ELORank

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Contents

Introduction

ELORank is a C library providing structures and functions implementing the ELO ranking system in a version supporting several players per run with eventual ties.

It uses the `PBErr`, `PBMath` and `GSet` library.

1 Definitions

The ELO rank is calculated incrementally by updating the current ELO rank of each entity according to their result in an evaluation process independant from the ELO ranking system. Given a result of this evaluation process, each pair of winner/looser in this result is updated as follow:

$$\begin{cases} E'_w = E_w + K * \left(1.0 - \frac{1.0}{1.0+10.0^{\frac{E_l - E_w}{400.0}}}\right) \\ E'_l = E_l - K * \left(\frac{1.0}{1.0+10.0^{\frac{E_w - E_l}{400.0}}}\right) \end{cases} \tag{1}$$

where $K = 8.0$ and, E_w and E_l are respectively the current ELO of the winner and the current ELO of the looser and, E'_w and E'_l are respectively the new ELO of the winner and the new ELO of the looser.

Tie between two entities results in no changes in their respective ELO rank.

2 Interface

```
// ============ ELORANK.H ================

#ifndef ELORANK_H
#define ELORANK_H

// ================= Include =================

#include <stdlib.h>
#include <stdio.h>
#include <math.h>
#include <string.h>
#include <stdbool.h>
#include "pberr.h"
#include "gset.h"
#include "pbmath.h"

// ================= Define ==================

#define ELORANK_K 8.0
#define ELORANK_STARTELO 0.0

// ================= Data structure ===================

typedef struct ELOEntity {
  // Pointer toward user struct
  void* _data;
  // Number of evaluation
  int _nbRun;
} ELOEntity;
```

```
typedef struct ELORank {
  // ELO coefficient
  float _k;
  // Set of ELO entities
  GSet _set;
} ELORank;


// ================ Functions declaration ====================

// Create a new ELORank
ELORank* ELORankCreate(void);
/*#if BUILDMODE == 0
ELORank ELORankCreateStatic(void);
#endif*/

// Free memory used by an ELORank
void ELORankFree(ELORank** that);

// Free memory used by an ELOEntity
void ELOEntityFree(ELOEntity** that);

// Set the K coefficient of 'that' to 'k'
#if BUILDMODE != 0
inline
#endif
void ELORankSetK(ELORank* const that, const float k);

// Get the K coefficient of 'that'
#if BUILDMODE != 0
inline
#endif
float ELORankGetK(const ELORank* const that);

// Add the entity 'data' to 'that'
void ELORankAdd(ELORank* const that, void* const data);

// Remove the entity 'data' from 'that'
void ELORankRemove(ELORank* const that, void* data);

// Get the number of entity in 'that'
#if BUILDMODE != 0
inline
#endif
int ELORankGetNb(const ELORank* const that);

// Update the ranks in 'that' with results 'res' given as a GSet of
// pointers toward entities (_data in GSetElem equals _data in
// ELOEntity) in winning order
// The _sortVal of the GSet represents the score (and so position)
// of the entities for this update (thus, equal _sortVal means tie)
// The set of results must contain at least 2 elements
// Elements in the result set must be in the ELORank
void ELORankUpdate(ELORank* const that, const GSet* const res);

// Get the current rank of the entity 'data' (starts at 0)
int ELORankGetRank(const ELORank* const that, const void* const data);

// Get the current ELO of the entity 'data'
float ELORankGetELO(const ELORank* const that, const void* const data);
```

```
// Set the current ELO of the entity 'data' to 'elo'
void ELORankSetELO(const ELORank* const that, const void* const data,
  const float elo);

// Get the 'rank'-th entity according to current ELO of 'that'
// (starts at 0)
const ELOEntity* ELORankGetRanked(const ELORank* const that, const int rank);

// ================ Inliner ====================

#if BUILDMODE != 0
#include "elorank-inline.c"
#endif


#endif
```

