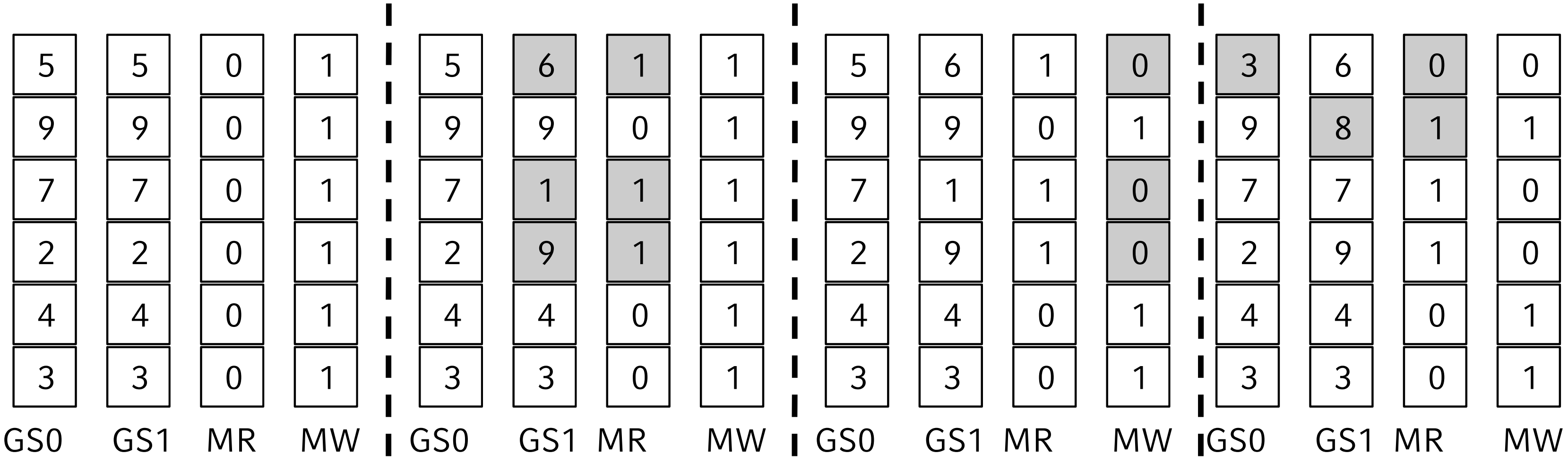
- every object contains two flags referring to a game state: MW (Write-State) and MR (Read-State) for handling actions
- entries in MW are not changed during the checkpoint period
- update: new value is set in $GS[MW_i]$ and MR_i is set to MW_i
- writer-thread reads the element from $GS[\neg MW_i]$ for object i
- end of checkpoint period: if MW_i equals MR_i, flip MW_i

Advantages:

- no locking necessary
- changes can be written over time

Disadvantage:

