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PROOF OF ALGEBRAIC STRUCTURES (RINGS AND FIELDS) WITH JAVA PROGRAMMING

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ABSTRACT

Many branches of algebraic structures, such as rings and fields, are difficult to comprehend and undesirable due to their abstract character. The testing of algebraic structures can be aided by a computer software application, which makes it simpler and more fun to learn algebraic structures. This program is expected to make algebraic structural proofing easier, faster, and more accurate than manual proof. Users and the software in the application are connected through the Cayley table. The Java programming is just used to demonstrate the algebraic structures of rings and fields. The application program's proof results for the subject showed correct results with a quick processing time when compared to manual processing.

Keywords: Abstract algebra, Rings, Fields, Java programming

ABSTRAK

Banyak cabang struktur aljabar, seperti Rings dan Fields, sulit dipahami dan tidak diinginkan karena karakter abstraknya. Pengujian struktur aljabar dapat dibantu dengan aplikasi perangkat lunak komputer, yang membuatnya lebih sederhana dan menyenangkan untuk mempelajari struktur aljabar. Program ini diharapkan dapat membuat pemeriksaan struktur aljabar menjadi lebih mudah, cepat, dan akurat dibandingkan dengan pemeriksaan manual. Pengguna dan perangkat lunak dalam aplikasi terhubung melalui tabel Cayley. Pemrograman Java hanya digunakan untuk mendemonstrasikan struktur aljabar Rings dan Fields. Hasil pembuktian program aplikasi untuk subjek menunjukkan hasil yang benar dengan waktu pengerjaan yang cepat jika dibandingkan dengan pengerjaan secara manual.

Kata kunci: Aljabar abstrak, Rings, Fields, Pemograman java

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INTRODUCTION

In the earlier research, it is discussed how the noncommutative using a group theory (S.Caenepeel & A. Verschoren, 2014). It is also showed how algebraic structures of the rings proven by utilizing the group theory (D. A. R. Wallace, 2014). Similarly with that, other study prove groups and subgroup by developing the GAP (Group, Algorithm, Programming) (M. Okur et al., 2015). Moreover, to prove the specific groups (groups, subgroups, and homomorphism groups), a software in computer is already designed by Manik et al (Manik et al., 2013). Additionally, Manik et al (Manik, 2017) discussed algebraic structures built on a group such that the K-Algebra shares the same features as the group. If subgroups and homomorphism groups exist, then K-Subalgebra and K-Homomorphisms exist as well (J. Pevtsova & S. Witherspoon, 2015). Ricky Aditya (Aditya et al., 2015) also mentioned rings and fields in their work Testing Division Rings and Fields Using a Computer Program, but solely in relation to division rings; in this study, more is said about rings and fields.

This study makes a distinction regarding the analysis software model testing scope based on the previous studies mentioned. It is able to carry proving groups, rings, and fields. Additionally, the user interface was redesigned to make it simpler for users to navigate between software modules and make it more user-friendly and effective (Carlson, 2013). Another feature of the application program is the addition of theory explanations for learning, which enables users to understand what has been theoretically proven. This paper outlines the software program's results, which showed that the proof of abstract algebra, in particular Ring and Fields,

Rings

An algebraic structure known as a ring is a set of R that is closed by the two binary operation: addition and multiplication which meets the requirements listed as: 1) R is abelian group under addition (+), 2) Associativity of multiplication for every a,b.c ϵ R with operation (a × b) × c = a × (b × c), 3) Distributive properties for every a,b.c ϵ R with Left Distributive and Right Distributive as follow: a × (b + c) = (a × b) + (a × c) and (a + b) × c = (a × c) + (b × c) (Marlow Anderson & Todd Feil, 2015; Vijayashree S. Gaonkar, 2017)

Fields

Any group of elements that satisfy the field axioms for binary operation: addition and multiplication as well as being a commutative division algebra is referred to is called as a Field. Every field must include at least two elements because the identity criterion must often be different for addition and multiplication. The integers (Z), which only form a ring, are examples, but not the complex numbers (C), rational numbers (Q), or real numbers (R). (J. A. Gallian, 2017; S. Wahyuni et al., 2016)

METHOD

By creating computer software based on an open source program, an application program was developed to demonstrate Rings and Fields. It often involved the following actions or phases: analysis, design, coding (building), testing, and maintenance. The system was created and designed in a way that results in an effective application program module that is simple for people to utilize. Additionally, it can produce clear results and is simple for application program users to grasp (Lethbridge & Laganière, 2014). Figure 1 depicts the study's overall structure.