3 Code

3.1 elorank.c

```
// ============ ELORANK.C ================

// ================= Include =================

#include "elorank.h"
#if BUILDMODE == 0
#include "elorank-inline.c"
#endif

// ================ Functions declaration ====================

// Create a new ELOEntity
static ELOEntity* ELOEntityCreate(void* const data);

// Return the GSetElem in 'that'->_set for the entity 'data'
static GSetElem* ELORankGetElem(const ELORank* const that, const void* const data);

// ================ Functions implementation ====================

// Create a new ELORank
ELORank* ELORankCreate(void) {
  // Allocate memory
  ELORank* that = PBErrMalloc(ELORankErr, sizeof(ELORank));
  // Set the default coefficient
  that->_k = ELORANK_K;
  // Create the set of entities
  that->_set = GSetCreateStatic();
  // Return the new ELORank
  return that;
}

// Free memory used by an ELORank
void ELORankFree(ELORank** that) {
  // Check the argument
  if (that == NULL || *that == NULL) return;
  // Empty the set of entities
  GSet* set = &((*that)->_set);
  while (GSetNbElem(set) > 0) {
    ELOEntity *ent = GSetPop(set);
    ELOEntityFree(&ent);
  }
  // Free memory
  free(*that);
  // Set the pointer to null
  *that = NULL;
}

// Free memory used by an ELOEntity
void ELOEntityFree(ELOEntity** that) {
  // Check the argument
  if (that == NULL || *that == NULL) return;
  // Free memory
  free(*that);
  // Set the pointer to null
  *that = NULL;
}

// Add the entity 'data' to 'that'
void ELORankAdd(ELORank* const that, void* const data) {
#if BUILDMODE == 0
  // Check arguments
  if (that == NULL) {
    ELORankErr->_type = PBErrTypeNullPointer;
    sprintf(ELORankErr->_msg, "'that' is null");
    PBErrCatch(ELORankErr);
  }
  if (data == NULL) {
    ELORankErr->_type = PBErrTypeNullPointer;
    sprintf(ELORankErr->_msg, "'data' is null");
    PBErrCatch(ELORankErr);
  }
#endif
  // Create a new ELOEntity
  ELOEntity *ent = ELOEntityCreate(data);
  // Add the new entity to the set with a default score
  GSetAddSort(&(that->_set), ent, ELORANK_STARTELO);
}

// Create a new ELOEntity
static ELOEntity* ELOEntityCreate(void* const data) {
#if BUILDMODE == 0
  // Check argument
  if (data == NULL) {
    ELORankErr->_type = PBErrTypeNullPointer;
    sprintf(ELORankErr->_msg, "'data' is null");
    PBErrCatch(ELORankErr);
  }
#endif
  // Allocate memory
  ELOEntity *that = PBErrMalloc(ELORankErr, sizeof(ELOEntity));
  // Set properties
  that->_data = data;
  that->_nbRun = 0;
  // Return the new ELOEntity
  return that;
}

// Remove the entity 'data' from 'that'
void ELORankRemove(ELORank* const that, void* data) {
```

```
#if BUILDMODE == 0
  // Check arguments
  if (that == NULL) {
    ELORankErr->_type = PBErrTypeNullPointer;
    sprintf(ELORankErr->_msg, "'that' is null");
    PBErrCatch(ELORankErr);
  }
  if (data == NULL) {
    ELORankErr->_type = PBErrTypeNullPointer;
    sprintf(ELORankErr->_msg, "'data' is null");
    PBErrCatch(ELORankErr);
  }
#endif
  // Search the entity
  GSetElem* elem = ELORankGetElem(that, data);
  // If we have found the entity
  if (elem != NULL) {
    // Free the memory
    ELOEntityFree((ELOEntity**)(&(elem->_data)));
    // Remove the element
    GSetRemoveElem(&(that->_set), &elem);
  }
}

// Return the GSetElem in 'that'->_set for the entity 'data'
static GSetElem* ELORankGetElem(const ELORank* const that, const void* const data) {
#if BUILDMODE == 0
  // Check arguments
  if (that == NULL) {
    ELORankErr->_type = PBErrTypeNullPointer;
    sprintf(ELORankErr->_msg, "'that' is null");
    PBErrCatch(ELORankErr);
  }
  if (data == NULL) {
    ELORankErr->_type = PBErrTypeNullPointer;
    sprintf(ELORankErr->_msg, "'data' is null");
    PBErrCatch(ELORankErr);
  }
#endif
  // Search the element
  GSetElem* elem = that->_set._head;
  while (elem != NULL && ((ELOEntity*)(elem->_data))->_data != data)
    elem = elem->_next;
  // Return the element
  return elem;
}

// Update the ranks in 'that' with results 'res' given as a GSet of
// pointers toward entities (_data in GSetElem equals _data in
// ELOEntity) in winning order
// The _sortVal of the GSet represents the score (and so position)
// of the entities for this update (thus, equal _sortVal means tie)
// The set of results must contain at least 2 elements
// Elements in the result set must be in the ELORank
void ELORankUpdate(ELORank* const that, const GSet* const res) {
#if BUILDMODE == 0
  // Check arguments
  if (that == NULL) {
    ELORankErr->_type = PBErrTypeNullPointer;
    sprintf(ELORankErr->_msg, "'that' is null");
    PBErrCatch(ELORankErr);
  }
  if (res == NULL) {
    ELORankErr->_type = PBErrTypeNullPointer;
    sprintf(ELORankErr->_msg, "'res' is null");
    PBErrCatch(ELORankErr);
  }
  if (GSetNbElem(res) < 2) {
    ELORankErr->_type = PBErrTypeInvalidArg;
    sprintf(ELORankErr->_msg,
      "Number of elements in result set invalid (%ld>=2)",
      GSetNbElem(res));
    PBErrCatch(ELORankErr);
  }
#endif
  // Declare a variable to memorise the delta of elo of each entity
  VecFloat* deltaElo = VecFloatCreate(GSetNbElem(res));
  // Calculate the delta of elo for each pair of entity
  GSetElem* elemA = res->_head;
  int iElem = 0;
  while (elemA != NULL) {
    GSetElem* elemAElo = ELORankGetElem(that, elemA->_data);
#if BUILDMODE == 0
    if (elemAElo == NULL) {
      ELORankErr->_type = PBErrTypeNullPointer;
      sprintf(ELORankErr->_msg,
        "Entity in the result set can't be found in the ELORank.");
