

## Record Prediction Using Time Series Models

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### Abstract

This paper uses Time Series models to predict a Major League Baseball team's final record. I explore several Time Series models and present the results. An advantage to the models explored in this paper is that they can generalize to any sport with minor changes. One sees that the best back-test was within an average of 5 games error throughout 2005-2017. This is a fairly good result, considering that these models do not condition on annual team changes, but rather focus on the temporal structure of a team throughout its history.

*Keywords:* Time Series, Sports Analytics, Record Prediction, MLB

## Record Prediction Using Time Series Models

I used data from the Lahman database for this project. There is an R package made by Friendly (2017) that I used to download the data. The Lahman data contains seasonal statistics. In order to predict a team's record, I modeled winning percentage using Time Series models. An assumption to use Time Series models is that the dependent variable is continuous and falls in the real line. In order to use this model, one must constrain the winning percentage interval to  $[0, 1]$ . This is done using the Transformation equation in Appendix C. This is a known technique used in logistic regression and is essential in this model.

### Methodology

I present two results in the paper. One is the Mean Squared Prediction Error and the other is the 2018 record predictions. The MSPE allows one to understand how the model performed in the past. In order to accomplish this one needs to limit themselves to data that would have been available at the time. If one is trying to predict a team's 2017 record, one can only use up to 2016 seasonal statistics. The 2018 record predictions lets one see how the models forecast the future, but also gives insight into how the models typically predicted in the past. To perform this experiment, I used the R language. This back-test is accomplished using procedural programming, but I also made use of object- oriented programming using the R6 package made by Chang (2017). To fit the Time Series models, I used the forecast package made by Hyndman (2017).

## Models

The basis for all of these models is an ARIMA model. ARIMA stands for Autoregressive Integrated Moving Average model and is essentially linear regression on the past. Since we are modeling winning percentage, the independent features of the regression are winning percentage lagged by a certain value. For each model, I used the Maximum Likelihood Estimation for the coefficients. The models can be broken into two categories: base and ensemble learners. The base learners are BIC, PE and PYRIMA models, and the ensemble learners are naive and after weights models.

**Bayesian Information Criteria (BIC).** The BIC model uses the Bayesian Information Criteria to find the appropriate model for the Time Series. In the MSPE table, we see that it has the lowest average error; making it the best overall model.

**Pythagorean Expectation (PE).** The PE model is known by most MLB analysts. We see that it performed the worst, but is not that far behind the statistical models. The PE model performs well for interpolation, but is not useful for predicting the future.

**Pythagorean Regressor (PYRIMA).** The PYRIMA model does slightly better than the PE model, but some of the disadvantages of the PE equation are transferred into the Time Series model and cause it to perform poorly.

**Naive Weights.** The Naive Weights model performs slightly better than the After 2 model. This is probably because in addition to the regular terms, I also used seasonal terms in this model. So it used 16 models. This causes more aggregation, which leads to a better generalization. In the Naive Weights model, you give equal weight to each prediction. The After Weights model uses a technique to learn non-trivial weights.

**After Weights.** The After Weights models was inspired by Zou and Yang (2001). I changed the equation around a little to emphasize the training error more and introduced an alpha parameter. We see that the After 2 model performs better than the After 4 model. After 4 used 16 models and the After 2 used 4 models. The After 4 model uses more complex models than the After 2 and provides bias towards the more complex model weights. More complex models have a higher variance and are typically not robust. We this see in the results, but there are outliers.

### **Mean Squared Prediction Error (MSPE)**

The MSPE table allows for the models to be compared. We see that each team has a best model, so a team's predictions should be chosen based on how well a model performed in its back-test. This is something that an Information Criteria would not reveal. One sees a common trend that either single or aggregated forecasts perform better for a team. Since we are modeling winning percentage, all MSPE values are in measurements of percentages. We see that the lowest error was around 3%, which translates to an error of 5 games.

### **2018 Predictions**

The raw predictions give the predicted value and a 95% confidence interval. This is useful because we can state that we are 95% certain that a team's final record will be inside this interval. Unfortunately, this interval is so large that it is blatantly obvious that the final record will be inside these bounds. In order to draw inference in the raw predictions, I sorted the teams for each model by the amount of wins. This allows each team to be ranked and lets one see how balanced the teams will be with regards to who is over and under .500.