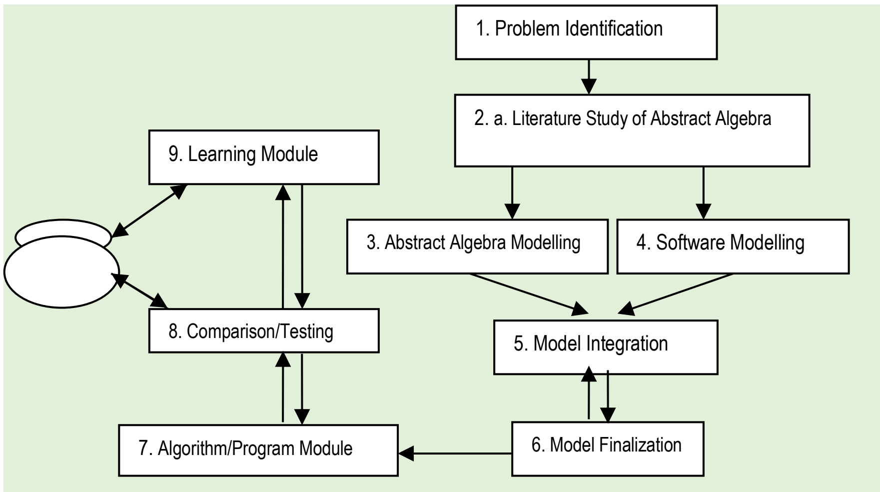

Figure 1. Research Framework

The steps used in this study are:

1) the task at hand in this step was to compile the issues under study and establish the scope of the issues that needed to be resolved.
2) After the identification, this task done by looking for information (data and formula) from references including books and journals in order to build the model.
3) After the literature, the abstract algebra is modeled by get the formulation of the abstract algebra model that was required from earlier investigations.
4) Parallel with the modeling, the software is also modeled. This step was taken to create a software model and the algorithms needed to answer the research challenge.
5) After step 3 and 4 done, the model is integrated. This activity involved making corrections to existing models and finding the best model among those that have already been finished. Here, the model repair was still carried out by hand.
6) After that a computer program will be finalized by making sure the efficiency and accuracy of the proving of abstract algebra. Since algorithms are necessary for creating programs, this activity concentrated on the models utilized for the algorithms.

7) Comparison/testing was done to check the accuracy of the software model that was created. Testing involved contrasting the model's development outcomes with manual proving outcomes that had been recorded in the database as question-and-answer pairs.
8) this activity was carried out to produce a module that can teach abstract algebra and is a summary of the proof that was acquired from earlier modules.(Hani'ah et al., 2021)

Design Module (Pseudocode)

The application program was created throughout development by assembling the software parts. The modules in this application program for ring & fields and groups test are shown in this figure 2 and the pseudocode modul are shown in this paper.

