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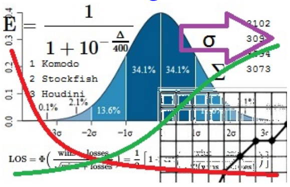

Match Statistics [1]

Match Statistics,
the statistics of chess tournaments and matches, that is a collection of chess games and the presentation, analysis, and interpretation of game related data, most common game results to determine the relative playing strength of chess playing entities, here with focus on chess engines. To apply match statistics, beside considering statistical population, it is conventional to hypothesize a statistical model describing a set of probability distributions.

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Ratios / Operating Figures

Common tools, ratios and figures to illustrate a tournament outcome and provide a base for its interpretation.

Number of games

The total number of games played by an engine in a tournament.

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Score

The score is a representation of the tournament-outcome from the viewpoint of a certain engine.

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Win & Draw Ratio

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These two ratios depend on the strength difference between the competitors, the average strength level, the color and the drawishness of the opening book-line. Due to the second reason given, these ratios are very much influenced by the timecontrol, what is also confirmed by the published statistics of the testing orgnisations CCRL and CEGT, showing an increase of the draw rate at longer time controls. This correlation was also shown by Kirill Kryukov, who was analyzing statistics of his test-games [2] . The program playing white seems to be more supported by the additional level of strength. So, although one would expect with increasing draw rates the win ratio to approach 50%, in fact it is remaining about equal.

Timecontrol	Draw Ratio	Win Ratio (white)	Source
40/4	30.9%	55.0%	CEGT
40/20	35.6%	54.6%	CEGT
40/120	41.3%	55.4%	CEGT
40/120 (4cpu)	45.2%	55.9%	CEGT

Timecontrol	Draw Ratio	Win Ratio (white)	Source
40/4	31.0%	54.1%	CCRL
40/40	37.2%	54.6%	CCRL

Doubling Time Control

As posted in October 2016 [3] , Andreas Strangmüller conducted an experiment with Komodo 9.3, time control doubling matches under Cutechess-cli, playing 3000 games with 1500 opening positions each, without pondering, learning, and tablebases, Intel i5-750 @ 3.5 GHz, 1 Core, 128 MB Hash [4] , see also Kai Laskos' 2013 results with Houdini 3 [5] and Diminishing Returns:

Time Control 2 vs 1	20+0.2 10+0.1	40+0.4 20+0.2	80+0.8 40+0.4	160+1.6 80+0.8	320+3.2 160+1.6	640+6.4 320+3.2	1280+12.8 640+6.4	2560+25.6 1280+12.8
Elo	144	133	112	101	93	73	59	51
Win	44.97 %	41.27 %	36.67 %	32.67 %	30.47 %	25.17 %	21.77 %	18.97 %
Draw	49.20 %	54.00 %	57.93 %	63.03 %	65.33 %	70.47 %	73.17 %	76.63 %
Loss	5.83 %	4.73 %	5.40 %	4.30 %	4.20 %	4.37 %	5.07 %	4.40 %

Elo-Rating & Win-Probability

see Pawn Advantage, Win Percentage, and Elo

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Generalization of the Elo-Formula:
win_probability of player i in a tournament with n players

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Likelihood of Superiority

See LOS Table

The likelihood of superiority (LOS) denotes how likely it would be for two players of the same strength to reach a certain result - in other fields called a p-value, a measure of statistical significance of a departure from the null hypothesis [6]. Doing this analysis after the tournament one has to differentiate between the case where one knows that a certain engine is either stronger or equally strong (directional or one-tailed test) or the case where one has no information of whether the other engine is stronger or weaker (non-directional or two-tailed test). The latter due to the reduced information results in larger confidence intervals.

Two-tailed Test
Null- and alternative hypothesis:

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-
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The probability of the null hypothesis being true can be calculated given the tournament outcome. In other words, how likely would it be for two players of the same strength to reach a certain result. The LOS would then be the inverse, 1 - the resulting probability.

For this type of analysis the trinomial distribution, a generalization of the binomial distribution, is needed. Whilest the binomial distribution can only calculate the probability to reach a certain outcome with two possible events, the trinominal distribution can account for all three possible events (win, draw, loss).

The following functions gives the probability of a certain game outcome assuming both players were of equal strength:

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This calculation becomes very inefficient for larger number of games. In this case the standard normal distribution can give a good approximation:

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where N(1 - draw_ratio) is the sum of wins and losses:

-

To calculate the LOS one needs the cumulative distribution function of the given normal distribution. However, as pointed out by Rémi Coulom, calculation can be done cleverly, and the normal approximation is not really required [7] . As further emphasized by Kai Laskos [8] and Rémi Coulom [9] [10] , draws do not count in LOS calculation and don't make a difference whether the game results were obtained when playing Black or White. It is a good approximation when the two players played the same number of games with each color:

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[11] [12] [13]

One-tailed Test
Null- and alternative hypothesis:

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-

Sample Program
A tiny C++11 program to compute Elo difference and LOS from W/L/D counts was given by Álvaro Begué [14] :

```
#include <cstdio>
#include <cstdlib>
#include <cmath>

int main(int argc, char **argv) {
  if (argc != 4) {
    std::printf("Wrong number of arguments.\n\n
```

```
Usage:%s <wins> <losses> <draws>\n", argv[0]);
    return 1;
  }
  int wins = std::atoi(argv[1]);
  int losses = std::atoi(argv[2]);
  int draws = std::atoi(argv[3]);

  double games = wins + losses + draws;
  std::printf("Number of games: %g\n", games);
  double winning_fraction = (wins + 0.5*draws) / games;
  std::printf("Winning fraction: %g\n", winning_fraction);
  double elo_difference = -std::log(1.0/
winning_fraction-1.0)*400.0/std::log(10.0);
  std::printf("Elo difference: %+g\n", elo_difference);
  double los = .5 + .5 * std::erf((wins-losses)/std::sqrt(2.0*(
wins+losses)));
  std::printf("LOS: %g\n", los);
}
```

Statistical Analysis

The trinomial versus the 5-nomial model

As indicated above a match between two engines is usually modeled as a sequence of independent trials taken from a trinomial distribution with probabilities (win_ratio,draw_ratio,loss_ratio). This model is appropriate for a match with randomly selected opening positions and randomly assigned colors (to maintain fairness). However one may show that under reasonable elo models the trinomial model is not correct in case games are played in pairs with reversed colors (as is commonly the case) and unbalanced opening positions are used.