### **Conclusion and Future Study**

Time Series modeling is a tool that provides decent results and limits the complexity of the model. One of the key attributes of Time Series models is that they can model anything that revolves around time, so this technique can be used for any sport, not just baseball. To increase the accuracy, one needs to factor in team annual changes. This would be useful since a team can improve dramatically over two seasons if they are in a rebuilding stage.

## References

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## Appendix A

MSPE from 2005-2017

Team	Naïve	Pyrima	Pythag	BIC	After 2	After 4
Arizona Diamondbacks	0.0900	0.0519	0.0513	0.0345	0.0919	0.0975
Atlanta Braves	0.0518	0.0798	0.0904	0.0650	0.0507	0.0524
Baltimore Orioles	0.0527	0.0433	0.0622	0.0480	0.0534	0.0536
Boston Red Sox	0.0662	0.0536	0.0615	0.0542	0.0652	0.0665
Chicago Cubs	0.0765	0.0666	0.0815	0.0579	0.0740	0.0755
Chicago White Sox	0.0584	0.1048	0.0854	0.0732	0.0553	0.0562
Cincinnati Reds	0.0586	0.0662	0.0629	0.0538	0.0560	0.0576
Cleveland Indians	0.0685	0.0707	0.0841	0.0688	0.0698	0.0699
Colorado Rockies	0.0581	0.0607	0.0780	0.0604	0.0591	0.0565
Detroit Tigers	0.0592	0.0512	0.0644	0.0537	0.0669	0.0667
Houston Astros	0.0736	0.0580	0.0797	0.0495	0.0787	0.0804
Kansas City Royals	0.0640	0.0822	0.0723	0.0563	0.0602	0.0639
Los Angeles Angels	0.0684	0.0568	0.0550	0.0509	0.0633	0.0647
Los Angeles Dodgers	0.0529	0.0722	0.0620	0.0640	0.0544	0.0612
Miami Marlins	0.0523	0.0764	0.0597	0.0450	0.0516	0.0593
Milwaukee Brewers	0.0574	0.0785	0.0855	0.0721	0.0588	0.0621
Minnesota Twins	0.0740	0.0660	0.0574	0.0679	0.0742	0.0786
New York Mets	0.0586	0.0644	0.0708	0.0599	0.0630	0.0683
New York Yankees	0.0343	0.0901	0.0683	0.0705	0.0346	0.0356
Oakland Athletics	0.0579	0.0655	0.0552	0.0572	0.0524	0.0540
Philadelphia Phillies	0.0507	0.0733	0.0436	0.0611	0.0505	0.0504
Pittsburgh Pirates	0.0590	0.0642	0.0638	0.0649	0.0601	0.0618
San Diego Padres	0.0581	0.0581	0.0771	0.0564	0.0588	0.0590
San Francisco Giants	0.0528	0.0532	0.0667	0.0551	0.0626	0.0633
Seattle Mariners	0.0635	0.0760	0.0804	0.0719	0.0617	0.0657
St. Louis Cardinals	0.0461	0.0484	0.0559	0.0412	0.0401	0.0423
Tampa Bay Rays	0.1056	0.0554	0.0652	0.0587	0.1012	0.1124
Texas Rangers	0.0641	0.0453	0.0451	0.0470	0.0656	0.0656
Toronto Blue Jays	0.0457	0.0634	0.0959	0.0593	0.0491	0.0501
Washington Nationals	0.0649	0.0773	0.0668	0.0927	0.0692	0.0723
L2 Norm	0.3444	0.3678	0.3806	0.3291	0.3459	0.3602
Average	0.0615	0.0658	0.0683	0.0590	0.0618	0.0641