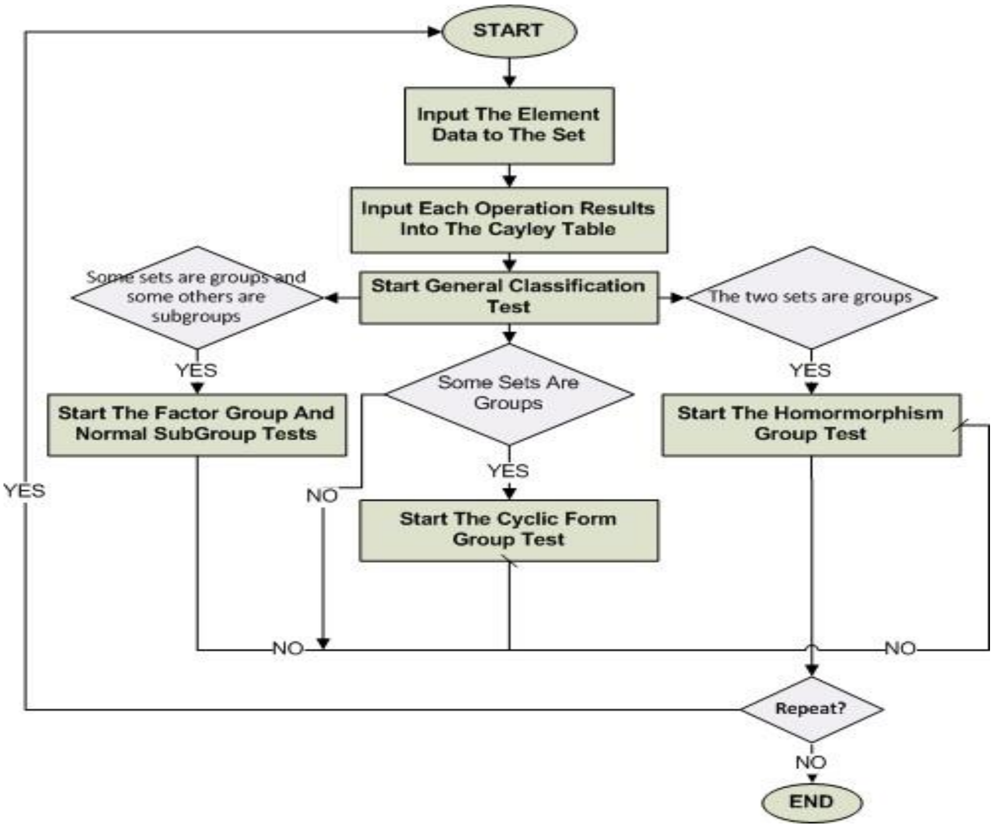

Figure 2. Flow chart of module control system group test

Pseudocode program RingFiled ;

To prove the ring and field problems above, a computer program has been developed using Java programming and the following is the pseudocode program that has been created (Hani'ah et al., 2021)

