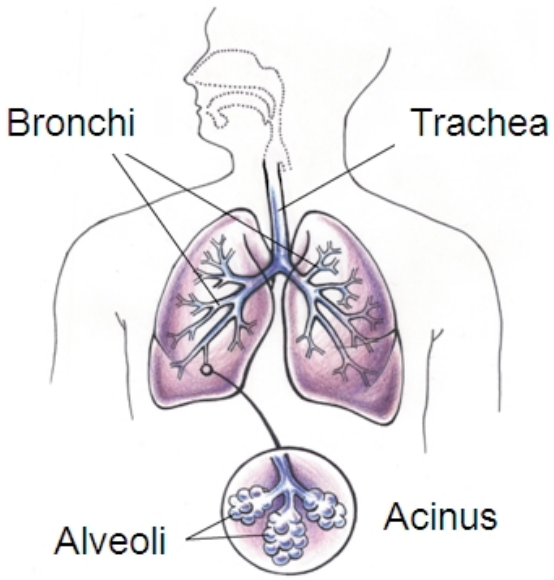

Fig. 1. Anatomical scheme of the human lung.

one correspondence between a branch and its air-supplying region in the lung.

The pulmonary acinus is defined as a parenchymal region supplied air by a terminal bronchiole (TB), and is regarded as a respiratory unit of the lung parenchyma (Weibel, 1963). The term of "bronchiole" means "a small bronchus". The TB branches three times in average and branched bronchioles are called "respiratory bronchioles (RB)" because there are a few alveolar opening in their inner walls. The last RB still branches several times, however, branched ducts are no more bronchioles but called "alveolar ducts" because the duct walls are completely replaced by alveoli (Weibel, 1963), as shown in a circle in Fig. 1. Terminal alveolar ducts with dead ends are called alveolar sacs. The subacinus, defined as the parenchymal region supplied air by the last RB, purely consists of the alveolar system without airway components (Haefeli-Bleuer and Weibel, 1998). Therefore, in this paper, not the acinus but the subacinus is used as the minimum respiratory unit. The inner structure of the subacinus is generated by two algorithms (Kitaoka *et al.*, 2000, 2007). The 3D labyrinthine algorithm assigns the air pathway in a given space (Kitaoka *et al.*, 2000), and the morphogenesis-based alveolar deformation algorithm assigns 4D structure of the alveolar duct (Kitaoka *et al.*, 2007). Although there are several other alveolar models (Weibel, 1963; Fung, 1988; Fichele *et al.*, 2004), those models do not include temporal changes. The whole lung motion is computed according to the formula in the previous paper (Kitaoka and Kawase, 2007).

Potentially, *Lung4Cer* can make a whole airway tree model with several hundred million alveoli. However, it requires incredibly huge amount of computer resource. Instead, it is feasible to select a model type according to user's interest and available computer resource. Model types provided by *Lung4Cer* are: (1) airway tree only, (2) airway tree with air-supplying parenchymal regions, (3) air pathway from the trachea to a subacinus with alveolar structure, and (4) alveolar system only.

2.2 Operation of *Lung4Cer*

The lung model generation is executed by assigning twelve parameters. "Model type" assigns a basic model type mentioned above. "Branch number in the airway tree" assigns the anatomical hierarchic level of terminal branches in the airway tree. "Region of interest (ROI)" assigns a target region for modeling, from the whole lung down to respective lung segments. There are five parameters for assigning composition of the alveolar system (details are described in the manual).

There are four parameters to assign breathing mode, lung capacities at the beginning and the end of inspiration, the ratio of inspiratory period to the total respiratory period, and the body posture. The lung capacity (LC) can be expressed by an equation as follows,

$$\mathrm{LC} = \mathrm{RV} + f \cdot \mathrm{VC},$$

where RV is the residual volume (=minimum lung volume), VC is the vital capacity (=the difference between minimum and maximum lung volumes), and f is the volume fraction of VC. LC is equal to the total lung capacity (TLC, =maximum lung volume) when $f = 1$, and is equal to RV when $f = 0$. In the present model, the functional residual capacity (FRC, =the expiratory lung volume at rest) is assigned at $f = 0.35$, and the inspiratory lung volume at rest is assigned at $f = 0.5$. Since the lung parenchymal volume is dependent on the parenchymal position and body posture, the value of f should be regarded as an approximated value rather than the absolute value. For the model type of alveolar system only, $f = 1$ indicates the maximum volume of the alveolar duct and $f = 0$ indicates the minimum value (about 20% of the maximum volume in the present algorithm).

After assignment of necessary parameters for model generation, a set of files for visualization is generated. All models indicated in the present paper are generated within ten minutes using a common PC (for example, single core of 3.3 GHz CPU with 2GB memory).

2.3 Observation of the model by "*ParaView*"

ParaView is one of the most popular free applications for scientific visualization developed in the US, which can easily be downloaded by internet. It visualizes various data from a simple graph to complex mechanical simulation data. A user can observe an object translucently, rotated, magnified, clipped, sliced, and animated. All pictures presented in the present paper were taken by *Paraview*. Basic methods for observing 4D lung models are described in the manual on the present author's homepage (http://www7b.biglobe.ne.jp/∼lung4cer/4CerManualE.pdf)

3. Examples of 4D Lung Model

3.1 Airway tree model with air-supplied parenchymal regions

A lung parenchymal region is approximated as a set of cubes whose side lengths are equal to the diameter of the air-supplying branch. There is an approximated relationship between the diameter of a branch (D) and the volume of parenchymal region to which the branch supplies air (V):

$$\mathrm{V} \simeq 1{,}000 \cdot \mathrm{D}^3.$$