Figure A1. MSPE

## Appendix B

## 2018 Predictions

## Raw

		Naive Weights				Pythagorean Arima				BIC				After (2-2)				After (4-4)			
Team	Type	W	L	W%	I	W	L	W%	I	W	L	W%	I	W	L	W%	I	W	L	W%	I
Arizona Diamondbacks	High 95	106	56	0.656	1	105	57	0.650	1	106	56	0.652	1	119	43	0.7328	1	119	43	0.7326	1
Arizona Diamondbacks	Yhat	78	84	0.482	0	80	82	0.496	0	81	81	0.500	0	90	72	0.5529	1	81	81	0.5000	0
Arizona Diamondbacks	Low 95	51	111	0.314	0	56	106	0.343	0	56	106	0.348	0	58	104	0.3591	0	46	116	0.2858	0
Atlanta Braves	High 95	100	62	0.614	1	95	67	0.586	1	98	64	0.602	1	101	61	0.6237	1	101	61	0.6263	1
Atlanta Braves	Yhat	78	84	0.481	0	74	88	0.455	0	76	86	0.470	0	79	83	0.4900	0	80	82	0.4926	0
Atlanta Braves	Low 95	57	105	0.351	0	54	108	0.330	0	56	106	0.343	0	58	104	0.3578	0	58	104	0.3599	0
Baltimore Orioles	High 95	102	60	0.633	1	101	61	0.622	1	102	60	0.631	1	95	67	0.5847	1	95	67	0.5837	1
Baltimore Orioles	Yhat	80	82	0.497	0	80	82	0.494	0	81	81	0.499	0	73	89	0.4479	0	72	90	0.4474	0
Baltimore Orioles	Low 95	58	104	0.361	0	59	103	0.367	0	59	103	0.367	0	52	110	0.3186	0	52	110	0.3185	0
Boston Red Sox	High 95	111	51	0.685	1	116	46	0.718	1	108	54	0.668	1	108	54	0.6651	1	108	54	0.6654	1
Boston Red Sox	Yhat	90	72	0.557	1	98	64	0.602	1	88	74	0.544	1	88	74	0.5408	1	88	74	0.5414	1
Boston Red Sox	Low 95	68	94	0.422	0	77	85	0.474	0	67	95	0.415	0	67	95	0.4111	0	67	95	0.4121	0
Chicago Cubs	High 95	107	55	0.662	1	110	52	0.680	1	107	55	0.662	1	95	67	0.5856	1	95	67	0.5876	1
Chicago Cubs	Yhat	86	76	0.532	1	91	71	0.564	1	87	75	0.535	1	74	88	0.4550	0	74	88	0.4570	0
Chicago Cubs	Low 95	64	98	0.397	0	71	91	0.440	0	65	97	0.403	0	53	109	0.3302	0	54	108	0.3321	0
Chicago White Sox	High 95	97	65	0.596	1	97	65	0.596	1	96	66	0.591	1	108	54	0.6688	1	108	54	0.6689	1
Chicago White Sox	Yhat	75	87	0.465	0	77	85	0.476	0	75	87	0.464	0	88	74	0.5462	1	89	73	0.5463	1
Chicago White Sox	Low 95	55	107	0.339	0	58	104	0.359	0	55	107	0.342	0	68	94	0.4178	0	68	94	0.4178	0
Cincinnati Reds	High 95	94	68	0.583	1	95	67	0.586	1	95	67	0.588	1	101	61	0.6233	1	101	61	0.6258	1
Cincinnati Reds	Yhat	73	89	0.450	0	75	87	0.463	0	75	87	0.460	0	80	82	0.4946	0	81	81	0.4971	0
Cincinnati Reds	Low 95	52	110	0.324	0	56	106	0.345	0	55	107	0.337	0	59	103	0.3666	0	60	102	0.3687	0
