Commissioning of SharePlan: The Liverpool Experience

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Abstract. SharePlan is a treatment planning system developed by Raysearch Laboratories AB to enable creation of a linear accelerator intensity modulated radiotherapy (IMRT) plan as a backup for a Tomotherapy plan. A 6MV Elekta Synergy Linear accelerator photon beam was modelled in SharePlan. The beam model was validated using Matrix Evolution, a 2D ion chamber array, for two head-neck and three prostate plans using 3%/3mm Gamma criteria. For 39 IMRT beams, the minimum and maximum Gamma pass rates are 95.4% and 98.7%. SharePlan is able to generate backup IMRT plans which are deliverable on a traditional linear accelerator and accurate in terms of clinical criteria. During use of SharePlan, however, an out-of-memory error frequently occurred and SharePlan was forced to be closed. This error occurred occasionally at any of these steps: loading the Tomotherapy plan into SharePlan, generating the IMRT plan, selecting the optimal plan, approving the plan and setting up a QA plan. The out-of-memory error was caused by memory leakage in one or more of the C/C++ functions implemented in SharePlan fluence engine, dose engine or optimizer, as acknowledged by the manufacturer. Because of the interruption caused by out-of-memory errors, SharePlan has not been implemented in our clinic although accuracy has been verified. A new software program is now being provided to our centre to replace SharePlan.

1. Introduction

SharePlan is a treatment planning system (TPS) developed by Raysearch Laboratories AB (Stockholm, Sweden) for TomoTherapy (Tomo) [1]. The system uses a Tomotherapy plan generated with the TomoTherapy Hi ART system as input and produces a step-and-shoot IMRT plan that is deliverable on a traditional linear accelerator (Linac). SharePlan was designed to replace the procedure of manually creating a backup IMRT plan for treatment on a traditional Linac for each patient being treated on Tomotherapy. Clinical use of SharePlan is expected to result in more efficient generation of backup-plan Tomotherapy plans for centres where only one Tomo unit is installed.

The first step towards introducing SharePlan into routine clinical practice is to commission the system. Commissioning and verification of a beam model in SharePlan was reported by Kristoffer Petersson and his colleagues [2]. Their investigation proved that SharePlan was a useful and time-saving complement for single Tomo unit clinics. In June 2012, one TomoTherapy Hi ART system was installed and commissioned in our centre. One step-and-shoot IMRT plan was created as a back-up plan in Pinnacle (Philips) treatment planning system for each Tomotherapy patient. As a high clinical priority, SharePlan was evaluated with the intention to integrate it into our clinical TomoTherapy procedure. The purpose of this paper is to report our experiences of commissioning SharePlan for clinical use.

2. Materials and Methods

2.1. The virtual linear accelerator in SharePlan

SharePlan includes a generic virtual linear accelerator model that can be adjusted to match the mechanic and dosimetric characteristics of a real Linac. The real Linac either manufactured by Elekta, Varian or Siemens is simulated using a fluence and dose engine. The fluence engine is used to generate the energy fluence map in air at an isocenter plane of a Linac for a given external beam, while the dose engine calculates the dose in patient or phantom for this beam. The fluence engine in SharePlan is a four-source model [3] that takes into account the photons and electrons coming from the target and flattening filter, whereas the dose engine is a collapsed cone (CC) type of algorithm based on the work by Ahnesjo [4].

The dose and fluence engine were implemented using a low-level programming language C/C++ as calculation of dose and fluence is computationally intensive [3]. The implementation details of the dose and fluence engine was hidden from the end-user, but the adjustable parameters of the fluence model and dose model were available to users through different user interfaces. These parameters have to be adjusted to make the virtual Linac model match a specific type of physical linear accelerator.

2.2. Establishment of a 6MV beam model

A virtual Linear accelerator for an Elekta Synergy Linac 6MV photon beam was established as a treatment unit model based on an existing template model in the machine data base. The virtual Linac head was configured to be the same as a Synergy Linac head using the geometric parameters provided by Elekta. The energy spectrum for the 6MV photon beams emitted from the virtual Linac were matched to the Elekta Linac by adjusting dose and fluence parameters to ensure the dose-engine calculated percentage depth dose data (PDDs) matched the PDDs measured on the Synergy Linac for the following fields: 2x2,3x3, 5x5,10x10,15x15,20x20 and 30x30 cm. Similarly the photon fluence calculated by the fluence engine and emitted from the Synergy Linac was matched at the isocenter plane by matching the in-plane and cross-plane dose profiles calculated with the measured profiles in water at depths of 1.5, 5, 10 and 20 cm. The matching criteria for PDDs were 2% for the depth beyond dmax and 2mm distance-to-agreement (DTA) for the build-up region. Criteria of 2% were used for matching the central part of dose profiles and 2 mm DTA for penumbra region [5].

