The Accuracy of the RK-4 and RK-5 Technique as a Numerical Solution to the SEIRS Model of Online Game Addiction on Mathematics Students

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Abstract. This study aims to determine the accuracy of Runge kutta order-4 (RK-4) and order-5 (RK-5) as a solution to the SEIRS numerical model for online game addiction in mathematics students at Universitas Negeri Makassar. The model used in online game addiction is the Suspected-Exposed-Infected-Recovered-Suspected (SEIRS). This is a quantitative research with secondary data obtained from a closed questionnaire where students were given several answer choices. It starts by examining the SEIRS model of online game addiction, before determining general solutions using the RK-4 and RK-5 techniques. The model is then analyzed and simulated using RK-4 and RK-5 techniques, which are compared to determine the most accurate one. The results show that the SEIRS simulation model is accurate for predicting the number of online game addictions. Furthermore, the Runge-Kutta technique can be used to observe the trend of increasing cases of online games among students. The numerical simulation showed that the RK-4 technique is more accurate than the RK-5 when the population is larger. The simulation results of the SEIRS model using MAPLE provided an estimated increase in online game addiction that can be used by students and their parents to limit the number of permits associated with launching online games.

Keywords: SEIRS model, RK-4, RK-5, online game addiction, mathematics students

1. Introduction

Online games are globally played by two or more people through the internet or other computer network, simultaneously [1]. This type of game is continuously increasing due to the significant growth in computer networks [2]. Online games are currently being performed by social networks, such as Facebook and Line, which tends to have positive and negative effect on teenagers. One of its negative effects is addiction, which prevents players from achieving their various goals [3-4]. Furthermore, when players are unable to control themselves, learning and working to achieve success becomes a problem. These games also harmful to the health [5].

Indonesia has approximately 6 million online game fanatics with 40% teenagers. A survey showed that of 64.45% and 47.85% of boys and girls aged 12-22 years are addicted [6]. Students rigorous participation in online games, leads to death. For instance, people have died from sitting in front of their computers for a prolonged period [2,5]
Several studies have been carried out on online game obsession in Makassar, which includes [7] discussions on its social effect despite the use of SIR, SIRS, SEIR, and SEIRS models to cases of the Covid-19 pandemic [8–16], Dengue Fever and Tuberculosis. Study on the mathematical model of online game addiction has been carried out by [17,18] and research on numerical solutions using the order-4 (RK-4) and order-5 (RK-5) Runge Kutta technique has been carried out by [19,20]. This study resulted in a numerical solution of [17] using the RK-4 and RK-5 SEIRS models on social dilemmas, particularly online game addiction. This study also investigated and simulated applying secondary data to determine and estimate the total student addicted to online games at the mathematics departments of the Makassar State University.

2. Technique

This is an applied research and the SEIRS mathematical model [15] was improved by examining and simulating the model using Maple. Secondary data were collected on online game addictions of students at Makassar State University. Furthermore, the numerical solution of the SEIRS model was obtained by applying the RK-4 and RK-5 [19,20]. The results were examined with the data on the number of online game addictions for Mathematics student at Universitas Negeri Makassar. The two techniques were compared to find out which RK-4 or RK-5 techniques were more specific in estimating the number of online game addictions in mathematics students.

3. Result

3.1. SEIRS model on the problem of online game addiction

Population differences in online game addiction problems using the SEIRS model can be described in Figure 1:

![Figure 1. SEIRS model scheme for online game addiction.](image)

The overall population is classified into 4 parts: Susceptible (S) which denotes the group of students that are susceptible to online game addiction, Exposed (E) represents players however not including addicts, Infected (I) denotes those that are addicted to online games, and recovered (R) represents the group of students free from online game addiction. The model parameters are shown in Table 1.