      PBErrCatch(ELORankErr);
    }
#endif
    GSetElem* elemB = res->_head;
    while (elemB != NULL) {
      // Ignore tie and match with itself
      if (ISEQUALF(elemA->_sortVal, elemB->_sortVal) == false) {
        GSetElem* elemBElo = ELORankGetElem(that, elemB->_data);
#if BUILDMODE == 0
        if (elemBElo == NULL) {
          ELORankErr->_type = PBErrTypeNullPointer;
          sprintf(ELORankErr->_msg,
            "Entity in the result set can't be found in the ELORank.");
          PBErrCatch(ELORankErr);
        }
#endif
        // If elemA has won
        if (elemA->_sortVal > elemB->_sortVal) {
          float winnerELO = elemAElo->_sortVal;
          float looserELO = elemBElo->_sortVal;
          float a =
            1.0 / (1.0 + pow(10.0, (looserELO - winnerELO) / 400.0));
          VecSetAdd(deltaElo, iElem, that->_k * (1.0 - a));
        // Else, if elemA has lost
        } else {
          float winnerELO = elemBElo->_sortVal;
          float looserELO = elemAElo->_sortVal;
          float b =
            1.0 / (1.0 + pow(10.0, (winnerELO - looserELO) / 400.0));
          VecSetAdd(deltaElo, iElem, -1.0 * that->_k * b);
        }
      }
      elemB = elemB->_next;
    }
    elemA = elemA->_next;
    ++iElem;
  }
  // Apply the delta of elo and update the number of run
  GSetElem* elem = res->_head;
  iElem = 0;
  while (elem != NULL) {
    GSetElem* elemElo = ELORankGetElem(that, elem->_data);
#if BUILDMODE == 0
    if (elemElo == NULL) {
      ELORankErr->_type = PBErrTypeNullPointer;
      sprintf(ELORankErr->_msg,
        "Entity in the result set can’t be found in the ELORank.");
      PBErrCatch(ELORankErr);
    }
#endif
    elemElo->_sortVal += VecGet(deltaElo, iElem);
    ++(((ELOEntity*)(elemElo->_data))->_nbRun);
    ++iElem;
    elem = elem->_next;
  }
  // Free memory
  VecFree(&deltaElo);
  // Sort the ELORank
  GSetSort(&(that->_set));
}

// Get the current rank of the entity ’data’ (starts at 0)
int ELORankGetRank(const ELORank* const that, const void* const data) {
#if BUILDMODE == 0
  // Check arguments
  if (that == NULL) {
    ELORankErr->_type = PBErrTypeNullPointer;
    sprintf(ELORankErr->_msg, "’that’ is null");
    PBErrCatch(ELORankErr);
  }
  if (data == NULL) {
    ELORankErr->_type = PBErrTypeNullPointer;
    sprintf(ELORankErr->_msg, "’data’ is null");
    PBErrCatch(ELORankErr);
  }
#endif
  // Declare a variable to memorize the rank
  int rank = 0;
  // Search the element
  GSetElem* elem = that->_set._tail;
  while (elem != NULL && ((ELOEntity*)(elem->_data))->_data != data) {
    elem = elem->_prev;
    ++rank;
  }
#if BUILDMODE == 0
  if (elem == NULL) {
    ELORankErr->_type = PBErrTypeNullPointer;
    sprintf(ELORankErr->_msg,
      "Entity requested can’t be found in the ELORank.");
    PBErrCatch(ELORankErr);
  }
#endif
  // Return the element
  return rank;
}

// Get the current ELO of the entity ’data’
float ELORankGetELO(const ELORank* const that, const void* const data) {
#if BUILDMODE == 0
```

```
  // Check arguments
  if (that == NULL) {
    ELORankErr->_type = PBErrTypeNullPointer;
    sprintf(ELORankErr->_msg, "'that' is null");
    PBErrCatch(ELORankErr);
  }
  if (data == NULL) {
    ELORankErr->_type = PBErrTypeNullPointer;
    sprintf(ELORankErr->_msg, "'data' is null");
    PBErrCatch(ELORankErr);
  }
#endif
  // Declare a variable to memorize the ELO
  float elo = ELORANK_STARTELO;
  // Search the element
  GSetElem* elem = that->_set._head;
  while (elem != NULL && ((ELOEntity*)(elem->_data))->_data != data) {
    elem = elem->_next;
  }
  if (elem != NULL) {
    elo = elem->_sortVal;
#if BUILDMODE == 0
  } else {
    ELORankErr->_type = PBErrTypeNullPointer;
    sprintf(ELORankErr->_msg,
      "Entity requested can't be found in the ELORank.");
    PBErrCatch(ELORankErr);
#endif
  }
  // Return the element
  return elo;
}

// Set the current ELO of the entity 'data' to 'elo'
void ELORankSetELO(const ELORank* const that, const void* const data,
  const float elo) {
#if BUILDMODE == 0
  // Check arguments
  if (that == NULL) {
    ELORankErr->_type = PBErrTypeNullPointer;
    sprintf(ELORankErr->_msg, "'that' is null");
    PBErrCatch(ELORankErr);
  }
  if (data == NULL) {
    ELORankErr->_type = PBErrTypeNullPointer;
    sprintf(ELORankErr->_msg, "'data' is null");
    PBErrCatch(ELORankErr);
  }
#endif
  // Search the element
  GSetElem* elem = that->_set._head;
  while (elem != NULL && ((ELOEntity*)(elem->_data))->_data != data) {
    elem = elem->_next;
  }
  if (elem != NULL) {
    // Set the elo
    elem->_sortVal = elo;
#if BUILDMODE == 0
  } else {
    ELORankErr->_type = PBErrTypeNullPointer;
    sprintf(ELORankErr->_msg,
      "Entity requested can't be found in the ELORank.");
    PBErrCatch(ELORankErr);
#endif
  }
}

// Get the 'rank'-th entity according to current ELO of 'that'
// (starts at 0)
const ELOEntity* ELORankGetRanked(const ELORank* const that, const int rank) {
#if BUILDMODE == 0
  // Check arguments
  if (that == NULL) {
    ELORankErr->_type = PBErrTypeNullPointer;
    sprintf(ELORankErr->_msg, "'that' is null");
    PBErrCatch(ELORankErr);
  }
  if (rank < 0 || rank >= GSetNbElem(&(that->_set))) {
    ELORankErr->_type = PBErrTypeInvalidArg;
    sprintf(ELORankErr->_msg, "'rank' is invalid (0<=%d<%ld)", rank,
      GSetNbElem(&(that->_set)));
    PBErrCatch(ELORankErr);
  }
#endif
  GSetElem* elem = that->_set._tail;
  for (int i = rank; i--;)
    elem = elem->_prev;
  return (ELOEntity*)(elem->_data);
}
```