Cleveland Indians	High 95	113	49	0.697	1	112	50	0.688	1	111	51	0.684	1	102	60	0.6303	1	102	60	0.6289	1
Cleveland Indians	Yhat	93	69	0.576	1	93	69	0.572	1	92	70	0.566	1	82	80	0.5074	1	82	80	0.5059	1
Cleveland Indians	Low 95	72	90	0.446	0	73	89	0.448	0	71	91	0.440	0	62	100	0.3835	0	62	100	0.3821	0
Colorado Rockies	High 95	98	64	0.603	1	91	71	0.563	1	91	71	0.563	1	90	72	0.5568	1	90	72	0.5573	1
Colorado Rockies	Yhat	80	82	0.492	0	76	86	0.468	0	76	86	0.469	0	78	84	0.4810	0	78	84	0.4814	0
Colorado Rockies	Low 95	62	100	0.381	0	61	101	0.376	0	61	101	0.377	0	66	96	0.4062	0	66	96	0.4064	0
Detroit Tigers	High 95	96	66	0.590	1	95	67	0.589	1	95	67	0.588	1	108	54	0.6660	1	108	54	0.6697	1
Detroit Tigers	Yhat	73	89	0.452	0	74	88	0.458	0	74	88	0.454	0	87	75	0.5352	1	87	75	0.5396	1
Detroit Tigers	Low 95	52	110	0.321	0	54	108	0.332	0	53	109	0.327	0	65	97	0.3993	0	65	97	0.4040	0
Houston Astros	High 95	112	50	0.689	1	109	53	0.671	1	110	52	0.678	1	100	62	0.6201	1	101	61	0.6238	1
Houston Astros	Yhat	93	69	0.575	1	92	70	0.570	1	92	70	0.570	1	84	78	0.5193	1	85	77	0.5229	1
Houston Astros	Low 95	73	89	0.453	0	75	87	0.463	0	74	88	0.456	0	68	94	0.4169	0	68	94	0.4201	0
Kansas City Royals	High 95	103	59	0.633	1	88	74	0.542	1	100	62	0.619	1	82	80	0.5063	1	80	82	0.4919	0
Kansas City Royals	Yhat	84	78	0.518	1	72	90	0.442	0	83	79	0.511	1	64	98	0.3972	0	62	100	0.3833	0
Kansas City Royals	Low 95	65	97	0.401	0	56	106	0.346	0	65	97	0.401	0	48	114	0.2975	0	46	116	0.2853	0
Los Angeles Angels	High 95	102	60	0.629	1	101	61	0.625	1	102	60	0.629	1	97	65	0.6015	1	98	64	0.6044	1
Los Angeles Angels	Yhat	84	78	0.520	1	84	78	0.518	1	85	77	0.524	1	80	82	0.4968	0	81	81	0.5002	0
Los Angeles Angels	Low 95	66	96	0.409	0	66	96	0.410	0	67	95	0.416	0	64	98	0.3925	0	64	98	0.3960	0
Los Angeles Dodgers	High 95	115	47	0.708	1	113	49	0.698	1	114	48	0.702	1	106	56	0.6522	1	106	56	0.6525	1
Los Angeles Dodgers	Yhat	96	66	0.594	1	95	67	0.586	1	95	67	0.589	1	86	76	0.5302	1	87	75	0.5342	1
Los Angeles Dodgers	Low 95	76	86	0.469	0	75	87	0.464	0	75	87	0.466	0	66	96	0.4044	0	67	95	0.4119	0
Miami Marlins	High 95	94	68	0.582	1	94	68	0.582	1	94	68	0.579	1	95	67	0.5893	1	94	68	0.5781	1
Miami Marlins	Yhat	74	88	0.455	0	77	85	0.473	0	76	86	0.469	0	73	89	0.4529	0	70	92	0.4307	0
Miami Marlins	Low 95	54	108	0.334	0	59	103	0.366	0	59	103	0.362	0	52	110	0.3231	0	48	114	0.2948	0