Matching the energy spectrum and energy fluence emitted from the virtual Linac model in SharePlan with ones from a physical Synergy Linac is an iterative procedure. The adjustable parameters for the dose and fluence engines were editable via simple user interfaces. There are two types of adjustable parameters for the energy-spectrum model: the relative weight of the energy spectrum and the output correction factor. SharePlan has a built-in automation tool to aid beam modelling. The auto-modelling tool was found to only be useful as a starting point for manual adjustment. After auto-beam modelling, PDDs and profiles were not matched in all regions for all

field sizes. Time-consuming manual adjustment was still required to commission a beam model in SharePlan. The same procedure was used for adjusting the fluence engine for the beam model. The adjustable parameters for fluence engine and how to adjust them are described in detail in the SharePlan physics manual [1].

*2.3. Validation of the beam model*

The commissioned beam model was used to generate step-and-shoot IMRT plans that were deliverable on an Elekta Synergy Linac. The optimizer implemented in SharePlan uses objective functions that take into account the difference between the dose volume histogram (DVH) of the plan under optimization and the DVH of the Tomotherapy plan to establish an optimal Linac plan. The accuracy of the optimization engine along with the dose and fluence engine can only be verified using IMRT beams. The accuracy of the commissioned beam model for square non-IMRT fields was validated by matching calculated PDD and dose profile with measured ones for these fields during beam modelling. End-to-end tests were performed to verify the beam model using two head neck and three prostate Tomotherapy plans.

For each patient plan, the Tomotherapy plan used for treatment was loaded into SharePlan. A corresponding step-and-shoot IMRT plan was generated for the Elekta Synergy linear accelerator. Seven beams were used for prostate while nine beams for head-neck cases. A quality-assurance (QA) plan was created using Matrix Evolution. Matrix is an array of chambers routinely used for patient delivery quality assurance for our Tomo plans. The QA plan was delivered to Matrix Evolution on an Elekta Synergy Linac. The measured dose distribution was compared with calculated ones utilising a two dimensional (2D) Gamma map with 3%/3 mm criteria [7].

3. Results and Discussion

3.1. Beam model verification results

Figure 2 shows the overlap between calculated PDDs and dose profiles for the simple square fields used for beam model commissioning. For PDDs, a good agreement between the model calculated and measured dose was achieved, indicating that the energy spectrum used by the commissioned 6MV virtual Linac model matched the physical energy spectrum of the 6MV photon beam emitted from the Elekta Synergy Linear accelerator. The accuracy of the fluence engine used for calculating the energy fluence at the isocenter plane in air was shown in figure 2(a). The calculated and measured dose profiles were in good agreement for the central part and penumbra regions. A trade-off had to be made ensuring a good match in the shoulder regions for small fields less than 15x15 cm while slightly sacrificing the shoulder regions for large fields.

(a)

