Chapter 6

Concluding Remarks

A prototype program called PlantVR has presented for continuous development of plant models by parametric functional symbols based on bracketed L-systems using soybean model as a case study. The proposed method consists of an order of steps:

- defining a qualitative model as L-systems,
- measuring key characteristics collected from actual plants,
- converting raw data to growth function based on sigmoidal curve,
- defining a quantitative model,
- visualizing the quantitative model, and
- evaluating the model and parameter adjustment.

The measurement of plant structure is time-consuming. The data of soybean was collected manually using rulers and protractors. This prototype can be used to generate a realistic model of any plant whose life cycle is similar to soybean.

One suggestion of this research is to add environmental parameters that need in plant growing to control the development of plant. The software can be used to generate an entire growth cycle for any plant including the reproductive state. To enhance the appearance of the plant, texture image can be applied to every component such as leaf, internode, flower, petiole, and fruit.

The advantages of the thesis are a very easy understanding of the L-systems coding and the smoother of animation that compared to the previous work. The disadvantages of the thesis is the prototype has not included the natural environment for plant growing, but this disadvantage will be extend for a future plan of this research.

The further works also to improve the component of plant, and the underground part and reproductive state will be studied.

To compare the previous work, the visualized images of L-studio software and PlantVR software are given in Figure 6.1, Figure 6.2, Figure 6.3, and Figure 6.4.