3.2 elorank-inline.c

```
// ============ ELORANK-INLINE.C ================

// ================ Functions implementation ====================

// Set the K coefficient of 'that' to 'k'
#if BUILDMODE != 0
inline
#endif
void ELORankSetK(ELORank* const that, const float k) {
#if BUILDMODE == 0
  // Check arguments
  if (that == NULL) {
    ELORankErr->_type = PBErrTypeNullPointer;
    sprintf(ELORankErr->_msg, "'that' is null");
    PBErrCatch(ELORankErr);
  }
#endif
  that->_k = k;
}

// Get the K coefficient of 'that'
#if BUILDMODE != 0
inline
#endif
float ELORankGetK(const ELORank* const that) {
#if BUILDMODE == 0
  // Check argument
  if (that == NULL) {
    ELORankErr->_type = PBErrTypeNullPointer;
    sprintf(ELORankErr->_msg, "'that' is null");
    PBErrCatch(ELORankErr);
  }
#endif
  return that->_k;
}

// Get the number of entity in 'that'
#if BUILDMODE != 0
inline
#endif
int ELORankGetNb(const ELORank* const that) {
#if BUILDMODE == 0
  // Check argument
  if (that == NULL) {
    ELORankErr->_type = PBErrTypeNullPointer;
    sprintf(ELORankErr->_msg, "'that' is null");
    PBErrCatch(ELORankErr);
  }
#endif
  return GSetNbElem(&(that->_set));
}
```