(b)
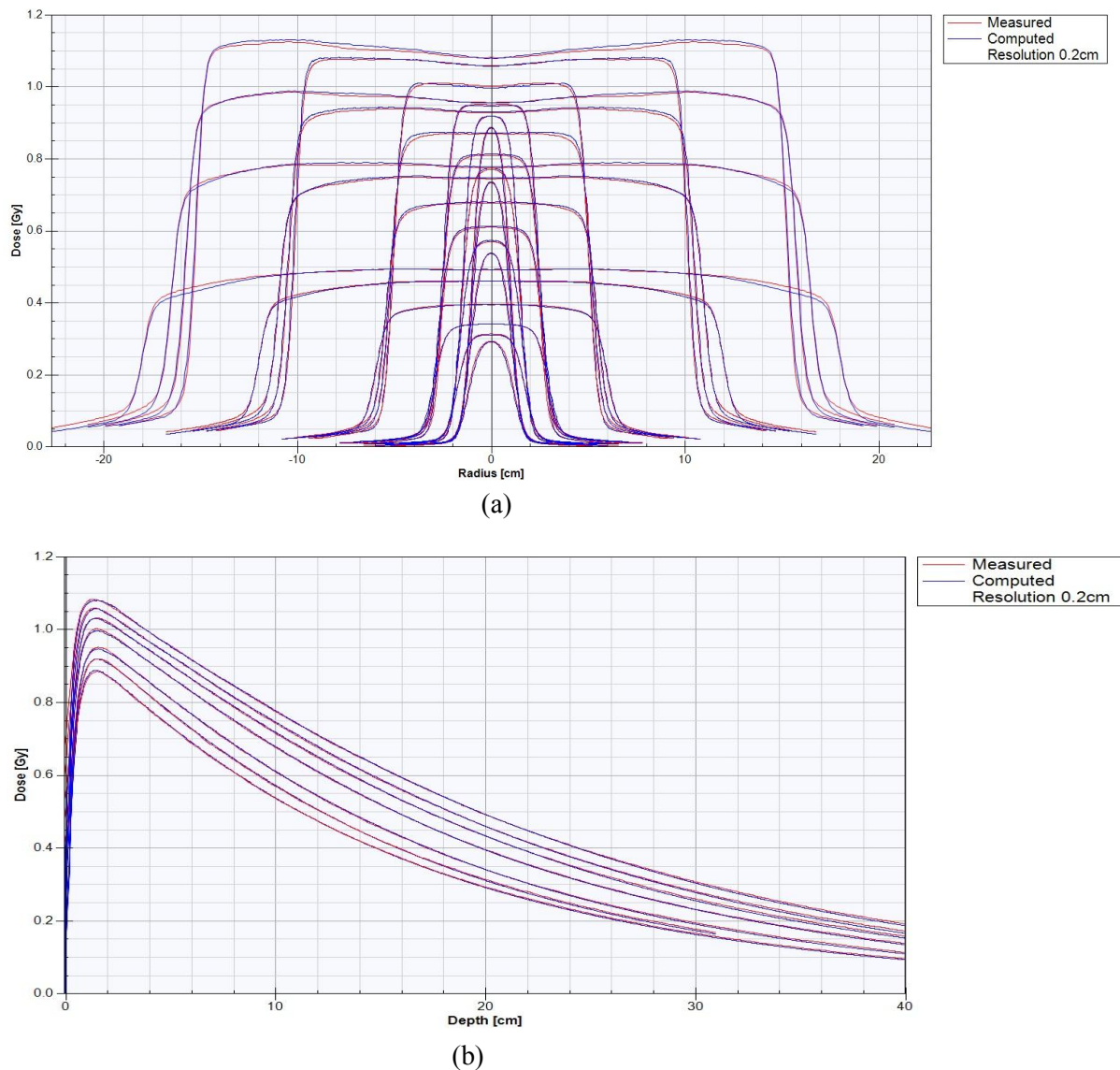
Figure 2. Comparison between measured dose in water and the dose calculated by the commissioned beam model for (a) cross-plane profiles and (b) PDDs for the following fields: 2x2,3x3, 5x5,10x10,15x15,20x20 and 30x30 cm. The measured data is represented by the redline while the blue line stands for the calculated data.

For end-to-end testing, a 2D dose distribution was measured for each of a total of 39 IMRT beams and compared with those calculated with SharePlan. The minimum and maximum pass rate was 95.4% and 98.7% with a mean value of 97.05%. The clinically acceptable criteria in our centre are over 95% [7]. The average gamma pass rate for each patient plan is shown in table 1 and figure 3 shows the gamma map for one IMRT beam from a prostate patient plan.

Table 1. Gamma pass rates averaged over patient IMRT beams for five patients

| Patient #	Averaged Gamma pass rate (%)
1	97.72
2	95.17
3	98.40
4	97.23
5	97.75
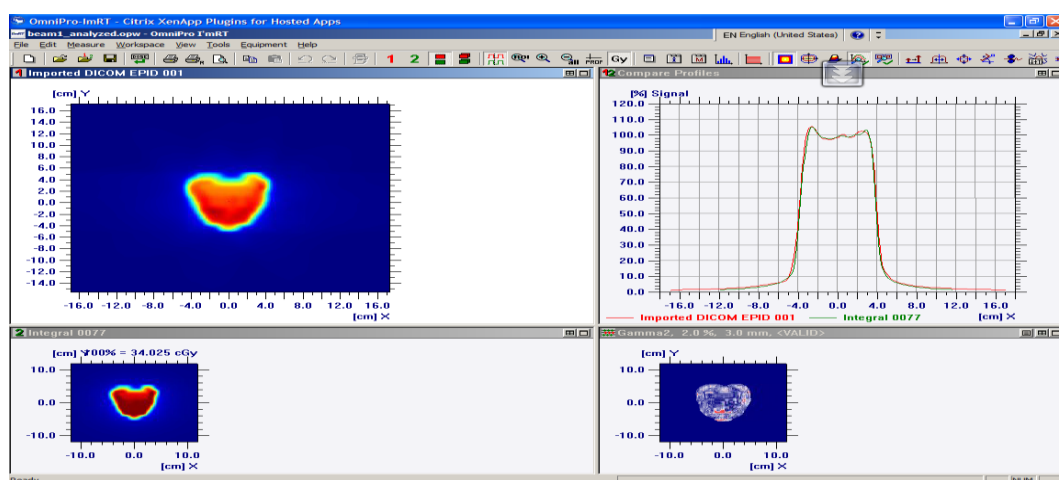
Figure 3. The Gamma map calculated for one IMRT beam from one prostate patient plan. The 2D dose map in the upper left corner shows the Matrix measured dose map while the bottom left corner shows the dose map calculated by SharePlan. The calculated Gamma map is shown at the right bottom panel. The profiles along x axis passing through the center of dose image are plotted at upper right panel.