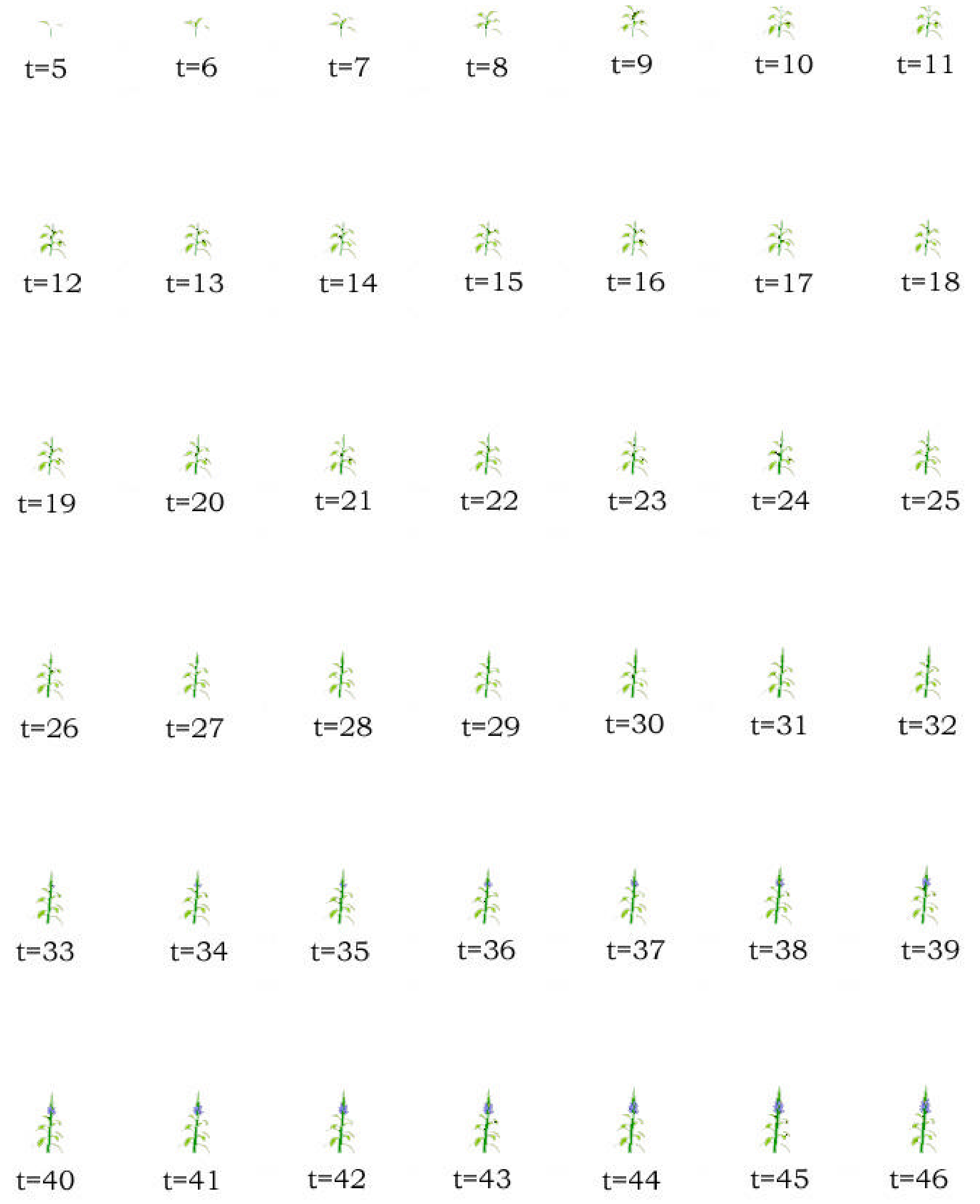

Figure 6.1: The plant growth using L-studio software at time t=5 to t=46.