4 Makefile

```
# Build mode
# 0: development (max safety, no optimisation)
# 1: release (min safety, optimisation)
# 2: fast and furious (no safety, optimisation)
BUILD_MODE?=1

all: pbmake_wget main

# Automatic installation of the repository PBMake in the parent folder
pbmake_wget:
if [ ! -d ../PBMake ]; then wget https://github.com/BayashiPascal/PBMake/archive/master.zip; unzip master.zip; rm -f

# Makefile definitions
MAKEFILE_INC=../PBMake/Makefile.inc
include $(MAKEFILE_INC)

# Rules to make the executable
repo=elorank
$($(repo)_EXENAME): \
$($(repo)_EXENAME).o \
$($(repo)_EXE_DEP) \
$($(repo)_DEP)
$(COMPILER) `echo "$($(repo)_EXE_DEP) $($(repo)_EXENAME).o" | tr ' ' '\n' | sort -u` $(LINK_ARG) $($(repo)_LINK_ARG)

$($(repo)_EXENAME).o: \
$($(repo)_DIR)/$($(repo)_EXENAME).c \
$($(repo)_INC_H_EXE) \
$($(repo)_EXE_DEP)
$(COMPILER) $(BUILD_ARG) $($(repo)_BUILD_ARG) `echo "$($(repo)_INC_DIR)" | tr ' ' '\n' | sort -u` -c $($(repo)_DIR)/
```

