Development of motion image prediction method using principal component analysis

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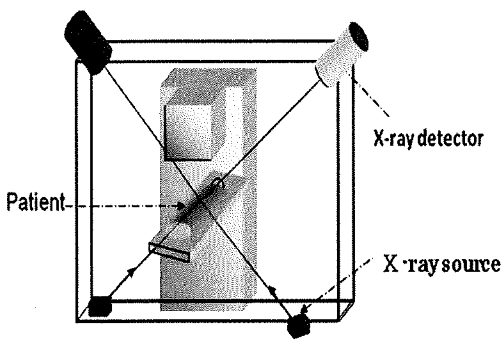
Respiratory motion can induce the limit in the accuracy of area irradiated during lung cancer radiation therapy. Many methods have been introduced to minimize the impact of healthy tissue irradiation due to the lung tumor motion. The purpose of this research is to develop an algorithm for the improvement of image guided radiation therapy by the prediction of motion images. We predict the motion images by using principal component analysis (PCA) and multi-channel singular spectral analysis (MSSA) method. The images/movies were successfully predicted and verified using the developed algorithm. With the proposed prediction method it is possible to forecast the tumor images over the next breathing period. The implementation of this method in real time is believed to be significant for higher level of tumor tracking including the detection of sudden abdominal changes during radiation therapy.

Key word: image prediction, lung tumor, radiation therapy, tumor tracking

Introduction :

Cancer related death in Japan is increasing yearly and lung cancer has the highest rate of occurrence among all other cancers. The standard treatment is surgery, radiation therapy, chemotherapy or the combination of both chemotherapy and radiation therapy. In modern day radiation therapy precision has been a major challenge, when it comes to a moving organ like lungs, the amplitude of motion can be clinically significant (~2-3cm)[1] so limiting the radiation to the target and sparing the surrounding healthy tissue is always a concern. In order to compensate the tumor motion, various strategies such as like radiation respiration gating, breath hold, beam tracking etc. have been investigated [2]. The breath hold technology is not widely accepted by the patients. Both respiratory gating and beam tracking requires a precise knowledge of tumor position. The advancing technology in image guidance has led to the more improved result for the patients in lung cancer radiation therapy. There are several methods to determine the position of the tumor during the treatment which includes direct fluoroscopic tumor tracking, using fiducial markers or interference of the tumor position from anatomic surrogates such as abdomen [1]. Direct tumor tracking is



still under investigation. Tumor tracking with fiducial marker is invasive for the patients as there is always a risk of pneumothorax. And localizing tumor based on the surrogates requires a good correlation between the tumor and the surrogate [4].

Hence the goal of this study is to predict the future motion image of the tumor in order to improve the image guided radiation therapy. (Fig1.)

Material and Methods

To develop the purposed algorithm time series x-ray images are used as an input. The input data are divided into training set of data and testing set of data.

The procedure mainly consists of three parts.

i). **Principal component calculation using PCA**

First we have number of time series images. Each image is considered as vector I_N, where N is the number of images. We construct a matrix X for vector I where each row represents a displacement vector of a certain voxel in the lung. Performing a PCA gives the eigen value and eigen vector. We can express X(t) as a linear combination of the eigen vectors obtained from PCA [3]. Eigenvector with highest eigenvalue is the principal component of the matrix. Then the coefficient is calculated as shown in equation (1) below.

$$a_i(t_1,t_2,t_3,\ldots\ldots t_N) = X^T(V_1,V_2,\ldots\ldots V_i) \quad \ldots\ldots\ldots(1)$$

Here, a is the coefficient, i is the number of principal component, t represents the time, T is the transpose and N is the number of images.

ii). **Prediction using MSSA**

The second part of our method is the prediction part using MSSA. The future coefficient is predicted using multiple channel singular spectral analysis by using the principal coefficient for the previous time series images. Equation (2) shows the future coefficient which are to be used for the reconstruction of future images.

$$a_i(t_{N+1}, t_{N+2}, t_{N+3}, ...)......(2)$$

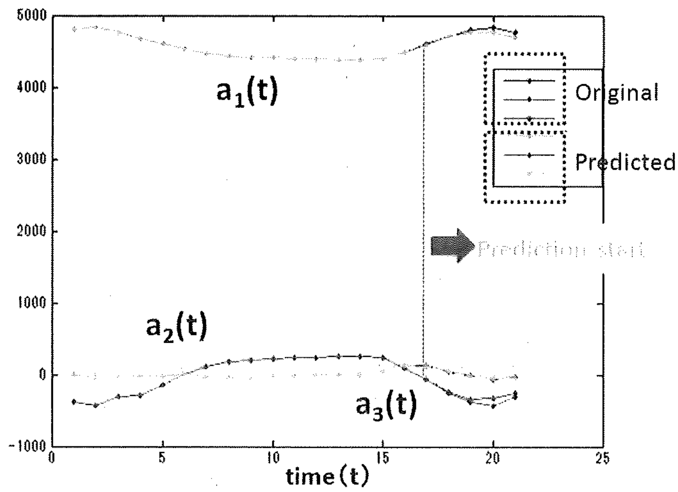
iii). **Reconstruction using PCA**

After the prediction of the coefficients by MSSA which is the extension to the multiple dimension from SSA, singular spectral analysis [4]. We reconstruct the new future motion image as shown in equation (3) using the coefficient predicted by MSSA.

$$I(t_N, t_{N+1}, t_{N+2}, t_{N+3}, ...).......(3)$$

Result and Discussion :

Fig 2. shows that the future coefficients were successfully predicted with some minimum error. $a_1(t)$, $a_2(t)$ and $a_3(t)$ are the coefficients obtained from PCA and successfully predicted using MSSA. We were also able to reconstruct the image with considerable accuracy and time less than 50secs. In addition to the prediction the evaluation of predictability was performed. We used some input image sequences as testing images to verify the result. The quantitative analysis of the error is less than 3%.



Conclusion :

We have developed the prediction method using PCA and MSSA. The prediction time is less than 50secs which seems to be quite considerable.

As a future task, the reduction of the error and improvement in calculation time for real time prediction needs to be done. We are also considering the sudden abdominal change detection and possibly its prediction for our future works.

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