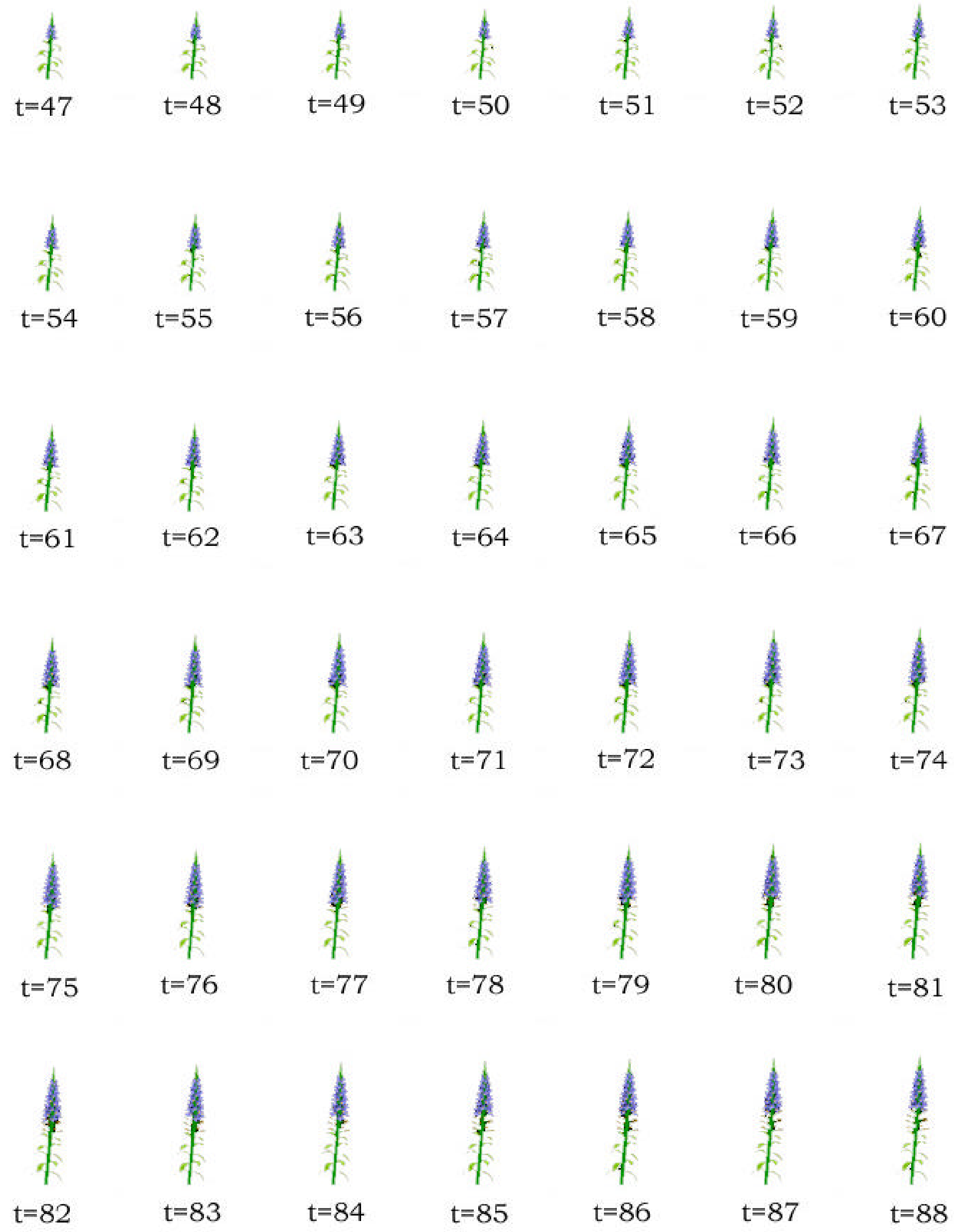

Figure 6.2: The plant growth using L-studio software at time t=47 to t=88.