Figure B1. Raw 1-15



Milwaukee Brewers	High 95	101	61	0.626	1	98	64	0.605	1	100	62	0.620	1	92	70	0.5695	1	91	71	0.5612	1
Milwaukee Brewers	Yhat	84	78	0.516	1	81	81	0.502	0	84	78	0.517	1	76	86	0.4680	0	75	87	0.4617	0
Milwaukee Brewers	Low 95	66	96	0.405	0	65	97	0.400	0	67	95	0.414	0	60	102	0.3691	0	59	103	0.3651	0
Minnesota Twins	High 95	100	62	0.617	1	100	62	0.616	1	100	62	0.620	1	108	54	0.6689	1	110	52	0.6779	1
Minnesota Twins	Yhat	77	85	0.475	0	78	84	0.480	0	78	84	0.481	0	87	75	0.5350	1	88	74	0.5462	1
Minnesota Twins	Low 95	54	108	0.336	0	56	106	0.346	0	56	106	0.345	0	64	98	0.3959	0	66	96	0.4078	0
New York Mets	High 95	95	67	0.586	1	91	71	0.562	1	92	70	0.565	1	113	49	0.6966	1	113	49	0.6999	1
New York Mets	Yhat	73	89	0.450	0	71	91	0.439	0	70	92	0.432	0	92	70	0.5708	1	93	69	0.5749	1
New York Mets	Low 95	52	110	0.321	0	52	110	0.323	0	50	112	0.308	0	71	91	0.4352	0	71	91	0.4396	0
New York Yankees	High 95	111	51	0.685	1	117	45	0.722	1	111	51	0.682	1	115	47	0.7114	1	116	46	0.7139	1
New York Yankees	Yhat	92	70	0.566	1	100	62	0.617	1	92	70	0.567	1	96	66	0.5952	1	97	65	0.5992	1
New York Yankees	Low 95	71	91	0.439	0	81	81	0.500	0	72	90	0.445	0	76	86	0.4673	0	77	85	0.4725	0
Oakland Athletics	High 95	101	61	0.623	1	98	64	0.608	1	102	60	0.630	1	114	48	0.7026	1	112	50	0.6903	1
Oakland Athletics	Yhat	74	88	0.458	0	74	88	0.455	0	77	85	0.475	0	89	73	0.5505	1	87	75	0.5393	1
Oakland Athletics	Low 95	49	113	0.302	0	50	112	0.311	0	52	110	0.324	0	63	99	0.3883	0	62	100	0.3807	0
Philadelphia Phillies	High 95	92	70	0.569	1	90	72	0.557	1	93	69	0.573	1	104	58	0.6419	1	104	58	0.6408	1
Philadelphia Phillies	Yhat	70	92	0.432	0	69	93	0.425	0	71	91	0.437	0	83	79	0.5093	1	82	80	0.5086	1
Philadelphia Phillies	Low 95	49	113	0.304	0	49	113	0.303	0	50	112	0.310	0	61	101	0.3755	0	61	101	0.3751	0
Pittsburgh Pirates	High 95	98	64	0.605	1	96	66	0.593	1	98	64	0.605	1	92	70	0.5694	1	93	69	0.5716	1
Pittsburgh Pirates	Yhat	77	85	0.475	0	76	86	0.468	0	77	85	0.477	0	71	91	0.4410	0	72	90	0.4432	0
Pittsburgh Pirates	Low 95	56	106	0.348	0	56	106	0.347	0	57	105	0.353	0	52	110	0.3200	0	52	110	0.3220	0
San Diego Padres	High 95	94	68	0.582	1	89	73	0.550	1	93	69	0.575	1	99	63	0.6102	1	100	62	0.6199	1