Based on Figure 1, the SEIRS mathematical model is obtained as shown in Equation (1) – (4).

\[
\frac{ds}{dt} = \mu + \theta r - \alpha s - \mu s \\
\frac{de}{dt} = \alpha s - \beta e - \mu e \\
\frac{di}{dt} = \beta e - \delta i - \mu i \\
\frac{dr}{dt} = \delta i - \theta r - \mu r
\]

Table 1. Parameters definition of the SEIRS model for online game addiction

| Parameter | Description |
|-----------|-------------|
| \(\alpha\) | the scale of movement from groups of students who are prone to online game addiction (suspected) to groups who start playing online games (exposed). |
| \(\beta\) | the scale of movement from a group of students who started playing online games (exposed) to a group who were addicted to online games (infected). |
| \(\delta\) | the scale of movement from a group of students who are addicted to online games (infected) to a group who are free from online game addiction (recovered). |
the scale of movement from a group of students who are free from online game addiction (recovered) to a group who are prone to online game addiction (suspected).

\[ \theta \] the rate of students leaving (moving, quitting, dropping out).

The first values of the variable and parameter applied of SEIRS model for online game addiction.

**Table 2. Initial values of SEIRS model for online game addiction**

| Parameters | Values | Variable | Initial Value | Sample Propotion |
|------------|--------|----------|---------------|-----------------|
| \( \mu \)  | 0.181  | S        | 49            | 0.17            |
| \( \alpha \) | 0.331  | E        | 220           | 0.78            |
| \( \beta \) | 0.036  | I        | 2             | 0.007           |
| \( \delta \) | 0.895  | R        | 13            | 0.04            |
| \( \theta \) | 0.351  | Total    | 284           | 1               |

According to the data and parameters in Table 2, the simulation model was used to determine the plot transmission by applying Maple. The results are performed by Figures 2 to 6. Based on these Figures the values of the number of SEIRS model for online game addiction presented on Table 3.

**Figure 2.** Prediction number of online game addiction for suspected and exposed cases

**Figure 3.** Prediction number of online game addiction for infected and recovered cases
### Table 3. The number of SEIRS model for online game addiction

| T | S    | E    | I    | R    |
|---|------|------|------|------|
| 0 | 49   | 220  | 2    | 13   |
| 1 | 47.0084 | 216.8489 | 2.5414 | 12.5251 |
| 2 | 45.1012 | 213.7016 | 3.01678 | 12.1190 |
| 3 | 43.2763 | 210.5608 | 3.4329 | 11.7728 |
| 4 | 41.5316 | 207.4289 | 3.7959 | 11.4784 |
| 5 | 39.8646 | 204.3086 | 4.1112 | 11.2288 |
| 6 | 38.2731 | 201.2018 | 4.3838 | 11.0176 |
| 7 | 36.7543 | 198.1108 | 4.6179 | 10.8394 |
| 8 | 35.2731 | 195.0375 | 4.8177 | 10.6893 |
| 9 | 33.9247 | 191.9839 | 4.9866 | 10.5631 |
| 10 | 32.6086 | 188.9518 | 5.1278 | 10.4569 |
| 11 | 31.3550 | 185.9427 | 5.2444 | 10.3674 |
| 12 | 30.1610 | 182.9581 | 5.3389 | 10.2917 |
| 13 | 29.0243 | 179.9949 | 5.4135 | 10.2272 |
| 14 | 27.9423 | 177.0679 | 5.3705 | 10.1718 |
| 15 | 26.9135 | 174.1648 | 5.5117 | 10.1235 |

### 3.2. Numerical solutions of SEIRS model for online game addiction

Numerical solution of SEIRS model for online game addiction using RK-4 and RK-5 adopted in [19,20]