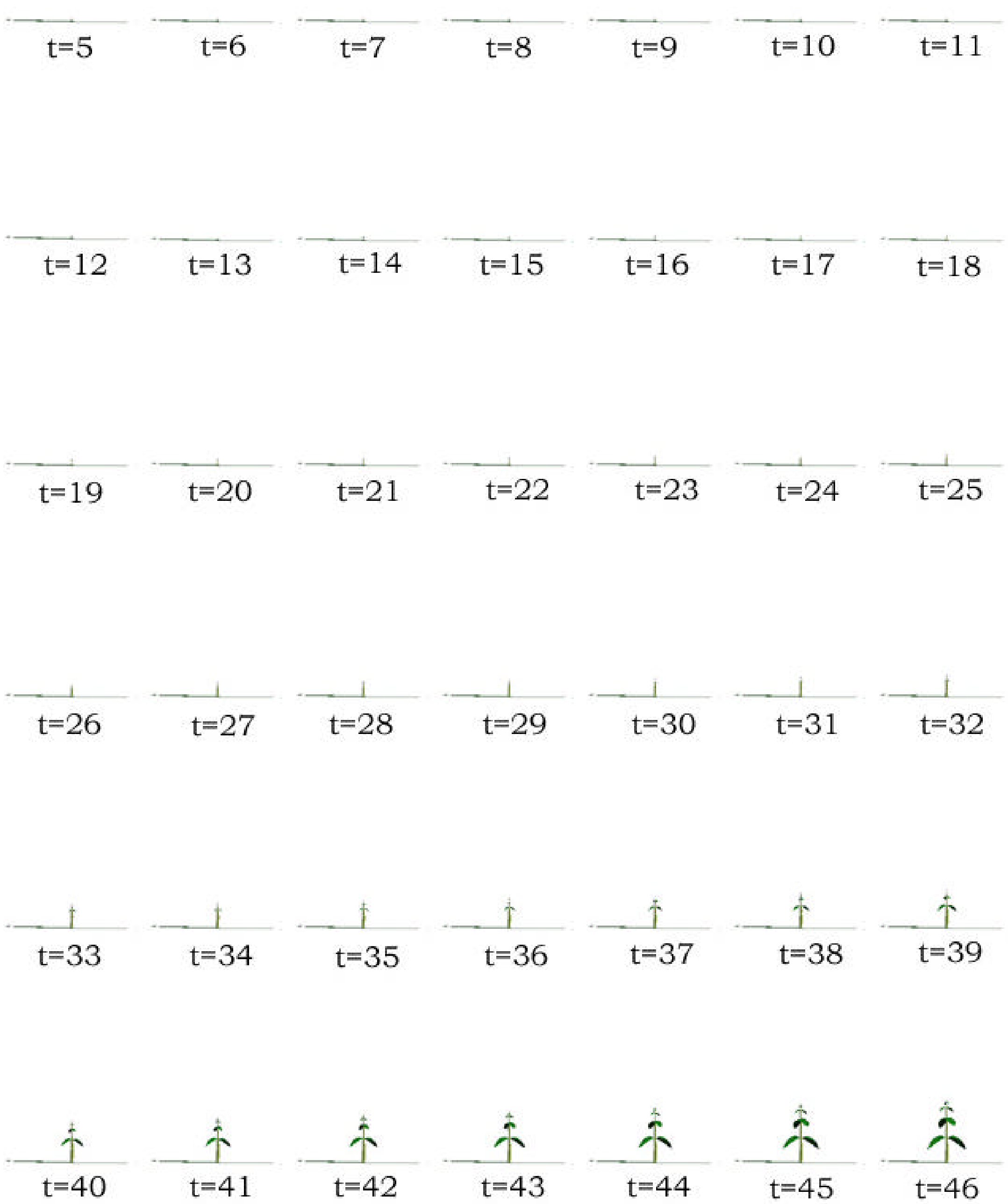

Figure 6.3: The plant growth using PlantVR software at time t=5 to t=46 with growth rate 4.0.

Figure 6.4: The plant growth using PlantVR software at time t=47 to t=88 with growth rate 4.0.

To compare the L-systems codes with the similar visualized image, the L-studio software and the PlantVR software are given below.

The L-systems of L-Studio Sotfware

```
/* #define STEPS 90 */
#define I0 30
#define S0 150
#define K0 70
#define KANG1 10
#define KANG2 20
#define SRATE 1.01
#define LRATE 1.05
#define BANG0 0
#define BANGI 1.0
#define BANGL 10.0
#define T0 5 /* the number of leaf pairs */
#define T1 20 /* the number of buds */
#define T2 40 /* the number of open flowers */
#define T3 25 /* the number of fruits */
Lsystem: 1
derivation length: T0+T1+T2+T3+4
Axiom: [-(5)/(35)#(2),(47)F(I0*10)A(0)]
/* Produce the vegetative part - decussate phyllotaxis */
A(t) : t [-(BANG0,t)!(47)~l(0.5,t)]/(180) [-(BANG0,t)!(47)~l(0.5,t)]/(95)F(I0*6)!A
    (t+1)
/* Produce the inflorescence - spiral phyllotaxis */
A(t) : t >= T0 --> [&(BANG0+15)F(S0/4)&(15)F(S0/8)] [!(2)&(BANG0)G(S0)X
(0)~b(0.5)]/(137.5)F(I0)!A(t+1)
b(s) --> b(s*SRATE)
X(t) : t X(t+1)
X(t) : t==T1 --> [C(0),(127)K/(72),K/(72),K/(72),K/(72),K!(2),(122)G(120)]%
K --> [!(1)&(KANG1){-(KANG2)F(K0)+(KANG2)F(K0)+(KANG2)F(K0)-
    (KANG2)| -(KANG2)F(K0)+(KANG2)F(K0)+(KANG2)F(K0)}]
```

```
C(t) : t C(t+1)
C(t) : t==T2 --> D%
D --> ~f(0.3),(121)F(80)&(10)F(60)&(10)F(40)
F(s) --> F(s*SRATE)
f(s) --> f(s*SRATE)
G(s) --> G(s*SRATE)
l(s,t) : t<1.2 && l(s*LRATE,t+1)
&(a) : a<135 --> &(a+BANGI)
-(a,t) : a<90 && t -(a+BANGL,t+1)
#(r) : r<6 --> #(r+0.1)
endlsystem
```

The L-systems of PlantVR Sotfware

```
ComparePlant1{
        Iterations=9
        Angle=45
        Diameter=1.5
        Axiom=iiii[-iL][+iL]BA
        A=I[-IF][+IF][/IF][\IF]AK
        ENDRULE
        A=I[-IF][+IF][/IF][\IF]K
        K=IF
        B= I[/iL][\iL]I[-iL][+iL]I[/iL][\iL]i
}
```

The L-systems codes of the L-studio software and PlantVR software are very different in the meaning of definition and the axiom string. The L-studio software uses an initial string to interpret the virtual plant which the graphics are performed at each time step t in Figure 6.5(a). On the other hand, the PlantVR software iterates an initial string to perform the final L-system string. The final L-system string which controlled by growth functions is interpreted to the virtual plant in each time step t. The axiom string of “ComparePlant1” prototype is shown in graphic form as Figure 6.5(b).