- still requires bit-reset at the end of each period



GS0	GS1	MR	MW
5	5	0	1
9	9	0	1
7	7	0	1
2	2	0	1
4	4	0	1
3	3	0	1

On Start

GS0	GS1	MR	MW
5	6	1	1
9	9	0	1
7	1	1	1
2	9	1	1
4	4	0	1
3	3	0	1

1. checkpoint period

GS0	GS1	MR	MW
5	6	1	0
9	9	0	1
7	1	1	0
2	9	1	0
4	4	0	1
3	3	0	1

Switch to
2. checkpoint period

GS0	GS1	MR	MW
3	6	0	0
9	8	1	1
7	7	1	0
2	9	1	0
4	4	0	1
3	3	0	1

2. checkpoint period

Wait-Free Ping-Pong

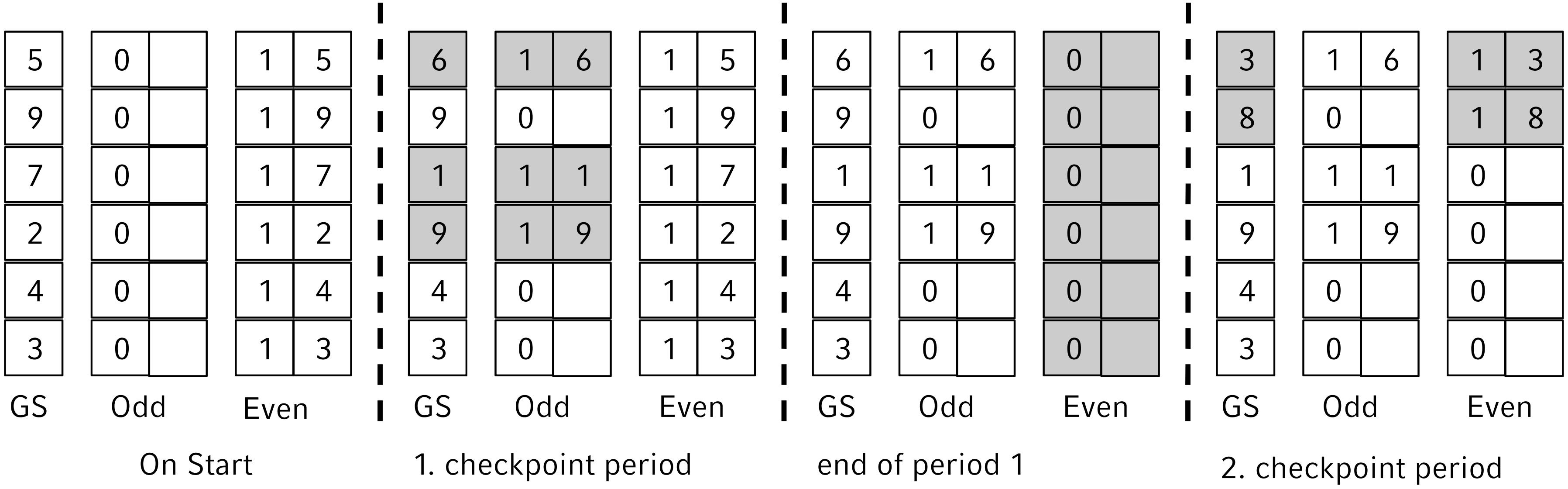
- uses 3 game states:
  action handling (GS), persistence-system (read), persistence-system (write) (odd or even)
- updates always take place in GS and persistence-system (write)
- writer-thread reads persistence-system (read)
- for a new period swap persistence-system(write) and persistence-system(read)

Advantage:

- neither locking nor bit-reset at the end of a period

Disadvantage:

- triple memory requirements instead of double



GS	Odd		Even	
5	0		1	5
9	0		1	9
7	0		1	7
2	0		1	2
4	0		1	4
3	0		1	3

On Start

GS	Odd		Even	
6	1	6	1	5
9	0		1	9
1	1	1	1	7
9	1	9	1	2
4	0		1	4
3	0		1	3

1. checkpoint period

GS	Odd		Even	
6	1	6	0	
9	0		0	
1	1	1	0	
9	1	9	0	
4	0		0	
3	0		0	

end of period 1

GS	Odd		Even	
3	1	6	1	3
8	0		1	8
1	1	1	0	
9	1	9	0	
4	0		0	
3	0		0	

2. checkpoint period

Discussion

- Naive-Snapshot is easiest to implement for very volatile systems with several changes

- the less changes happen, the more advantageous the other methods become

- Wait-Free Ping-Pong and Wait-Free Zig-Zag prevent locking the game entity by the persistence-system

- Wait-Free Ping-Pong also reduces overhead for phase-shifts, but uses a great deal of memory

Learning Goals

- functionality of the persistence system
  - saving a game state
  - saving a sequence of game states (Replay)

- types of save games and replays:
- state-log, transition-log, action-log

- persistency in MMOs:

  Databases, Logging and Hybrid Architectures

- check-point recovery methods for MMOs
  - Naive-Snap Shot
  - Copy-on-update
  - Wait-Free Zigzag
  - Wait-Free Ping-Pong

Literature

- Tuan Cao, Marcos Vaz Salles, Benjamin Sowell, Yao Yue, Alan Demers, Johannes Gehrke, Walker White
  Fast checkpoint recovery algorithms for frequently consistent applications
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- Marcos Antonio Vaz Salles, Tuan Cao, Benjamin Sowell, Alan J. Demers, Johannes Gehrke, Christoph Koch, Walker M. White
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  PVLDB, 2(1): 1258-1269, 2009.

- Kaiwen Zhang, Bettina Kemme, and Alexandre Denault. 2008. **Persistence in massively multiplayer online games**. In *Proceedings of the 7th ACM SIGCOMM Workshop on Network and System Support for Games* (NetGames '08), ACM, New York, NY, USA, 53-58.