### 3.3. Numerical solution of SEIRS model using RK-4

The standard formula of the RK-4 technique as in [19,20], then the model for online game addiction can be described as follows:

\[ S_{t+1} = S_t + \frac{1}{6}(k_1 + 2k_2 + 2k_3 + k_4)i \]  
\[ E_{t+1} = E_t + \frac{1}{6}(l_1 + 2l_2 + 2l_3 + l_4)i \]  
\[ I_{t+1} = I_t + \frac{1}{6}(m_1 + 2m_2 + 2m_3 + m_4)i \]  
\[ R_{t+1} = R_t + \frac{1}{6}(j_1 + 2j_2 + 2j_3 + j_4)i \]

with

\[ k_1 = \mu + \theta r - \alpha s - \mu s; \]  
\[ k_2 = \mu + \theta (r + n_1 \frac{l}{2}) - \alpha (s + k_1 \frac{l}{2}) - \mu (s + k_1 \frac{l}{2}) - \beta (e + l_1 \frac{l}{2}) \]  
\[ k_3 = \mu + \theta (r + n_2 \frac{l}{2}) - \alpha (s + k_2 \frac{l}{2}) - \mu (s + k_2 \frac{l}{2}) - \beta (e + l_2 \frac{l}{2}) \]  
\[ k_4 = \mu + \theta (r + n_3) - \alpha (s + k_3) - \mu (s + k_3) - \beta (e + l_3) - \mu (e + l_3); \]  
\[ m_4 = \beta (e + l_3) - \delta (i + m_3) - \mu (i + m_3); \]

By using the initial values and parameters values as in Table 2, then:

\[ s_{0+1} = s_0 + \frac{1}{6}(k_1 + 2k_2 + 2k_3 + k_4) = 48.1851 \]
\[ s_{1+1} = s_1 + \frac{1}{6}(k_1 + 2k_2 + 2k_3 + k_4) = 47.3702 \]
\[ e_{0+1} = e_0 + \frac{1}{6}(l_1 + 2l_2 + 2l_3 + l_4) = 218.7267 \]
\[ e_{1+1} = e_1 + \frac{1}{6}(l_1 + 2l_2 + 2l_3 + l_4) = 217.4533 \]
\[ i_{0+1} = i_0 + \frac{1}{6}(m_1 + 2m_2 + 2m_3 + m_4) = 2.2271 \]
\[ i_{1+1} = i_1 + \frac{1}{6}(m_1 + 2m_2 + 2m_3 + m_4) = 2.4542 \]
\[ r_{0+1} = r_0 + \frac{1}{6}(n_1 + 2n_2 + 2n_3 + n_4) = 12.7992 \]
\[ r_{1+1} = r_1 + \frac{1}{6}(n_1 + 2n_2 + 2n_3 + n_4) = 12.5985 \]

The iteration continues until \( t = 15 \), then a estimation for online game addiction number is found as described on Table 4.

Table 4. The number estimation of SEIRS Model for online game addiction by RK-4

| t  | S     | E     | I     | R     |
|----|-------|-------|-------|-------|
| 0  | 49    | 220   | 2     | 13    |
| 1  | 48.1851 | 218.7267 | 2.2271 | 12.7992 |
| 2  | 47.3702 | 217.4533 | 2.4542 | 12.5984 |
| 3  | 46.5553 | 216.1801 | 2.6814 | 12.3977 |
| 4  | 45.7405 | 214.9067 | 2.9085 | 12.1969 |
| 5  | 44.9256 | 213.6333 | 3.1356 | 11.9961 |
| 6  | 44.1107 | 212.3601 | 3.3627 | 11.7954 |
| 7  | 43.2958 | 211.0867 | 3.5898 | 11.5946 |
| 8  | 42.4809 | 209.8133 | 3.8170 | 11.3938 |
| 9  | 41.6660 | 208.5400 | 4.0440 | 11.1931 |
| 10 | 40.8511 | 207.2667 | 4.2712 | 10.9923 |
| 11 | 40.0363 | 205.9933 | 4.4983 | 10.7915 |
| 12 | 39.2214 | 204.7200 | 4.7255 | 10.5908 |
| 13 | 38.4065 | 203.4467 | 4.9525 | 10.3900 |
| 14 | 37.5916 | 202.1734 | 5.1797 | 10.1892 |
| 15 | 36.7767 | 200.9001 | 5.4068 | 9.9885 |