The L-systems of PlantVR software are shorter than the L-studio software. The visualized images of two methods are similar, but the initial images are different. The initial image of L-studio software depends on an axiom which design at an observation position while the initial image of PlantVR depends on an actual plant development by mean of the growth function.

Another axiom of the L-systems code "ComparePlant2" of PlantVR software is shown in Figure 6.5(c). Notice that, the first frame of the animation by the PlantVR software is not similar to the axiom "ComparePlant1", but the final L-system string of "ComparePlant1" and "ComparePlant2" have the same prototype. The growth rate that used to control the final string of PlantVR can be changed, the visualized images of different growth rates are shown in Figure 6.3-6.4 and Figure 6.6-6.7. Figure 6.7 shows that the growth function is stabled at time step t = 57 which means the image of life cycle of any plant is controlled by the growth rate.

```
ComparePlant2{
	Iterations=9
	Angle=45
	Diameter=1.5
	Axiom=iiii[-iL][+iL]I[/iL][\iL]BA
	A=I[-IF][+IF][/IF][\IF]AK
	ENDRULE
	A=I[-IF][+IF][/IF][\IF]K
	K=IF
	B=I[-iL][+iL]I[/iL][\iL]i
}
```

(a) (b) (c)

Figure 6.5: The visualized image of axiom
(a) L-studio software,
(b) PlantVR software with "ComparePlant1" prototype,
(c) PlantVR software with "ComparePlant2" prototype.

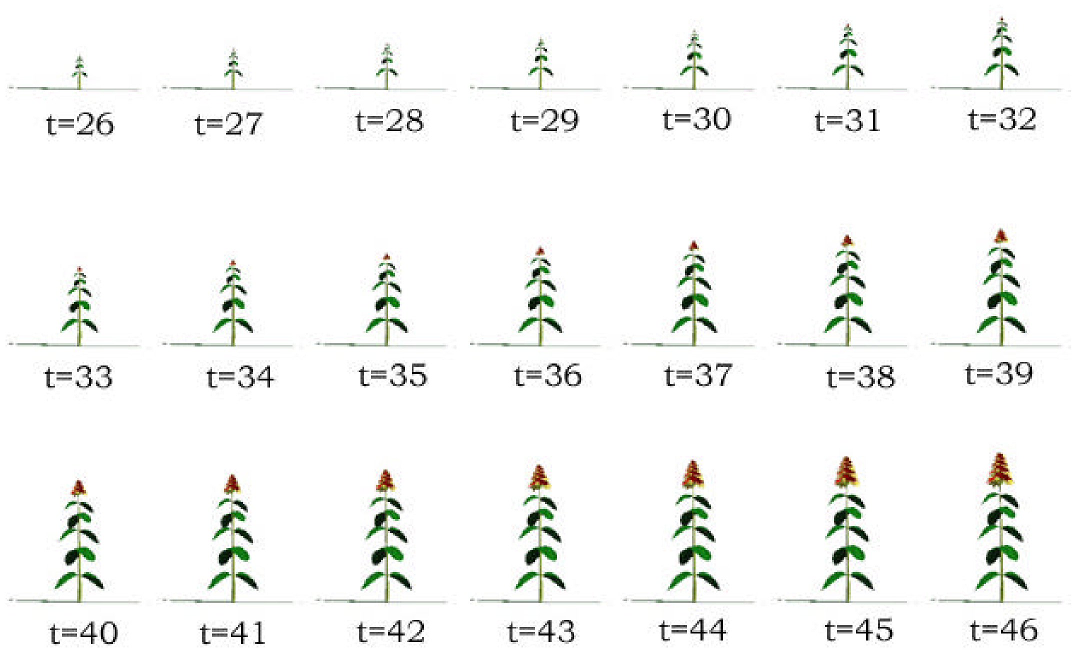

Figure 6.6: The plant growth using PlantVR software at time t=5 to t=46 with growth rate 1.70.