San Diego Padres	Yhat	74	88	0.459	0	70	92	0.434	0	74	88	0.454	0	79	83	0.4851	0	81	81	0.4970	0
San Diego Padres	Low 95	55	107	0.341	0	53	109	0.325	0	55	107	0.338	0	59	103	0.3619	0	61	101	0.3745	0
San Francisco Giants	High 95	95	67	0.585	1	96	66	0.591	1	96	66	0.595	1	104	58	0.6410	1	105	57	0.6460	1
San Francisco Giants	Yhat	73	89	0.452	0	76	86	0.467	0	75	87	0.464	0	83	79	0.5119	1	84	78	0.5167	1
San Francisco Giants	Low 95	53	109	0.325	0	56	106	0.348	0	55	107	0.338	0	62	100	0.3812	0	62	100	0.3851	0
Seattle Mariners	High 95	104	58	0.643	1	101	61	0.626	1	101	61	0.625	1	104	58	0.6394	1	107	55	0.6627	1
Seattle Mariners	Yhat	81	81	0.501	0	81	81	0.497	0	79	83	0.487	0	82	80	0.5073	1	87	75	0.5372	1
Seattle Mariners	Low 95	58	104	0.359	0	60	102	0.369	0	57	105	0.352	0	61	101	0.3744	0	66	96	0.4071	0
St. Louis Cardinals	High 95	109	53	0.674	1	110	52	0.678	1	109	53	0.670	1	110	52	0.6792	1	111	51	0.6866	1
St. Louis Cardinals	Yhat	89	73	0.550	1	91	71	0.564	1	89	73	0.548	1	90	72	0.5552	1	92	70	0.5648	1
St. Louis Cardinals	Low 95	68	94	0.420	0	72	90	0.443	0	68	94	0.420	0	69	93	0.4239	0	70	92	0.4347	0
Tampa Bay Rays	High 95	100	62	0.617	1	97	65	0.596	1	101	61	0.622	1	65	97	0.4036	0	70	92	0.4296	0
Tampa Bay Rays	Yhat	76	86	0.467	0	79	83	0.485	0	80	82	0.494	0	60	102	0.3703	0	59	103	0.3647	0
Tampa Bay Rays	Low 95	52	110	0.323	0	61	101	0.376	0	59	103	0.367	0	55	107	0.3385	0	52	110	0.3200	0
Texas Rangers	High 95	106	56	0.652	1	99	63	0.613	1	104	58	0.644	1	99	63	0.6123	1	101	61	0.6247	1
Texas Rangers	Yhat	87	75	0.540	1	79	83	0.489	0	85	77	0.525	1	80	82	0.4965	0	83	79	0.5112	1
Texas Rangers	Low 95	69	93	0.424	0	59	103	0.366	0	65	97	0.403	0	62	100	0.3812	0	64	98	0.3966	0
Toronto Blue Jays	High 95	97	65	0.600	1	92	70	0.568	1	95	67	0.588	1	106	56	0.6523	1	103	59	0.6349	1
Toronto Blue Jays	Yhat	78	84	0.481	0	75	87	0.462	0	78	84	0.479	0	87	75	0.5383	1	85	77	0.5257	1
Toronto Blue Jays	Low 95	59	103	0.364	0	58	104	0.360	0	60	102	0.372	0	68	94	0.4203	0	67	95	0.4139	0
Washington Nationals	High 95	116	46	0.715	1	107	55	0.661	1	109	53	0.672	1	95	67	0.5884	1	94	68	0.5800	1
Washington Nationals	Yhat	96	66	0.593	1	89	73	0.551	1	89	73	0.552	1	76	86	0.4668	0	74	88	0.4598	0
Washington Nationals	Low 95	74	88	0.457	0	71	91	0.436	0	69	93	0.426	0	57	105	0.3489	0	56	106	0.3441	0