import java.awt.*; import java.awt.event.*; import java.io.*; import javax.swing.*;
public class main_menu extends JFrame implements ActionListener
{

```
private static final long serialVersionUID = 1L;
JPanel panel_utama = new JPanel(new BorderLayout());
JTabbedPane tab_main_menu = new JTabbedPane(JTabbedPane.LEFT);
JTabbedPane tab_menu1 = new JTabbedPane(); // untuk menu1
JTabbedPane tab_menu2 = new JTabbedPane(); // untuk menu2
JTabbedPane tab_menu3 = new JTabbedPane(); // untuk menu3

JPanel pnl_ksg1 = new JPanel(); JPanel pnl_ksg2 = new JPanel();
JPanel pnl_ksg3 = new JPanel(); JPanel pnl_ksg4 = new JPanel();
JLabel lbl_ksg1 = new JLabel(); JLabel lbl_ksg2 = new JLabel();

// tab di dalam tab main_menu ke 1
JPanel pnl_input_1 = new JPanel(new BorderLayout()); JPanel
pnl_analisis_1 = new JPanel(new FlowLayout());
JPanel pnl_hasil_1 = new JPanel(new FlowLayout());
// tab di dalam tab main_menu ke 2
JPanel pnl_input_2 = new JPanel(new FlowLayout()); JPanel pnl_analisis_2
= new JPanel(new FlowLayout());
JPanel pnl_hasil_2 = new JPanel(new FlowLayout());
// tab di dalam tab main_menu ke 3
JPanel pnl_input_3 = new JPanel(new FlowLayout()); JPanel pnl_analisis_3
= new JPanel(new FlowLayout());
JPanel pnl_hasil_3 = new JPanel(new FlowLayout());
JLabel input_1 = new JLabel("Please enter the member of the set and the
operating results on the Cayley table");
JLabel analisis_1 = new JLabel("Below is the results of analysis of the data
contained on the Cayley table");
JLabel hasil_1 = new JLabel("Below is the conclusions obtained from
analysis of data on the Cayley table");

JLabel input_2 = new JLabel("Please enter the member of the set of the Ring
and Subring that want to be tested");
JLabel analisis_2 = new JLabel("Please enter the operating results of the
structure of algebra (S,+,*) on the Cayley table below");
JLabel input_3 = new JLabel("Please enter the member of the set of the Ring
(R,+,*) and Ring (S,<+>,<*>) that  want to be tested");
JLabel analisis_3 = new JLabel("Please enter the operating results of the the
Ring (R,+,*) and Ring (S,<+>,<*>)
on the Cayley table below");
JLabel hasil_3 = new JLabel("Below is the conclusions obtained from
analysis of data on the Cayley table");
JLabel kredit = new JLabel("Credit ");
JPanel pnl_tab_1[] = new JPanel[5]; // untuk panel di dalam tab ring
JPanel pnl_tab_2[] = new JPanel[5]; // untuk panel di dalam tab sub ring
JPanel pnl_tab_3[] = new JPanel[5]; // untuk panel di dalam tab
homomorfisma
JPanel pnl_tab_extra[] = new JPanel[3]; // untuk tab ideal dan
homomorfisma
```

```
  JPanel pnl_kredit = new JPanel(new FlowLayout(FlowLayout.CENTER, 0, 20));

 // input data dan tabel Cayley
 JTextField txt_input[] = new JTextField[5]; JButton but_input[] = new JButton[5];
 JButton but_del[] = new JButton[5]; JButton but_del_all[] = new JButton[5];
 JButton but_OK[] = new JButton[5];   JButton but_new[] = new JButton[5];
 DefaultListModel list[] = new DefaultListModel[5];   JList myList[] = new JList[5];
 JScrollPane scroll_input[] = new JScrollPane[5];
 JPanel pnl_input[] = new JPanel[5]; JPanel pnl_list[] = new JPanel[5];
 JPanel pnl_il[] = new JPanel[5]; JPanel pnl_all[] = new JPanel[5];

 //tambahan untuk tab subring & ideal & homomorfis
 JLabel lbl_ket[] = new JLabel[5];// 1&2 subring-ideal ; 3&4 homomorfis
     JPanel pnl_tbl[] = new JPanel[4];// 0&1 subring-ideal ; 2&3 homomorfis
 JPanel pnl_btn[] = new JPanel[2];// 0 subring-ideal ; 1 homomorfis
 JButton btn_tmp = new JButton("<html>Input the Member<br><center>of Sub Ring</center<html>");
 JButton btn_hsl_sub = new JButton("Sub Ring");

 JPanel pnl_isi[] = new JPanel[5]; JPanel pnl_tmbh[] = new JPanel[5]; JPanel pnl_kali[] = new JPanel[5];
 JPanel pnl_but[] = new JPanel[5]; JButton but_reset_tmbh[] = new JButton[5];
