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Shapes of Trees within a Controlled Sphere of Light

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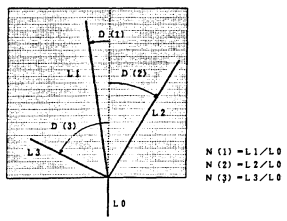
All plants have common chalacteristics of growth and reaction to the environment. The affect of the environmental conditions on the different types of plants determines their shapes.

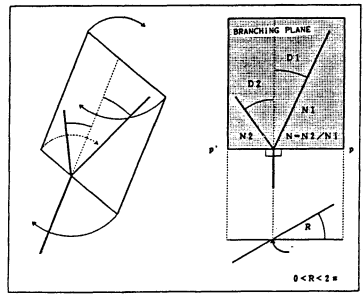
Most of the major growth and reaction characteristics of trees have been selected through observation and analysis. A system to control and measure the light conditions for an actual tree has been set up.

Computer simulation has been employed in order to show the variations of shapes produced by different types of trees under pre-determined light conditions.

1. BRANCHING SYSTEM

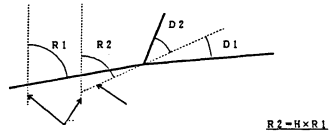
EC — Number of Daughter Branches
D (1～3) — Degree of Devergence (f.1)
N (1～3) — Proportional Length (f.2)





(Fig.1)

H — Force Against Gravity (f.3)



(Fig.2)

U — Tendencies in Frequency of Branching Planes (f.4)

With exeptions, the more horizontal the mother branches, the more frequent the horizontal branching plane is.

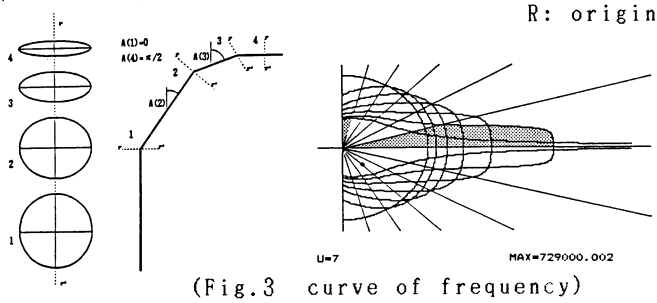
$$U' = 1 - | (\pi \div 2 - A) | \div (\pi \div 2) \quad (1)$$

A: angle of the mother branch to the vertical

$$(-\pi \div 2 < R < \pi \div 2)$$
$$r = R \div (\pi \div 2)$$
$$R' = \{U' \times r^u + (1-U') \times r\} \times (\pi \div 2) \quad (2a)$$

$$(\pi \div 2 < R < 3\pi \div 2)$$
$$r = (R-2) \div (\pi \div 2)$$
$$R' = \{U' \times r^u + (1-U') \times r\} \times (\pi \div 2) + \pi \quad (2b)$$

R: original degree



(Fig.3 curve of frequency)

2. THREE FACTORS IN TRUNK CHARACTERISTICS (V) (f.5)

I. High Growth Rate
$F = F \times V$ F: Growth Rate

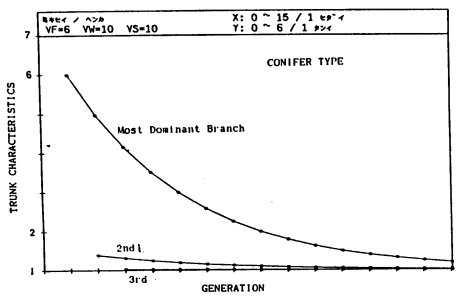
II. High Branch Frequency
$VC = V$ VC: Branch Frequency

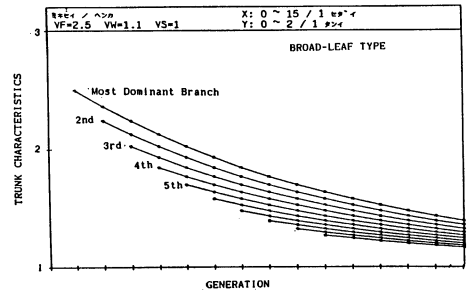
III. Strong Force Against Gravity
$A = A \div V$ A: Angle of Trunk to the Vertical