5 Unit tests

```
#include <stdlib.h>
#include <stdio.h>
#include <time.h>
#include <string.h>
#include <time.h>
#include <unistd.h>
#include <sys/time.h>
#include "elorank.h"
#include "pberr.h"
#include "pbmath.h"

#define RANDOMSEED 2

typedef struct Player {
  int _id;
} Player;

void UnitTestCreateFree() {
  ELORank* elo = ELORankCreate();
  if (elo == NULL || elo->_k != ELORANK_K) {
    ELORankErr->_type = PBErrTypeUnitTestFailed;
    sprintf(ELORankErr->_msg, "ELORankCreate failed");
    PBErrCatch(ELORankErr);
  }
  ELORankFree(&elo);
  if (elo != NULL) {
    ELORankErr->_type = PBErrTypeUnitTestFailed;
    sprintf(ELORankErr->_msg, "ELORankFree failed");
    PBErrCatch(ELORankErr);
  }
  printf("UnitTestCreateFree OK\n");
}

void UnitTestSetGetK() {
  ELORank* elo = ELORankCreate();
  float k = 1.0;
  ELORankSetK(elo, k);
  if (ISEQUALF(elo->_k, k) == false) {
    ELORankErr->_type = PBErrTypeUnitTestFailed;
    sprintf(ELORankErr->_msg, "ELORankSetK failed");
    PBErrCatch(ELORankErr);
  }
  if (ISEQUALF(ELORankGetK(elo), k) == false) {
    ELORankErr->_type = PBErrTypeUnitTestFailed;
    sprintf(ELORankErr->_msg, "ELORankGetK failed");
    PBErrCatch(ELORankErr);
  }
  ELORankFree(&elo);
  printf("UnitTestSetGetK OK\n");
}

void UnitTestAddRemoveGetNb() {
  ELORank* elo = ELORankCreate();
  Player *playerA = PBErrMalloc(ELORankErr, sizeof(Player));
  Player *playerB = PBErrMalloc(ELORankErr, sizeof(Player));
  ELORankAdd(elo, playerA);
  if (ELORankGetNb(elo) != 1) {
    ELORankErr->_type = PBErrTypeUnitTestFailed;
    sprintf(ELORankErr->_msg, "ELORankAdd failed");
    PBErrCatch(ELORankErr);
  }
  if (((ELOEntity*)(elo->_set._head->_data))->_data != playerA) {
    ELORankErr->_type = PBErrTypeUnitTestFailed;
    sprintf(ELORankErr->_msg, "ELORankAdd failed, _data invalid");
    PBErrCatch(ELORankErr);
  }
  if (((ELOEntity*)(elo->_set._head->_data))->_nbRun != 0) {
    ELORankErr->_type = PBErrTypeUnitTestFailed;
    sprintf(ELORankErr->_msg, "ELORankAdd failed, _nbRun invalid");
    PBErrCatch(ELORankErr);
  }
  if (ISEQUALF(elo->_set._head->_sortVal, ELORANK_STARTELO) == false) {
    ELORankErr->_type = PBErrTypeUnitTestFailed;
    sprintf(ELORankErr->_msg, "ELORankAdd failed, _sortVal invalid");
    PBErrCatch(ELORankErr);
  }
  ELORankAdd(elo, playerB);
  if (ELORankGetNb(elo) != 2) {
    ELORankErr->_type = PBErrTypeUnitTestFailed;
    sprintf(ELORankErr->_msg, "ELORankAdd failed");
    PBErrCatch(ELORankErr);
  }
  if (((ELOEntity*)(elo->_set._head->_next->_data))->_data !=
    playerB) {
    ELORankErr->_type = PBErrTypeUnitTestFailed;
    sprintf(ELORankErr->_msg, "ELORankAdd failed, _data invalid");
    PBErrCatch(ELORankErr);
  }
  ELORankRemove(elo, playerA);
  if (ELORankGetNb(elo) != 1) {
    ELORankErr->_type = PBErrTypeUnitTestFailed;
    sprintf(ELORankErr->_msg, "ELORankRemove failed");
    PBErrCatch(ELORankErr);
  }
  if (((ELOEntity*)(elo->_set._head->_data))->_data != playerB) {
    ELORankErr->_type = PBErrTypeUnitTestFailed;
    sprintf(ELORankErr->_msg, "ELORankRemove failed, _data invalid");
    PBErrCatch(ELORankErr);
  }
  ELORankFree(&elo);
  free(playerA);
  free(playerB);
  printf("UnitTestAddRemoveGetNb OK\n");
}

void UnitTestUpdateGetRankGetElo() {
  srandom(RANDOMSEED);
  ELORank* elo = ELORankCreate();
  Player *players[3] = {NULL};
  GSet res = GSetCreateStatic();
  Gauss gausses[3];
  for (int i = 3; i--;) {
    players[i] = PBErrMalloc(ELORankErr, sizeof(Player));
    players[i]->_id = i;
    ELORankAdd(elo, players[i]);
    gausses[i] = GaussCreateStatic(3 - i, 1.0);
  }
  int nbRun = 100;
  FILE* f = fopen("./elorank.txt", "w");
  for (int iRun = nbRun; iRun--;) {
    GSetFlush(&res);
    for (int i = 3; i--;)
      GSetAddSort(&res, players[i], GaussRnd(gausses + i));
    ELORankUpdate(elo, &res);
    fprintf(f, "%d %f %f %f\n", (nbRun - iRun),
      ELORankGetELO(elo, players[0]),
      ELORankGetELO(elo, players[1]),
      ELORankGetELO(elo, players[2]));
  }
  fclose(f);
  for (int i = 3; i--;) {
    if (ELORankGetRank(elo, players[i]) != i) {
      ELORankErr->_type = PBErrTypeUnitTestFailed;
      sprintf(ELORankErr->_msg, "ELORankUpdate failed");
      PBErrCatch(ELORankErr);
    }
  }
  const ELOEntity *winner = ELORankGetRanked(elo, 0);
  if (winner->_data != players[0]) {
    ELORankErr->_type = PBErrTypeUnitTestFailed;
    sprintf(ELORankErr->_msg, "ELORankGeRanked failed");
    PBErrCatch(ELORankErr);
  }
  if (winner->_nbRun != nbRun) {
    ELORankErr->_type = PBErrTypeUnitTestFailed;
    sprintf(ELORankErr->_msg, "nbRun invalid");
    PBErrCatch(ELORankErr);
  }
  ELORankSetELO(elo, players[0], 10.0);
  if (!ISEQUALF(ELORankGetELO(elo, players[0]), 10.0)) {
    ELORankErr->_type = PBErrTypeUnitTestFailed;
    sprintf(ELORankErr->_msg, "ELORankSetELO failed");
    PBErrCatch(ELORankErr);
  }
  ELORankFree(&elo);
  GSetFlush(&res);
  for (int i = 3; i--;)
    free(players[i]);
  printf("UnitTestUpdateGetRankGetElo OK\n");
}

void UnitTestAll() {
  UnitTestCreateFree();
  UnitTestSetGetK();
  UnitTestAddRemoveGetNb();
  UnitTestUpdateGetRankGetElo();
  printf("UnitTestAll OK\n");
}

int main() {
  UnitTestAll();
  // Return success code
  return 0;
}
```