3.4. Numerical solution of SEIRS model using runge kutta method

The standart formula of the RK-5 technique as in [19,20], then the model for online game addiction is described as follows:

\[ S_{r+1} = S_r + \frac{1}{90}(7k_1 + 32k_3 + 12k_4 + 32k_5 + 7k_6)i \]
\[ E_{r+1} = E_r + \frac{1}{90}(7l_1 + 32l_3 + 12l_4 + 32l_5 + 7l_6)i \]
\[ I_{h+1} = I_h + \frac{1}{90}(7m_1 + 32m_3 + 12m_4 + 32m_5 + 7m_6)i \]
\[ I_{i+1} = I_i + \frac{1}{90}(7n_1 + 32n_3 + 12n_4 + 32n_5 + 7n_6)i \]
\[ R_{r+1} = R_r + \frac{1}{90}(7j_1 + 32j_3 + 12j_4 + 32j_5 + 7j_6)i \]

By using the initial values and parameters values as in Table 2, then:

\[ s_{0+1} = s_0 + \frac{1}{90}(7k_1 + 32k_3 + 12k_4 + 32k_5 + 7k_6)i = 48.1851 \]
\[ s_{1+1} = s_1 + \frac{1}{90}(7k_1 + 32k_3 + 12k_4 + 32k_5 + 7k_6)i = 47.3702 \]
The iteration continues until $t = 15$, then an estimation of the number of online game addiction is gained as described in Table 5.

**Table 5.** The number prediction of SEIRS model for online game addiction by RK-5

| t  | S     | E     | I     | R     |
|----|-------|-------|-------|-------|
| 0  | 49    | 220   | 2     | 13    |
| 1  | 48.185 | 218.7267 | 2.2271 | 12.7992 |
| 2  | 47.3702 | 217.4533 | 2.4542 | 12.5984 |
| 3  | 46.5553 | 216.1801 | 2.6814 | 12.3977 |
| 4  | 45.7405 | 214.9067 | 2.9085 | 12.1969 |
| 5  | 44.9256 | 213.6333 | 3.1356 | 11.9961 |
| 6  | 44.1107 | 212.3601 | 3.3627 | 11.7954 |
| 7  | 43.2958 | 211.0867 | 3.5898 | 11.5946 |
| 8  | 42.4809 | 209.8133 | 3.8170 | 11.3938 |
| 9  | 41.6660 | 208.5400 | 4.0440 | 11.1931 |
| 10 | 40.8511 | 207.2667 | 4.2712 | 10.9923 |
| 11 | 40.0363 | 205.9933 | 4.4983 | 10.7915 |
| 12 | 39.2214 | 204.7200 | 4.7255 | 10.5908 |
| 13 | 38.4065 | 203.4467 | 4.9525 | 10.3900 |
| 14 | 37.5916 | 202.1734 | 5.1797 | 10.1892 |
| 15 | 36.7767 | 200.9001 | 5.4068 | 9.9885 |

The uses of SEIR to determine online game addiction of Mathematics Students, at Universitas Negeri Makassar with the RK-4 and RK-5 techniques are shown in Tables 6 and 7.

