# EasySM: A Data-Driven Intelligent Decision Support System for Server Merge

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## Abstract

As independent social economic entities, game servers play a dominant role in building a living and attractive virtual world in massive multi-player online role-playing games (MMORPGs). We propose and implement a novel intelligent decision support system for server merge (SM) which could benefit the maintaining of game ecology at the macro level. The services provided by the system consist of server health diagnosis, server merge assessment, and combination strategy recommendation. In particular, we design an effective time series prediction algorithm to diagnose the health status of one server (e.g., player activity) based on real game scenarios, and then select the servers with poor status from all servers. Moreover, to dig out the inherent development laws of servers from the historical merge records, we leverage a correlation measurement algorithm to find the historical merged servers that are similar to the servers to be merged and then evaluate the potential trend after merging, which can assist experts to make reasonable decisions. We deploy our system online for multiple MMORPGs and achieve sound online performance endorsed by the game operation team.

## Introduction

In MMORPGs, especially for the large-scale ones, multiple game servers are deployed to divide massive players for ensuring load balance and facilitating server expansion. These game servers are actually independent social and economic virtual worlds (Chun et al. 2018), which are usually born extremely prosper, gradually become stable, and decline and fall with the leaving players. To maintain the healthy ecology of game servers, increase game activity and improve the players' game experience, a fundamental and common strategy is to merge the servers with fewer players, which have been proven to be effective in real-world applications.

However, in actual operations, the strategy of merging servers is often based on artificial experience, which not only lacks reasonable data to support the decisions but is also labor-consuming. Besides, manual decision-making process is often subjective, and difficult to predict the performance after merging. Like server merge in MMORPGs, Merger and Acquisition (M&A) is a common practice in business (Seo and Hill 2005; Ragothaman, Naik, and Ramakrishnan 2003; Moriarty et al. 2019) and has been well studied. For instance, Yan et al. (2016) focused on the dual problem of predicting an investor's prospective M&A based on its activities and profiles. Various information like patent data (Wei, Jiang, and Yang 2008) and relevant texts in social media (Xiang et al. 2012) could be employed in M&A.

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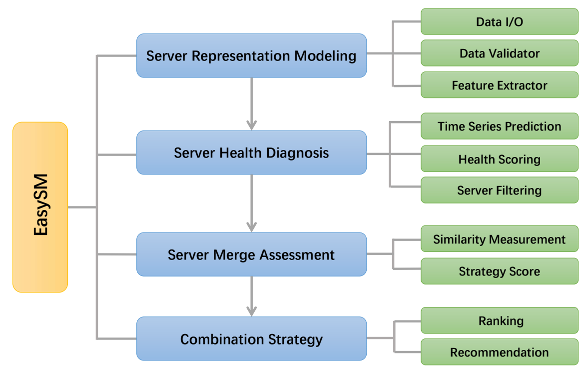



Figure 1: System overview.

Inspired by M&A prediction, we propose a novel and effective solution for server merge from the perspective of data mining. Specifically, based on the long-term and short-term characteristics of server running status, we design a time series prediction algorithm to make real time health diagnosis for servers. The system then will automatically filter out the servers with poor health status as the candidates that need to be merged. To provide effective server merge strategies, we further design an auxiliary decision-making algorithm. With the observation that the life cycles of different servers in one game always share similar properties, we first search for the merged server pairs that are similar to the candidate server pair by mining the correlation between servers. Then we give an assessment of the merger for the candidate server pair based on the potential laws extracted from historical server merger records. Quantitatively, the overall system gives us insights into server merge. In general, our key contributions are summarized as follows:

- To our knowledge, this paper represents the first effort to make decisions for server merge based on data mining.
- We deliberately design an effective time series prediction method to diagnose the health status of servers. In addi-

tion, a novel server merge assessment module is designed to assist decision-making, which can mine trends before and after merging from the historical merger records.

- The online deployment and application in multiple MMORPGs[1,2] demonstrate the generality and effectiveness of our system.

## System Overview

Figure 1 shows an overview of our EasySM system, and we will describe the details of the system design below.

### Methodology

**Server Representation Modeling.** We first extract several crucial features from server running logs to characterize the status of servers. And the features will be further used for subsequent server health diagnosis. Without loss of generality, the features we consider can be represented as $\Pi = \{\pi_i\}$ of which each element corresponds to a certain type of feature. And for server $j$, its status feature at time $t$ is denoted by $v_j(t) \in \mathbb{R}^{|\Pi|}$. Empirically, we propose to use *activity*, *player churn*, *economic benefits*, *experience* and *equipment* to characterize server status in our system.