6 Unit tests output

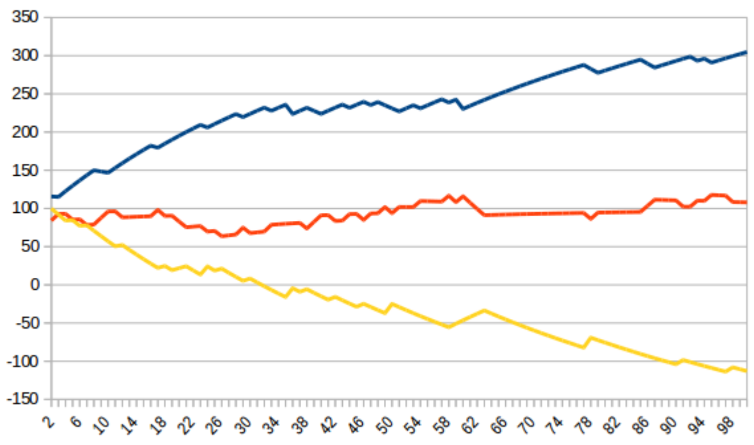
```
UnitTestCreateFree OK
UnitTestSetGetK OK
```

```
UnitTestAddRemoveGetNb OK
UnitTestUpdateGetRankGetElo OK
UnitTestAll OK
```