OTHER TRUNK CHARACTERISTICS

VF — Trunk Characteristics at the Sapling Stage (f.5.1)
VW — Trunk Division Range Characteristics (f.5.2)
VS — Change in Trunk Characteristics with Age (f.5.3)

(Table 1 change in trunk characteristics with age)



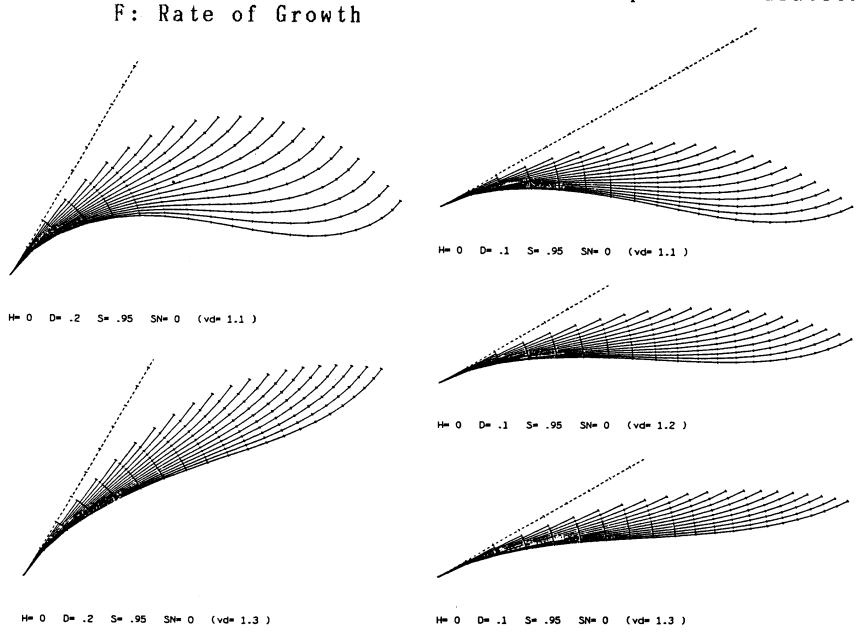


3. CURVE OF BRANCHES

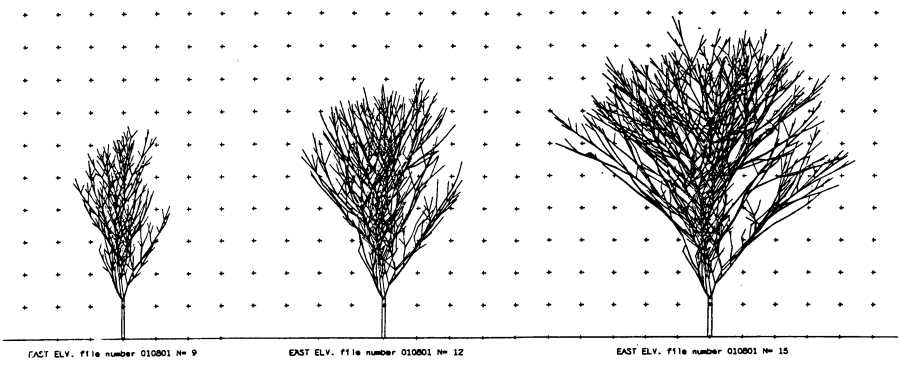
D — Tendency of Branches to Curve Downward with Age (f.6)

$$AA_P = AA_{P-1} + SIN\ A_P \times D \div [(N-N_P)^{1.2} \times F_P]$$

P: Number of Brunch Points
A: Angle of Branch to the Vertical
AA: Degree of Curving
N: Generation (discrete time in computer simulation)
F: Rate of Growth