This was also empirically observed by Kai Laskos [15] . He noted that the statistical predictions of the trinomial model do not match reality very well in the case of paired games. In particular he observed that for some data sets the variance of the match score as predicted by the trinomial model greatly exceeds the variance as calculated by the jackknife estimator. The jackknife estimator is a non-parametric estimator, so it does not depend on any particular statistical model. It appears the mismatch may even occur for balanced opening positions, an effect which can only be explained by the existence of correlations between paired games - something not considered by any elo model.

Over estimating the variance of the match score implies that derived quantities such as the number of games required to establish the superiority of one engine over another with a given level of significance are also over estimated. To obtain agreement between statistical predictions and actual measurements one may adopt the more general 5-nomial model. In the 5-nomial model the outcome of paired games is assumed to follow a 5-nomial distribution with probabilities

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These unknown probabilities may be estimated from the outcome frequencies of the paired games and then subsequently be used to compute an estimate for the variance of the match score. Summarizing: in the case of paired games the 5-nomial model handles the following effects correctly which the trinomial model does not:

- Unbalanced openings
- Correlations between paired games

For further discussion on the potential use of unbalanced opening positions in engine testing see the posting by Kai Laskos [16] .

SPRT

The sequential probability ratio test (SPRT) is a specific sequential hypothesis test - a statistical analysis where the sample size is not fixed in advance - developed by Abraham Wald [17] . While originally developed for use in quality control studies in the realm of manufacturing, SPRT has been formulated for use in the computerized testing of human examinees as a termination criterion [18]. As mentioned by Arthur Guez in this 2015 Ph.D. thesis *Sample-based Search Methods for Bayes-Adaptive Planning* [19], Alan Turing assisted by Jack Good used a similar sequential testing technique to help decipher enigma codes at Bletchley Park [20]. SPRT is applied in Stockfish testing to terminate self-testing series early if the result is likely outside a given elo-window [21] . In August 2016, Michel Van den Bergh posted following Python code in CCC to implement the SPRT a la Cutechess-cli or Fishtest: [22] [23]

```
from __future__ import division

import math

def LL(x):
    return 1/(1+10**(-x/400))

def LLR(W,D,L,elo0,elo1):
    """
This function computes the log likelihood ratio of H0:elo_diff=elo0 ve
rsus
H1:elo_diff=elo1 under the logistic elo model

expected_score=1/(1+10**(-elo_diff/400)).

W/D/L are respectively the Win/Draw/Loss count. It is assumed that the
```

```
 outcomes of
the games follow a trinomial distribution with probabilities (w,d,l).
Technically
this is not quite an SPRT but a so-
called GSPRT as the full set of parameters (w,d,l)
cannot be derived from elo_diff, only w+(1/2)d. For a description and
properties of
the GSPRT (which are very similar to those of the SPRT) see

http://stat.columbia.edu/~jcliu/paper/GSPRT_SQA3.pdf

This function uses the convenient approximation for log likelihood
ratios derived here:

http://hardy.uhasselt.be/Toga/GSPRT_approximation.pdf

The previous link also discusses how to adapt the code to the 5-nomial
 model
discussed above.
"""
# avoid division by zero
    if W==0 or D==0 or  L==0:
        return 0.0
    N=W+D+L
    w,d,l=W/N,D/N,L/N
    s=w+d/2
    m2=w+d/4
    var=m2-s**2
    var_s=var/N
    s0=LL(elo0)
    s1=LL(elo1)
    return (s1-s0)*(2*s-s0-s1)/var_s/2.0

def SPRT(W,D,L,elo0,elo1,alpha,beta):
    """
This function sequentially tests the hypothesis H0:elo_diff=elo0 versu
s
the hypothesis H1:elo_diff=elo1 for elo0<elo1. It should be called aft
er
each game until it returns either 'H0' or 'H1' in which case the test
stops
and the returned hypothesis is accepted.

alpha is the probability that H1 is accepted while H0 is true
(a false positive) and beta is the probability that H0 is accepted
while H1 is true (a false negative). W/D/L are the current win/draw/lo
```

```
ss
counts, as before.
"""
    LLR_=LLR(W,D,L,elo0,elo1)
    LA=math.log(beta/(1-alpha))
    LB=math.log((1-beta)/alpha)
    if LLR_>LB:
        return 'H1'
    elif LLR_<LA:
        return 'H0'
    else:
        return ''
```

Tournament Manager

- Arena
- Amoeba Tournament Manager
- ChessGUI
- Cutechess-cli
- LittleBlitzer

See also

- Automated Tuning
- Bishop versus Knight - Winning Percentages
- Chess Server
- Depth | Diminishing Returns
- Draw
- Engine Rating Lists
- LOS Table
- Pawn Advantage, Win Percentage, and Elo
- Playing Strength
- Search Statistics
- Time Controls
- Who is the Master?

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