 JButton but_reset_kali[] = new JButton[5]; JButton but_proses[] = new JButton[5];
 JTextField tmbh[][][] = new JTextField[5][30][30]; JTextField kali[][][] = new JTextField[5][30][30];
 JLabel lbl_tmbh[][][] = new JLabel[5][30][30]; JLabel lbl_kali[][][] = new JLabel[5][30][30];
 JScrollPane scroll_tmbh[] = new JScrollPane[5];JScrollPane scroll_kali[] = new JScrollPane[5];
 // hasil analisis dari tabel
  JPanel pnl_uji[] = new JPanel[2]; JLabel lbl_uji[][] = new JLabel[2][9];
 JButton btn_tmbh[][] = new JButton[2][6]; JButton btn_kali[][] = new JButton[2][6];
 JButton btn_dis[] = new JButton[2]; JTextArea txt_ket[] = new JTextArea[2];
 JScrollPane scroll_ket[] = new JScrollPane[2];

  // hasil kesimpulan yang didapat dr analisis tabel
  JPanel pnl_hsl[] = new JPanel[3]; JLabel lbl_hsl[][] = new JLabel[3][6];
  JButton btn_hsl[][] = new JButton[3][6]; JPanel pnl_ket[] = new JPanel[5];
  JTextArea txt_hsl[] = new JTextArea[5]; // button untuk simpan data d tab save file
  JButton btn1, btn2, btn3 ;
```

```
  // variabel global
int jmlh_agt[] = new int[5]; String anggota[][] = new String[6][30]; String
isi_tbl[][] = new String[30][30];
int hsl_tmbh[][] = new int[2][6]; int hsl_kali[][] = new int[2][6]; int dis[] =
new int[2];
String ket[][] = new String[2][11]; String unkes_tmbh[] = new String[2];
String unkes_kali[] = new String[2];
String hsl[] = new String[10]; int subring = 0; String str_tls[] = new String[3];

  // untuk ngecek isi file; 1=ring. 2=subring, 3=ideal, 4=homo
  int tes1=0, tes2=0, tes3=0, tes4=0;
public void setObject()
{
  int a,i;
  pnl_tab_extra[1] = new JPanel(new FlowLayout());pnl_tab_extra[2] = new
JPanel(new FlowLayout());
        for(a=0 ; a<=4 ; a++)
        {
  //untuk input anggota himpunan
pnl_input[a] = new JPanel(new GridLayout(4,1)); pnl_list[a] = new
JPanel(new FlowLayout());
pnl_il[a] = new JPanel(new GridLayout(1,2)); txt_input[a] = new
JTextField(10);
but_input[a] = new JButton("Add"); but_del[a] = new JButton("Delete");
but_del_all[a] = new JButton("Delete All"); list[a] = new
DefaultListModel();
myList[a] = new JList(list[a]); scroll_input[a] = new JScrollPane(myList[a]);

scroll_input[a].setPreferredSize(newDimension(100,100));
t_input[a].addActionListener(this);
but_del[a].addActionListener(this); but_del_all[a].addActionListener(this);
but_new[a] = new JButton("New"); but_OK[a] = new JButton("Process");
but_new[a].addActionListener(this); but_OK[a].addActionListener(this);

pnl_tab_1[a] = new JPanel(new FlowLayout()); pnl_tab_2[a] = new
JPanel(new FlowLayout());
pnl_tab_3[a] = new JPanel(new FlowLayout()); pnl_isi[a] = new JPanel(new
BorderLayout(10,10));
but_reset_tmbh[a] = new JButton("<html>Reset<br>Op '+'</html>");
but_reset_kali[a] = new JButton("<html>Reset<br>Op 'x'</html>");
but_proses[a] = new JButton("Analysis");
but_reset_tmbh[a].addActionListener(this);
but_reset_kali[a].addActionListener(this);
but_proses[a].addActionListener(this);

if(a==0 || a==1)
for(i=0 ; i<=8 ; i++)lbl_uji[a][i] = new JLabel();
  for(i=1 ; i<=5 ; i++)
```

```
{
btn_tmbh[a][i] = new JButton(); btn_kali[a][i] = new JButton();lbl_hsl[a][i]
= new JLabel();
btn_hsl[a][i] = new JButton();
}
pnl_uji[a] = new JPanel(new GridLayout(6,3));btn_dis[a] = new JButton();
txt_ket[a] = new JTextArea(); scroll_ket[a] = new JScrollPane(txt_ket[a]);
pnl_hsl[a] = new  Panel(new GridLayout(5,2));
}
        txt_hsl[a] = new JTextArea();
        }
        for(a=0 ; a<=10 ; a++)
        {
                for(i=0 ; i<=1 ; i++)
                {
                ket[i][a] = ""; if(a<=5)
                        {
                        hsl_tmbh[i][a] = 0;     hsl_kali[i][a] = 0;
                        }
                }
}
        for(a=0;a<=9;a++)hsl[a]=new String("");
```