**Table 6.** Errors comparison of suspected and exposed for online game addiction

| t  | SRK-4 | SRK-5 | SExact | ΔSRK-4 | ΔSRK-5 | ERK-4 | ERK-5 | EExact | ΔERK-4 | ΔERK-5 |
|----|-------|-------|--------|--------|--------|-------|-------|--------|--------|--------|
| 0  | 49    | 49    | 49     | 0      | 0      | 220   | 220   | 0      | 0      | 0      |
| 1  | 48.1851 | 48.185 | 47.008 | 1.177  | 1.177  | 218.727 | 218.727 | 216.849 | 1.878  | 1.878  |
| 2  | 47.3702 | 47.3702 | 45.101 | 2.269  | 2.269  | 217.453 | 217.453 | 213.849 | 3.752  | 3.752  |
| 3  | 46.5553 | 46.5553 | 43.276 | 3.279  | 3.279  | 216.633 | 216.633 | 210.561 | 5.619  | 5.619  |
| 4  | 45.7405 | 45.7405 | 41.532 | 4.209  | 4.209  | 214.907 | 214.907 | 207.429 | 7.748  | 7.748  |
| 5  | 44.9256 | 44.9256 | 39.865 | 5.061  | 5.061  | 213.633 | 213.633 | 204.309 | 9.325  | 9.325  |
| 6  | 44.1107 | 44.1107 | 38.273 | 5.837  | 5.837  | 212.360 | 212.360 | 201.202 | 11.158 | 11.158 |
| 7  | 43.2958 | 43.2958 | 36.754 | 6.542  | 6.542  | 211.087 | 211.087 | 198.111 | 12.976 | 12.976 |
| 8  | 42.4809 | 42.4809 | 35.306 | 7.175  | 7.175  | 209.813 | 209.813 | 195.038 | 14.776 | 14.776 |
| 9  | 41.6660 | 41.6660 | 33.925 | 7.741  | 7.741  | 208.540 | 208.540 | 191.984 | 16.556 | 16.556 |
| 10 | 40.8512 | 40.8512 | 32.609 | 8.242  | 8.242  | 207.267 | 207.267 | 189.952 | 18.315 | 18.315 |
| 11 | 40.0363 | 40.0363 | 31.355 | 8.681  | 8.681  | 205.993 | 205.993 | 185.943 | 20.051 | 20.051 |
| 12 | 39.2214 | 39.2214 | 30.161 | 9.060  | 9.060  | 204.720 | 204.720 | 182.958 | 21.762 | 21.762 |
| 13 | 38.4065 | 38.4065 | 29.024 | 9.382  | 9.382  | 203.447 | 203.447 | 179.999 | 23.447 | 23.447 |
Table 7. Errors comparison of infected and recovered for online game addiction

| t  | IRK-4 | IRK-5 | lExact | ΔIRK-4 | ΔIRK-5 | RRK-4 | RRK-5 | RElact | ΔRRK-4 | ΔRRK-5 |
|----|-------|-------|--------|--------|--------|-------|-------|--------|--------|--------|
| 0  | 2.2271| 2.2271| 2.2514 | 0.0243 | 0.0243 | 2.0948| 2.0948| 0.0243 | 0.0243 | 0.0243 |
| 1  | 2.4542| 2.4542| 2.3168 | 0.0376 | 0.0376 | 2.1295| 2.1295| 0.0376 | 0.0376 | 0.0376 |
| 2  | 2.6814| 2.6814| 2.3429 | 0.0516 | 0.0516 | 2.1397| 2.1397| 0.0516 | 0.0516 | 0.0516 |
| 3  | 2.9085| 2.9085| 2.3790 | 0.0785 | 0.0785 | 2.1296| 2.1296| 0.0785 | 0.0785 | 0.0785 |
| 4  | 3.1356| 3.1356| 2.4111 | 0.0975 | 0.0975 | 2.1196| 2.1196| 0.0975 | 0.0975 | 0.0975 |
| 5  | 3.3627| 3.3627| 2.4383 | 1.0211 | 1.0211 | 2.1194| 2.1194| 1.0211 | 1.0211 | 1.0211 |
| 6  | 3.5899| 3.5899| 2.4617 | 1.0281 | 1.0281 | 2.1094| 2.1094| 1.0281 | 1.0281 | 1.0281 |
| 7  | 3.8170| 3.8170| 2.4817 | 1.0007 | 1.0007 | 2.0994| 2.0994| 1.0007 | 1.0007 | 1.0007 |
| 8  | 4.0441| 4.0441| 2.4966 | 0.9425 | 0.9425 | 2.0894| 2.0894| 0.9425 | 0.9425 | 0.9425 |
| 9  | 4.2712| 4.2712| 5.1277 | 0.8566 | 0.8566 | 2.0794| 2.0794| 0.8566 | 0.8566 | 0.8566 |
| 10 | 4.4983| 4.4983| 5.2444 | 0.7461 | 0.7461 | 2.0694| 2.0694| 0.7461 | 0.7461 | 0.7461 |
| 11 | 4.7255| 4.7255| 5.3389 | 0.6134 | 0.6134 | 2.0594| 2.0594| 0.6134 | 0.6134 | 0.6134 |
| 12 | 4.9526| 4.9526| 5.4135 | 0.4609 | 0.4609 | 2.0494| 2.0494| 0.4609 | 0.4609 | 0.4609 |
| 13 | 5.1797| 5.1797| 5.4705 | 0.2908 | 0.2908 | 2.0394| 2.0394| 0.2908 | 0.2908 | 0.2908 |
| 14 | 5.4068| 5.4068| 5.5118 | 0.1049 | 0.1049 | 2.0294| 2.0294| 0.1049 | 0.1049 | 0.1049 |