**Server Health Diagnosis.** A key step before server merge is to identify which servers need improvement. With the extracted status features, we now investigate into the status trend to find the candidate servers. Developed from Prophet algorithm (Taylor and Letham 2018), we propose a time series prediction method by considering different time scales:

$$f_\pi(t) = \sum_{n=1}^{N} \alpha_n y_n(t), \quad \sum_{i=1}^{n} \alpha_n = 1, \tag{1}$$

where $y_n(t) = g_n(t) + s_n(t) + h_n(t) + \epsilon_n(t)$ is the basic Prophet model, which can fit nonlinear trends by considering trend item $g(t)$, seasonal item (week or month) $s(t)$, holiday item $h(t)$ and noise item $\epsilon(t)$. In our implementation, we consider the prediction in both long-term (e.g, two months) and short-term (e.g., two weeks) perspectives by setting $N = 2$.

To obtain a comprehensive health score for one server, we take the weighted average of the predicted value of all five features we considered. And we further normalize the health score by dividing the average score of all servers. Note that the weight for each feature need careful selection in different scenarios. After the health diagnosis, the system automatically filters out the servers of which the health scores are small than $\delta$. Those servers with poor health status could be regarded as the candidates for server merge.

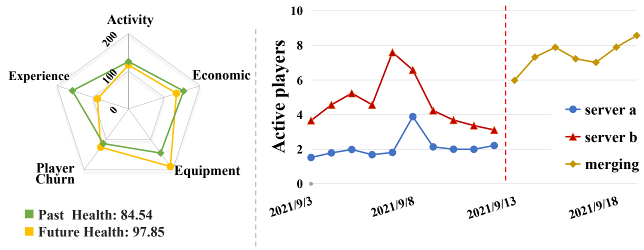
**Server Merge Assessment.** With the obtained server health status, we then measure the similarity of the servers. Let $s_{ij}$ be the similarity between server $i$ and $j$ and $s_{ij} = \rho(v_i, v_j)$ with $\rho(\cdot,\cdot)$ as the measurement. We empirically choose Pearson correlation coefficient (Benesty et al. 2009) for measuring the similarity in our implementation.

Based on the server similarity, we next predict the status trend of two candidate servers according to the historical

[1]https://qnm.163.com/

[2]https://ty.163.com

| Combinations | Change | Ranking | Recommend? |
|---|---|---|---|
| (a,b) | +15.7% | 21/97 | True |
| (c,d) | -21.8% | 76/97 | False |




(a) Server Health Diagnosis (b) Server Merge Prediction

Figure 2: Demonstration of EasySM system.

records of merged servers. Let $\mathbf{p} = (a, b)$ be an ordered pair of candidate servers and $\mathbf{q} = (c, d)$ be two merged servers. The similarity between $\mathbf{p}$ and $\mathbf{q}$ could be defined as $c_{\mathbf{pq}} = \frac{1}{2}(s_{ac} + s_{bd})$. To determine whether server $a$ and $b$ should be merged, we select $k$ merged server pairs which are most similar to $\mathbf{p}$ and obtain a strategy score by fusing their status tendencies with respect to different features. Denoted by $\tau$, the status tendency of $\mathbf{p}$ is modeled as

$$\tau = \frac{1}{k} \sum_{\mathbf{q} \in Q} \sum_{\pi \in \Pi} \beta_\pi c_{\mathbf{pq}} r_{\mathbf{q}}^{\pi}, \quad \sum_{\pi \in \Pi} \beta_\pi = 1, \tag{2}$$

where $Q$ denotes the selected $k$ pairs of merged servers and $r_{\mathbf{q}}^{\pi}$ represents the improvement with respect to feature $\pi$ that the servers in $\mathbf{q}$ gained after merging. The system finally offers server merge strategies based on the assessment.

### Demonstration

In this subsection, we will demonstrate two critical modules in our system: health diagnosis and server merge assessment. The radar chart in Figure 2 (a) shows the health status of one server on 5 important features. Our EasySM system can monitor the status of servers in real time and return the candidate servers that need merge for operators. As shown in Figure 2 (b), the decision support module can not only predict the development trend of the two servers after merging, but also rank the combination strategies to assist operators in decision making. Finally, the online deployment of the system proves that our method is superior to traditional empirical or heuristic methods (e.g., random). Moreover, our system can dramatically save the time for decision making. An illustrative video is available on YouTube[3].

## Conclusion

In this paper, we designed an intelligent decision support system for merging servers from the perspective of data mining. We designed a special time series prediction module to monitor the health status of servers in real time. Besides, a decision support module was proposed to predict the performance of merging servers and recommend potential merging combinations for operators. This paper provides a novel solution for server merge. The research area is still in its infancy, and we anticipate that more techniques will be developed in the future.

[3]https://www.youtube.com/watch?v=RfZ-KLA7qns

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