RESULTS AND DISCUSSION

Result

By manually comparing the program's output, it is necessary to confirm the program's functionality. The Cayley table, which will be used for testing, is displayed below.

Table 1 Testing for Ring, Field, Ring Division and Commutative Ring using Sum modulo 3

+	**0**	**1**	**2**
0	0	1	2
1	1	2	0
2	2	0	1

Table 2. Testing for Ring, Field, Ring Division and Commutative Ring using Multiplication modulo 3

*****	**0**	**1**	**2**
0	0	0	0
1	0	1	2
2	0	2	1

Proof with the application

The produced application program will be used to process the examples of the aforementioned algebraic system in this step to determine whether it can produce the desired results as decided by the manual testing. The primary menu will first appear as shown below in Figure 3.

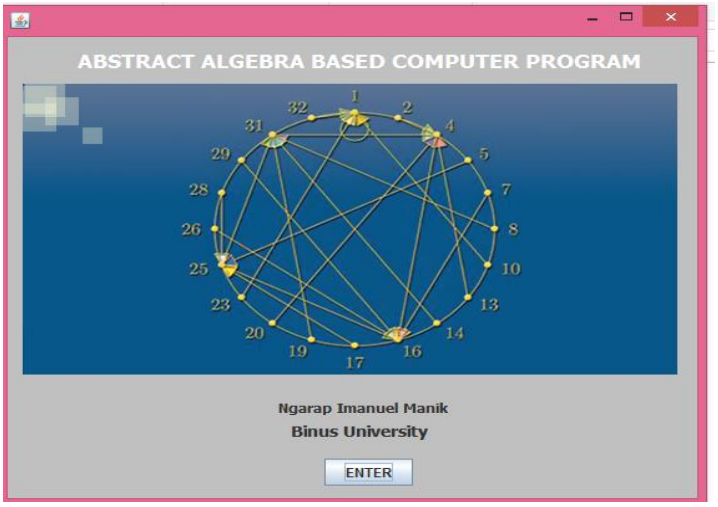

Figure 3. Menu Option of Rings Matters

A menu choice about groups is divided into two pieces in Figure 3. One involves studying definitions or descriptions of rings and fields, and the other involves proving rings and their types. If we select "prove," Figures 4 and 5 of the input display will appear.