Figure B2. Raw 16-30

## Ranked

Pythagorean Arima					BIC					Pythagorean				
Team	W	L	W%	I	Team	W	L	W%	I	Team	W	L	W%	I
New York Yankees	100	62	0.6172	1	Los Angeles Dodgers	95	67	0.5889	1	Cleveland Indians	110	52	0.6778	1
Boston Red Sox	98	64	0.6023	1	Cleveland Indians	92	70	0.5657	1	Los Angeles Dodgers	103	59	0.6380	1
Los Angeles Dodgers	95	67	0.5860	1	Houston Astros	92	70	0.5703	1	New York Yankees	102	60	0.6283	1
Cleveland Indians	93	69	0.5723	1	New York Yankees	92	70	0.5674	1	Boston Red Sox	101	61	0.6235	1
Houston Astros	92	70	0.5700	1	St. Louis Cardinals	89	73	0.5480	1	Chicago Cubs	101	61	0.6255	1
Chicago Cubs	91	71	0.5637	1	Washington Nationals	89	73	0.5520	1	Houston Astros	101	61	0.6210	1
St. Louis Cardinals	91	71	0.5644	1	Boston Red Sox	88	74	0.5443	1	Arizona Diamondbacks	98	64	0.6029	1
Washington Nationals	89	73	0.5508	1	Chicago Cubs	87	75	0.5348	1	Washington Nationals	97	65	0.5976	1
Los Angeles Angels	84	78	0.5182	1	Los Angeles Angels	85	77	0.5238	1	Colorado Rockies	88	74	0.5423	1
Milwaukee Brewers	81	81	0.5024	0	Texas Rangers	85	77	0.5252	1	St. Louis Cardinals	87	75	0.5381	1
Seattle Mariners	81	81	0.4975	0	Milwaukee Brewers	84	78	0.5174	1	Milwaukee Brewers	85	77	0.5245	1
Arizona Diamondbacks	80	82	0.4963	0	Kansas City Royals	83	79	0.5108	1	Minnesota Twins	84	78	0.5168	1
Baltimore Orioles	80	82	0.4942	0	Arizona Diamondbacks	81	81	0.5000	0	Los Angeles Angels	81	81	0.5007	0
Tampa Bay Rays	79	83	0.4854	0	Baltimore Orioles	81	81	0.4986	0	Tampa Bay Rays	80	82	0.4928	0
Texas Rangers	79	83	0.4889	0	Tampa Bay Rays	80	82	0.4938	0	Seattle Mariners	79	83	0.4855	0
Minnesota Twins	78	84	0.4798	0	Seattle Mariners	79	83	0.4874	0	Texas Rangers	79	83	0.4895	0
Chicago White Sox	77	85	0.4761	0	Minnesota Twins	78	84	0.4811	0	Miami Marlins	77	85	0.4725	0
Miami Marlins	77	85	0.4729	0	Toronto Blue Jays	78	84	0.4794	0	Pittsburgh Pirates	74	88	0.4551	0
Colorado Rockies	76	86	0.4682	0	Oakland Athletics	77	85	0.4745	0	Atlanta Braves	72	90	0.4429	0
Pittsburgh Pirates	76	86	0.4680	0	Pittsburgh Pirates	77	85	0.4775	0	Oakland Athletics	72	90	0.4446	0
San Francisco Giants	76	86	0.4673	0	Atlanta Braves	76	86	0.4705	0	Baltimore Orioles	71	91	0.4384	0
Cincinnati Reds	75	87	0.4632	0	Colorado Rockies	76	86	0.4690	0	Kansas City Royals	71	91	0.4406	0
Toronto Blue Jays	75	87	0.4622	0	Miami Marlins	76	86	0.4690	0	Philadelphia Phillies	71	91	0.4377	0
Atlanta Braves	74	88	0.4554	0	Chicago White Sox	75	87	0.4641	0	Toronto Blue Jays	71	91	0.4386	0
Detroit Tigers	74	88	0.4577	0	Cincinnati Reds	75	87	0.4602	0	Chicago White Sox	69	93	0.4257	0
Oakland Athletics	74	88	0.4551	0	San Francisco Giants	75	87	0.4645	0	Cincinnati Reds	69	93	0.4288	0
Kansas City Royals	72	90	0.4421	0	Detroit Tigers	74	88	0.4539	0	New York Mets	68	94	0.4204	0
New York Mets	71	91	0.4392	0	San Diego Padres	74	88	0.4542	0	Detroit Tigers	65	97	0.4033	0
San Diego Padres	70	92	0.4340	0	Philadelphia Phillies	71	91	0.4371	0	San Francisco Giants	65	97	0.4041	0
Philadelphia Phillies	69	93	0.4248	0	New York Mets	70	92	0.4321	0	San Diego Padres	57	105	0.3540	0