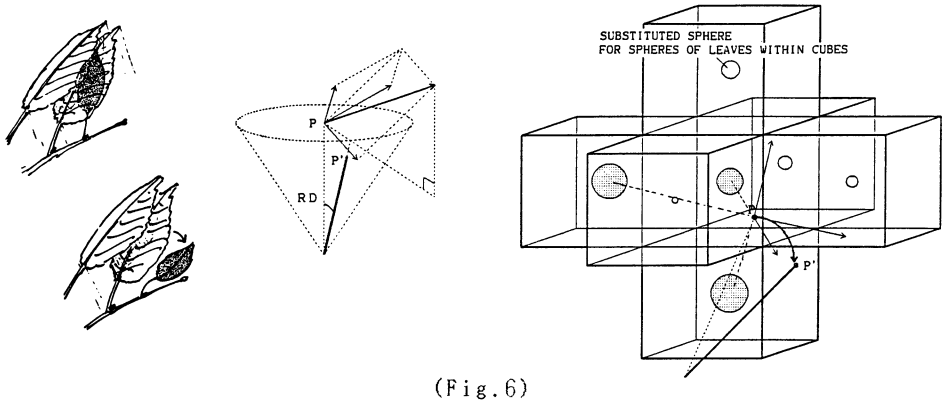
(Fig.4 in branches which tend to curve downward the force against gravity tends to strong, and vice versa.)



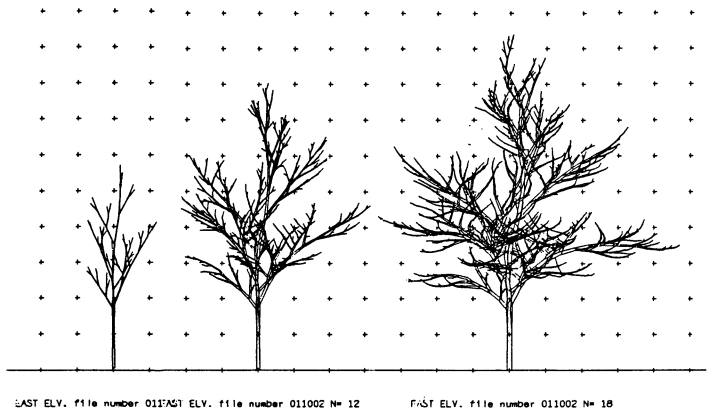
(Fig.5 the downward growth curve provides the necessary outside surface area of the crown to permit further branching)

4. TWINING CHARACTERISTICS
(Ability to Sense and React to the Environment)

RD — Maximum Angle of Rotation (f.7)



(Fig.6)



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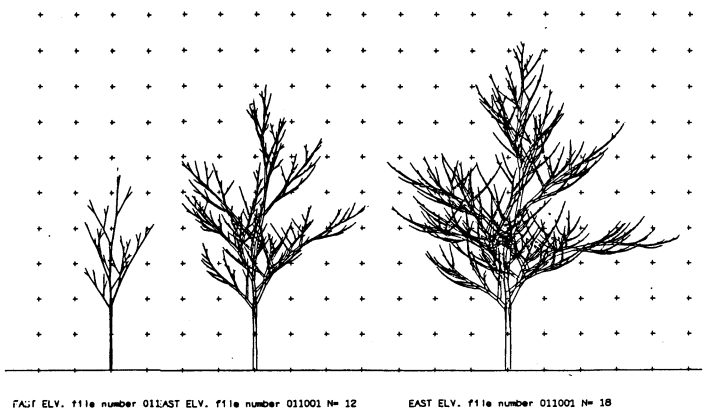
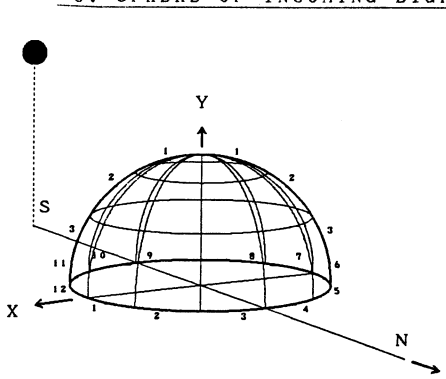
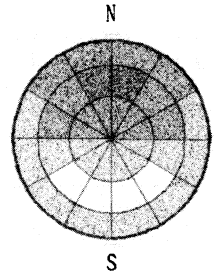


EXCLUDED

(Fig.7 when the twining character is included in the program, it produces a more typical tree shape)