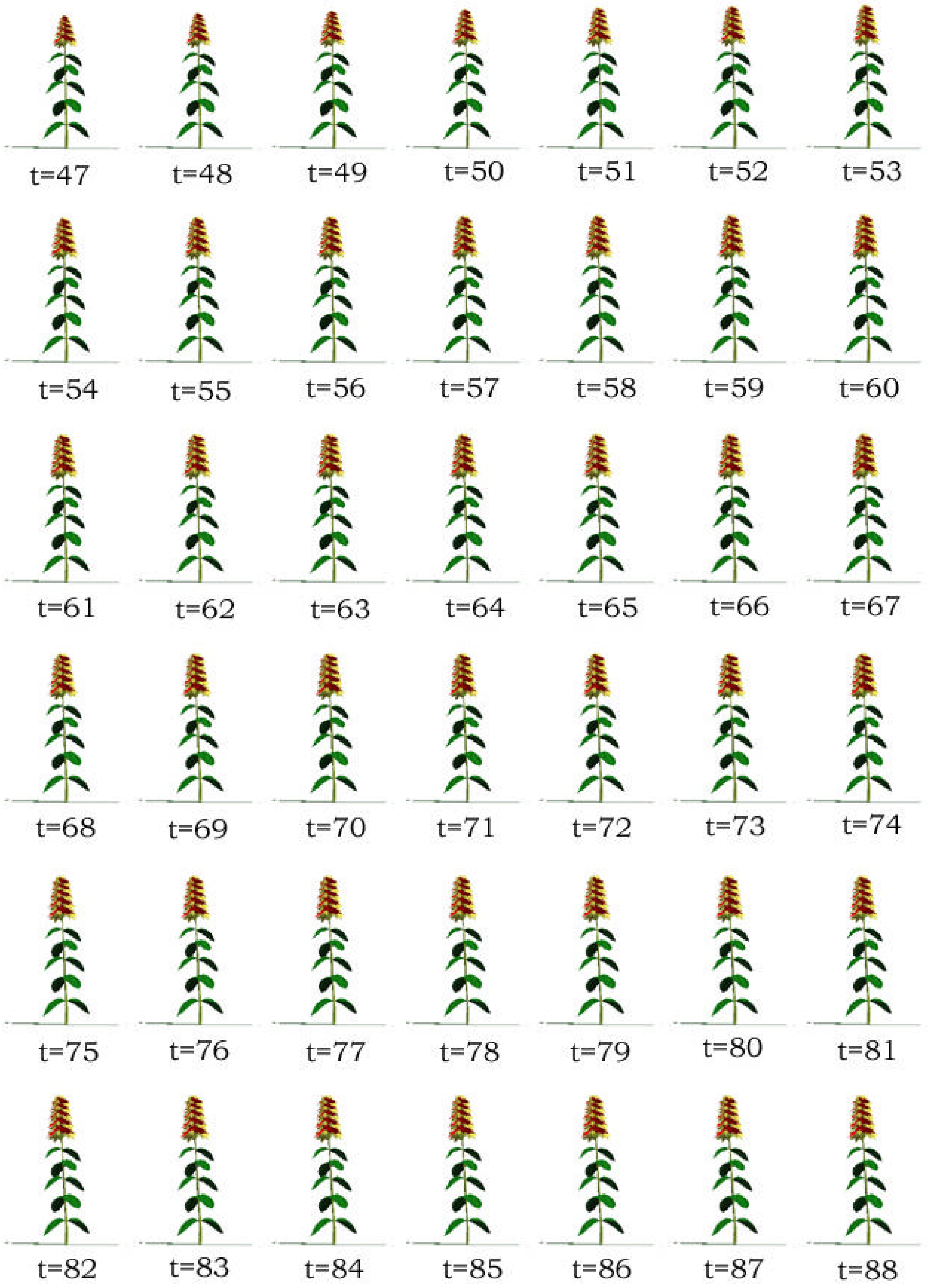

Figure 6.7: The plant growth using PlantVR software at time t=47 to t=88 with growth rate 1.70.