Figure B3. Ranked 1-15

After (2,2)					After (4,4)					Naive Weights				
Team	W	L	W%	I	Team	W	L	W%	I	Team	W	L	W%	I
New York Yankees	96	66	0.5952	1	New York Yankees	97	65	0.5992	1	Los Angeles Dodgers	96	66	0.5941	1
New York Mets	92	70	0.5708	1	New York Mets	93	69	0.5749	1	Washington Nationals	96	66	0.5928	1
Arizona Diamondbacks	90	72	0.5529	1	St. Louis Cardinals	92	70	0.5648	1	Cleveland Indians	93	69	0.5765	1
St. Louis Cardinals	90	72	0.5552	1	Chicago White Sox	89	73	0.5463	1	Houston Astros	93	69	0.5753	1
Oakland Athletics	89	73	0.5505	1	Boston Red Sox	88	74	0.5414	1	New York Yankees	92	70	0.5660	1
Boston Red Sox	88	74	0.5408	1	Minnesota Twins	88	74	0.5462	1	Boston Red Sox	90	72	0.5573	1
Chicago White Sox	88	74	0.5462	1	Detroit Tigers	87	75	0.5396	1	St. Louis Cardinals	89	73	0.5502	1
Detroit Tigers	87	75	0.5352	1	Los Angeles Dodgers	87	75	0.5342	1	Texas Rangers	87	75	0.5399	1
Minnesota Twins	87	75	0.5350	1	Oakland Athletics	87	75	0.5393	1	Chicago Cubs	86	76	0.5316	1
Toronto Blue Jays	87	75	0.5383	1	Seattle Mariners	87	75	0.5372	1	Kansas City Royals	84	78	0.5178	1
Los Angeles Dodgers	86	76	0.5302	1	Houston Astros	85	77	0.5229	1	Los Angeles Angels	84	78	0.5197	1
Houston Astros	84	78	0.5193	1	Toronto Blue Jays	85	77	0.5257	1	Milwaukee Brewers	84	78	0.5162	1
Philadelphia Phillies	83	79	0.5093	1	San Francisco Giants	84	78	0.5167	1	Seattle Mariners	81	81	0.5012	0
San Francisco Giants	83	79	0.5119	1	Texas Rangers	83	79	0.5112	1	Baltimore Orioles	80	82	0.4966	0
Cleveland Indians	82	80	0.5074	1	Cleveland Indians	82	80	0.5059	1	Colorado Rockies	80	82	0.4917	0
Seattle Mariners	82	80	0.5073	1	Philadelphia Phillies	82	80	0.5086	1	Arizona Diamondbacks	78	84	0.4821	0
Cincinnati Reds	80	82	0.4946	0	Arizona Diamondbacks	81	81	0.5000	0	Atlanta Braves	78	84	0.4813	0
Los Angeles Angels	80	82	0.4968	0	Cincinnati Reds	81	81	0.4971	0	Toronto Blue Jays	78	84	0.4811	0
Texas Rangers	80	82	0.4965	0	Los Angeles Angels	81	81	0.5002	0	Minnesota Twins	77	85	0.4749	0
Atlanta Braves	79	83	0.4900	0	San Diego Padres	81	81	0.4970	0	Pittsburgh Pirates	77	85	0.4747	0
San Diego Padres	79	83	0.4851	0	Atlanta Braves	80	82	0.4926	0	Tampa Bay Rays	76	86	0.4671	0
Colorado Rockies	78	84	0.4810	0	Colorado Rockies	78	84	0.4814	0	Chicago White Sox	75	87	0.4649	0
Milwaukee Brewers	76	86	0.4680	0	Milwaukee Brewers	75	87	0.4617	0	Miami Marlins	74	88	0.4552	0
Washington Nationals	76	86	0.4668	0	Chicago Cubs	74	88	0.4570	0	Oakland Athletics	74	88	0.4585	0
Chicago Cubs	74	88	0.4550	0	Washington Nationals	74	88	0.4598	0	San Diego Padres	74	88	0.4593	0
Baltimore Orioles	73	89	0.4479	0	Baltimore Orioles	72	90	0.4474	0	Cincinnati Reds	73	89	0.4497	0
Miami Marlins	73	89	0.4529	0	Pittsburgh Pirates	72	90	0.4432	0	Detroit Tigers	73	89	0.4521	0
Pittsburgh Pirates	71	91	0.4410	0	Miami Marlins	70	92	0.4307	0	New York Mets	73	89	0.4496	0
Kansas City Royals	64	98	0.3972	0	Kansas City Royals	62	100	0.3833	0	San Francisco Giants	73	89	0.4520	0
Tampa Bay Rays	60	102	0.3703	0	Tampa Bay Rays	59	103	0.3647	0	Philadelphia Phillies	70	92	0.4315	0

Figure B4. Ranked 16-30

## Appendix C

## Equations

**Mean Squared Prediction Error (MSPE)**

$$\text{MSPE} = \sqrt{\frac{\sum_{i=1}^n (y_i - \hat{y}_i)^2}{n}}$$

**Transformation**

$$W'_t = \log\left(\frac{W_t}{1 - W_t}\right)$$

$$W_t^{-1} = \frac{1}{e^{-W'_t} + 1}$$

**Arima(p, d, q)**

$$Y_t = (1 - B)^d W'_t$$

$$\left(1 - \sum_{i=1}^p \phi_i B^i\right) Y_t = \left(1 + \sum_{i=1}^q \theta_i B^i\right) \epsilon_t$$

**Bayesian Information Criteria (BIC)**

$$W'_t = \text{Arima}(\text{BIC})$$

**Pythagorean Expectation**

$$W_t = P_{t-1} = \frac{RS_{t-1}^2}{RS_{t-1}^2 + RA_{t-1}^2}$$

**Pyrima**

$$W'_t = \text{Arima}(\text{BIC}) + \beta P_{t-1}$$

**Naive Weights**

$$W'_t = \frac{\sum_{i=1}^p \sum_{j=1}^q \text{Arima}(i, d, j)}{p * q}$$

**After Weights**

$$\lambda_{m,t=1} = \frac{1}{M}$$

$$\lambda_{m,t \geq 2} = \frac{\prod_{i=1}^{n-1} e^{\frac{-\alpha}{n_{tr,i}} \sum_{j=1}^{n_{tr,i}} W_{j,i} - \hat{W}_{j,i}}}{\sum_{m=1}^M \prod_{i=1}^{n-1} e^{\frac{-\alpha}{n_{tr,i}} \sum_{j=1}^{n_{tr,i}} W_{j,i} - \hat{W}_{j,i}}}$$

$$W'_t = \sum_{i=1}^M \lambda_{i,t} \hat{W}_{t,i}$$