5. SPHERE OF INCOMING LIGHT

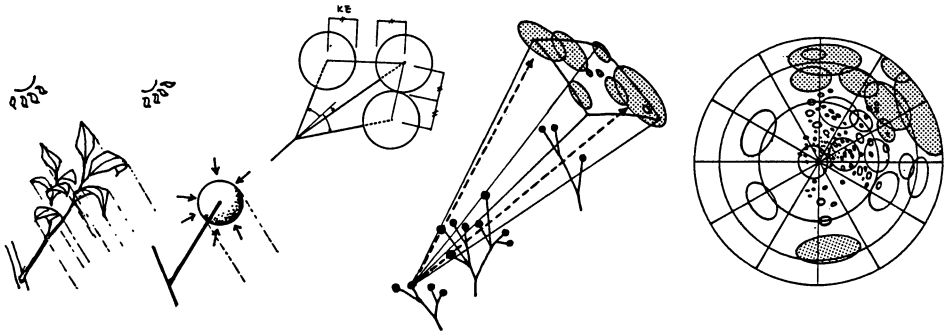




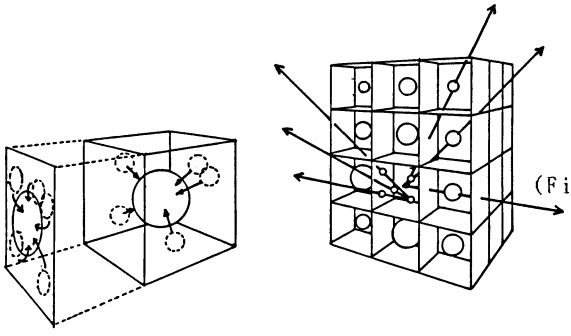
(Fig.8 possible to control variations in areas of intencity)

6. SPHERE TO SCREEN OUT LIGHT

KK — Radius of Sphere (f.8)



(Fig.9 the assumed spheres of leaves are projected onto a spherical screen)

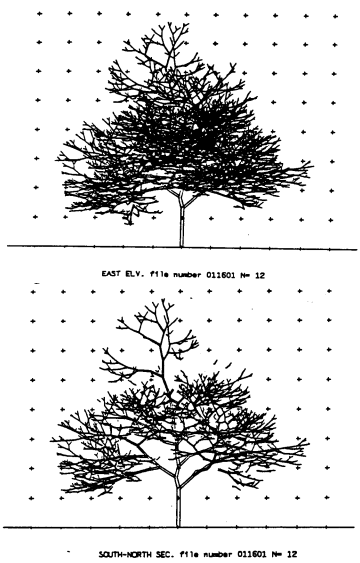


(Fig.10 only near spheres of leaves are projected individually, more distant ones are done in cubes)

The Minimum Amount of Light Necessary to Prevent Stems from Dying.

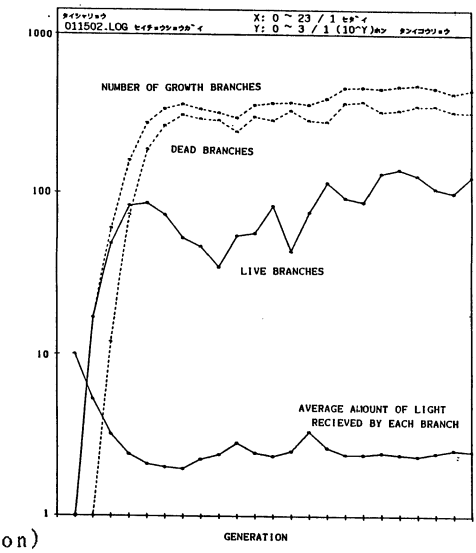
FW — Ratio of Amount of Light Recieved by the Sphere of Leaves to Entire Incoming Light (f.9)

The computer simulation turned out to be very similer to actual growth patterns.
Live branches have a very rapid growth rate in early generations after the tree has produce a crown the growth rate declines dramatically.
Even in a constant environment without natural variations, the zig-zag growth rate curve of the natural environment remaind valid.