Table 8. Average errors identification of RK-4 and RK-5 technique for online game addiction

| f(x) | Error Average RK-4 | Error Average RK-5 | Difference | Difference(%) |
|------|-------------------|-------------------|------------|--------------|
| S    | 6.07705084        | 6.07705085        | 3.7373E-08 | 0.0000000615%|
| E    | 42.0459023        | 42.04580231       | 1.91906E-08| 0.0000000046%|
| I    | 4.69749512        | 4.69749534        | 2.095E-07  | 0.0000000460%|
| R    | 2.68850459        | 2.68850493        | 3.39897E-07| 0.0000012643%|

According to Table 8 the RK-4 technique is more precise in calculating total students prone to online game addiction than the RK-5, and the number of students who are no longer addicted to online games. While the RK-5 technique is more precise than the RK-4 to calculate total students who have the potential for addiction (have symptoms). The comparison of these 2 techniques is very small and they all have their individual benefits in estimating the scale of population movement. However, the accuracy of the 2 techniques is significantly different from the technique used to calculate students’ subject movement, this will be very influential if the research is carried out widely, not only on students but at all levels of students in Indonesia. Because in this research the data obtained is very small, the results obtained are also very small, namely 0.000004% for addicted students, or in other words the difference obtained does not reach a student, so this study concluded that the RK-4 and RK-5 techniques have the same level of accuracy, although significantly larger data and the same parameter scale (comparison) will provide accuracy to RK-4.

4. Discussion

Research on cases associated with online game addiction conducted by [7] showed that a decrease in depression level, lowers students addiction and vice versa. The results on the SEIR and SEIRS mathematical model by [17,18] focused on model construction and analysis, while the research focused on the numerical solution of the model applying the RK-4 and RK-5 techniques whose effects provided information that the RK-4 for The SEIRS model as a solution to the dilemma of online game addiction in students majoring in mathematics is more precise in estimating the number of cases than the RK-5. The results of the SEIRS model simulation using the RK-4 and RK-5 techniques which are the development of the RK-4 technique, in other words the error in RK-4 is getting smaller, but the
results prove that the RK-4 is still more precise than the RK-4. If the population is larger, it is influenced by the parameter values of each compartment.

5. Conclusion
In conclusion, online game addiction cases formed using the SEIRS mathematical model, analysis and simulation has the ability to predict the addiction cases in students in the future. The numerical solution of the SEIR model of online game addiction is carried out using the RK-4 and 5 techniques, which means both techniques have the same level of accuracy, this is shown in the trend of the relatively the same value of \( \Delta \).

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