7 ELORank.txt

```
1 8.000000 -8.000000 0.000000
2 15.723836 -15.723836 -0.000000
3 15.181863 -7.181863 -8.000000
4 22.658251 -6.934165 -15.724085
5 29.878273 -14.695467 -15.182804
6 36.852001 -14.190701 -22.661297
7 43.589993 -21.704742 -21.885246
8 50.101974 -20.963814 -29.138155
9 48.398232 -12.250955 -36.147270
10 46.752392 -3.834395 -42.917988
11 53.164032 -3.704153 -49.459869
12 59.366798 -11.578976 -47.787811
13 65.365189 -11.188716 -54.176464
14 71.173401 -10.813753 -60.359642
15 76.800728 -10.453563 -66.347153
16 82.256058 -10.107615 -72.148430
17 79.547867 -1.775375 -77.772476
18 84.931526 -9.717095 -75.214417
19 90.144630 -9.398850 -80.745766
20 95.206184 -17.093233 -78.112938
21 100.111649 -24.538937 -75.572701
22 104.868889 -23.745762 -81.123116
23 109.494507 -22.983797 -86.510704
24 105.994957 -30.251780 -75.743172
25 110.581802 -29.279697 -81.302094
26 115.044350 -36.345665 -78.698669
27 119.379044 -35.190456 -84.188576
28 123.600494 -34.080109 -89.520370
29 119.714195 -25.012819 -94.701355
30 123.941559 -32.228443 -91.713097
31 128.049164 -31.220741 -96.828400
32 132.054733 -30.252058 -101.802650
33 127.963089 -21.320766 -106.642296
34 131.989212 -20.663591 -111.325592
35 135.918457 -20.031824 -115.886597
36 123.755226 -19.424370 -104.330818
37 127.890121 -18.821854 -109.068230
38 131.923431 -26.242733 -105.680656
39 127.842506 -17.436901 -110.405563
40 123.880096 -8.900932 -114.979118
41 128.036240 -8.627240 -119.408958
42 132.091034 -16.364151 -115.726845
43 136.027908 -15.865696 -120.162178
44 131.872452 -7.386406 -124.486008
45 135.838455 -7.163136 -128.675278
46 139.711716 -14.948422 -124.763252
47 135.472931 -6.500619 -128.972260
48 139.356705 -6.305744 -133.050919
49 135.151398 1.881705 -137.033066
50 131.069504 -6.174252 -124.895218
51 127.058136 2.012465 -129.070572
52 131.167801 1.951608 -133.119385
53 135.179230 1.893085 -137.072296
```

```
54 131.096741 9.836794 -140.933502
55 135.137115 9.544323 -144.681412
56 139.082886 9.262930 -148.345795
57 142.938095 8.992129 -151.930206
58 138.706543 16.731459 -155.437988
59 142.600052 8.246344 -150.846375
60 130.373032 16.006891 -146.379913
61 134.453491 7.533657 -141.987137
62 138.407562 -0.689304 -137.718246
63 142.242188 -8.668893 -133.573273
64 145.964005 -8.412176 -137.551804
65 149.603500 -8.165155 -141.438309
66 153.164139 -7.927407 -145.236694
67 156.649200 -7.698526 -148.950638
68 160.061768 -7.478126 -152.583603
69 163.404770 -7.265838 -156.138885
70 166.680939 -7.061309 -159.619583
71 169.892883 -6.864205 -163.028641
72 173.043076 -6.674206 -166.368820
73 176.133820 -6.491009 -169.642776
74 179.167343 -6.314322 -172.852982
75 182.145721 -6.143868 -176.001816
76 185.070938 -5.979387 -179.091507
77 187.944855 -5.820625 -182.124191
78 182.769272 -13.667344 -169.101898
79 177.653793 -5.298442 -172.355316
80 180.664001 -5.155023 -175.508942
81 183.619919 -5.016639 -178.603241
82 186.523483 -4.883080 -181.640366
83 189.376526 -4.754143 -184.622345
84 192.180801 -4.629635 -187.551117
85 194.937943 -4.509374 -190.428528
86 189.649536 3.606816 -193.256317
87 184.486328 11.513550 -195.999832
88 187.449646 11.214846 -198.664444
89 190.360336 10.926239 -201.286530
90 193.220200 10.647317 -203.867477
91 196.030945 2.377687 -198.408585
92 198.755539 2.317230 -201.072723
93 193.435593 10.258780 -203.694321
94 196.240829 9.999002 -206.239792
95 190.998749 17.747816 -208.746536
96 193.882751 17.300257 -211.182983
97 196.716660 16.867434 -213.584076
98 199.502136 8.448761 -207.950882
99 202.199768 8.238097 -210.437851
100 204.853592 8.034303 -212.887878
```


350
300
250
200
150
100
50
0
-50
-100
-150
2
6
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