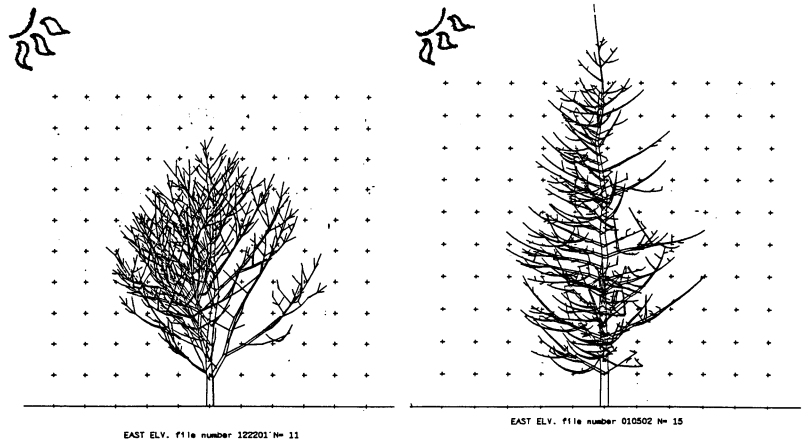


(Fig. 11 crown; elevation & section)

(Table 2 curves of growth)



Irregular light intensity over the light sphere causes irregular growth of the crown, with the light intense area having the more dense growth.

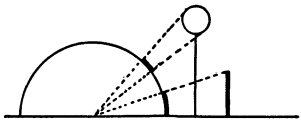


(FIG. 12 east elevation)

SHAPES OF TREES WITHIN A SPHERE OF LIGHT

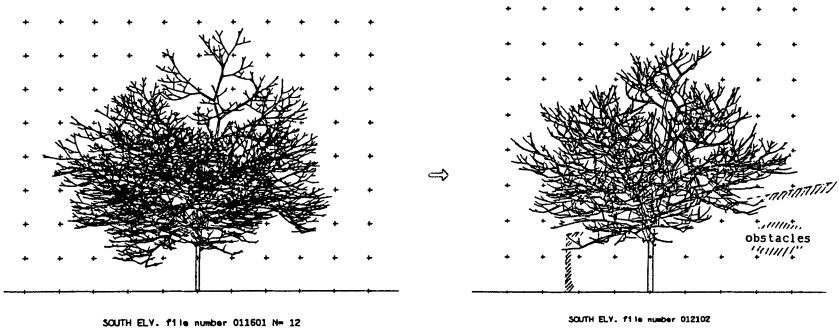
Two Types of Obstacles, Stationary and Live, can be Painted on the Spherical Screen.

I. Stationary Obstacles



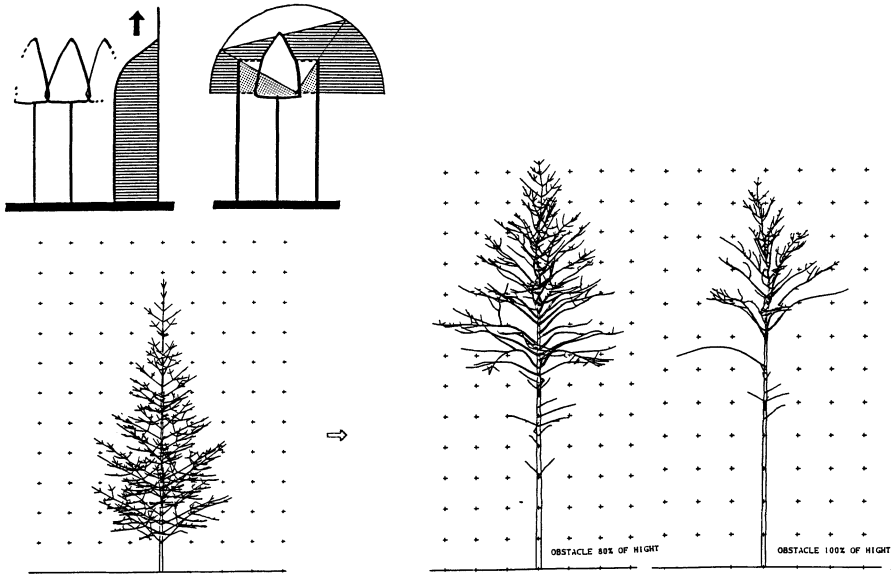
0	0	0	0	3	2	0	0	0	0	0	0
0	0	20	16	47	40	0	0	0	0	0	15
34	36	70	100	60	22	49	80	62	51	65	100

(%)



(Fig.13 stationary obstacles have a constant effect on the resultant tree shape)

II. Live Obstacles



(Fig.14 the resultant shape of tree with a live obstacle 80% or 100% of its hight in a planted forest can be simulated)

7. PROGRAM FLOWCHART & VARIATIONS OF SHAPES