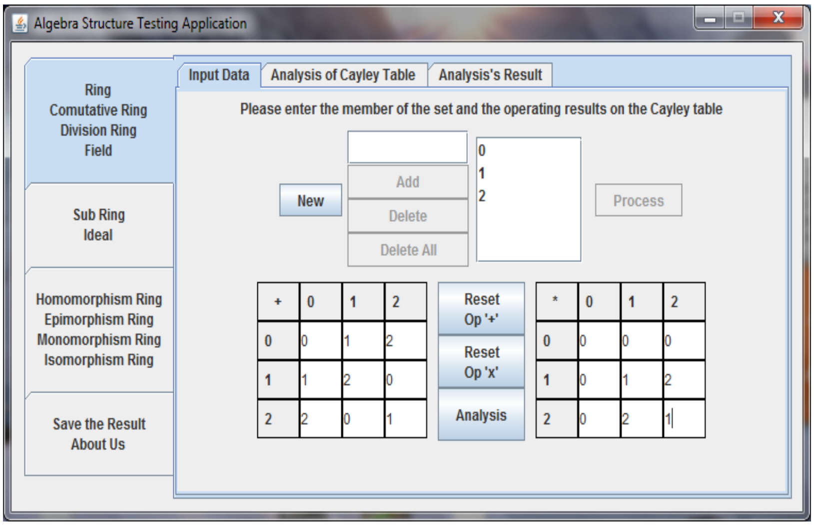

Figure 4. Input data for Ring

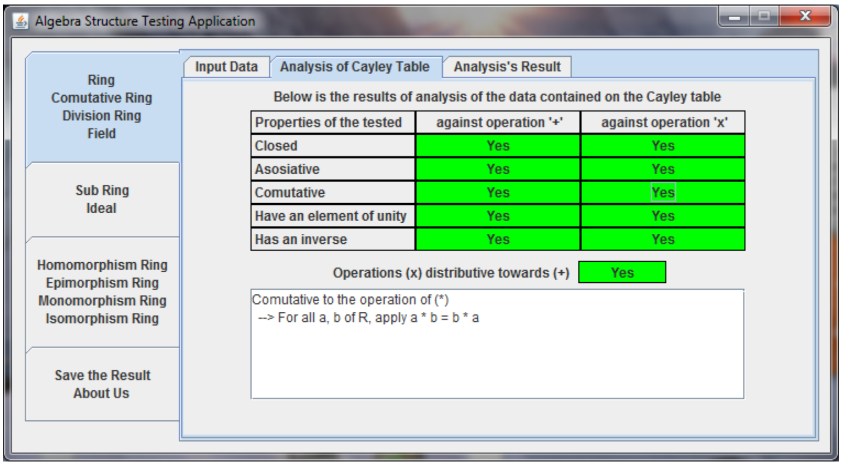

Figure 5. JButton Commutative againts operation 'x'

Once we return to the option in Figure 5 and select it, the theory explaining the significance of the issue that was used as an example in Figure 6 will be displayed.

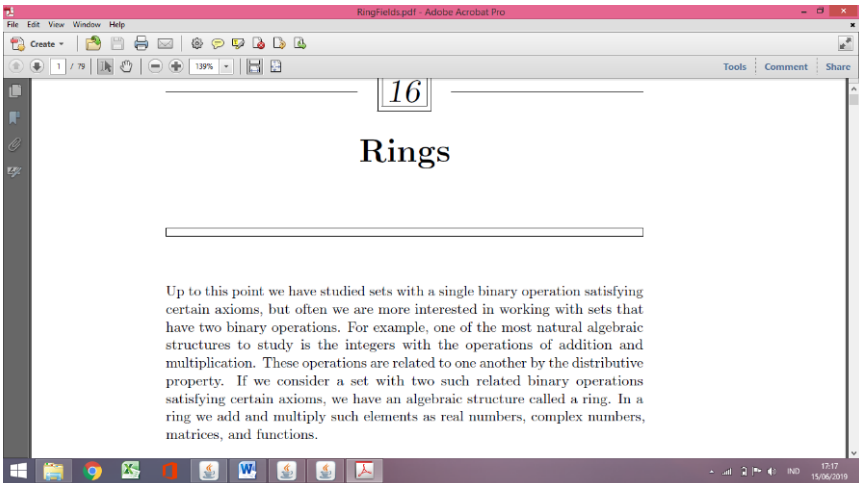

Figure 6. Explanation of the Theory of Rings

Discussion

Of the cases that have been described previously, then evaluated and analyzed the results obtained by the program module by comparing it with the completion and verification if done manually, then the results obtained that all the examples of cases given have the same answer and correct if done manually. Another thing obtained is that:

a. The work time needed by the program to provide proof results is very short, so it is far more efficient than manual verification. The program has been tested with several algebraic systems that have varying number of elements, and there is no visible increase in time in the program processing time. Small program file sizes and program algorithms are designed with basic algorithms that are not complex, so it does not require high computer specifications to run the program.

b. The accuracy of the verification results depends on the accuracy of the user entering the contents of the Cayley table. If the user is less careful in entering data, it can be ascertained that the results of the verification are less accurate.
c. The results of the program module analysis show that this program can help users to learn and prove abstract algebra.

CONCLUSION

Overall the software model that has been created can be used as a comparison material for Abstract Algebra completion in teaching both at school and in mathematics.Then after an evaluation of the program modules that have been developed, through discussion to users (High School Mathematics Teachers, Students of Mathematics), some results of the discussion are obtained as follows: The module is correct according to the verification manually, the program module can help teachers become mathematical in terms of teaching, need to be developed again, so that it is easier to use by everyone, in order to add other types of evidence that have not been included in this program module and this program module can be given to all high school math teachers and other interested people.

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