The end-to-end results demonstrate that the generic linear accelerator implemented in SharePlan can be customized to match a physical linear accelerator via a commissioning procedure. After the beam model was commissioned, the dose and fluence engine were demonstrated to accurately calculate the dose and energy fluence in patients. The IMRT plan generated by the SharePlan optimization engine is deliverable and accurate in term of clinically acceptable criteria, which was also demonstrated by Petersons [2].

3.2. Out-of-memory errors in the SharePlan workflow

To generate a step-and-shoot IMRT plan from a Tomotherapy plan, there are four simple steps to follow after importing the patient Tomotherapy plan into the system: generate plans, plan selection, plan approval and QA setup. The patient IMRT plan and QA plan used for verification were generated following these steps. During our commissioning as shown in figure 4, an error message window frequently popped up saying the system is running out of memory. It occurred on occasion during all of these steps, requiring SharePlan to be closed and restarted again. To avoid this restart requiring the entire workflow to be reinitiated, progressive work had to be regularly saved by the user. The calculation grid was reduced to reduce memory requirements however this did not improve the

situation. For each plan, in order to generate the patient IMRT plan and QA plan, SharePlan or the computer had to be restarted many times.
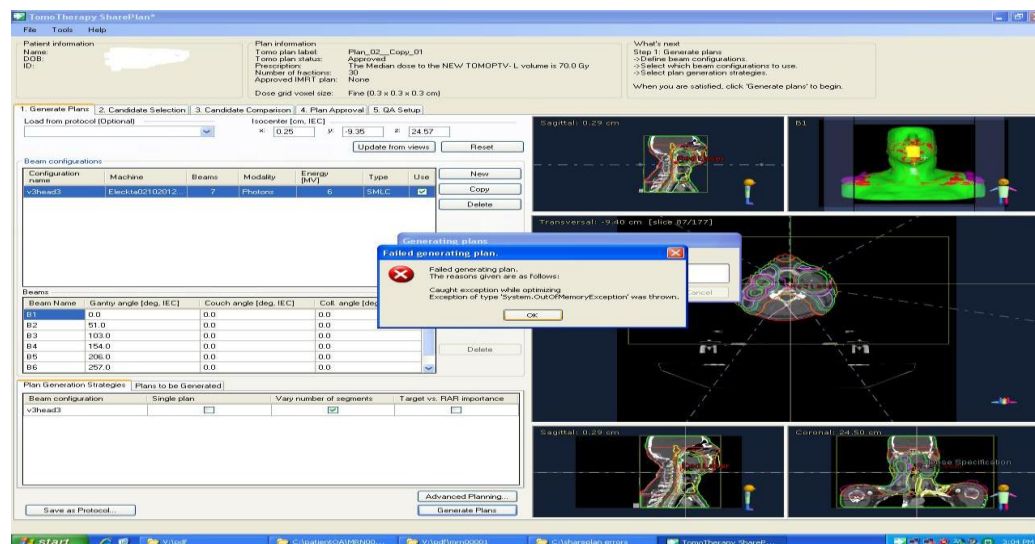
Figure 4. An example of the out-of-memory error thrown out during the use of SharePlan. Following this error SharePlan must be closed and restarted.

The out-of-memory issue is caused by one or more C/C++ functions implemented in the SharePlan fluence engine, dose engine or optimizer. In these functions, some variables are allocated memory, but the memory assigned is not freed at the end of the lifetime of these variables. For each occasion that the functions were called during the dose calculation or optimization increased memory is required resulting in the system running out of available memory. This is a well-know memory-leakage issue in C/C++ programming [6]. As a result of the out-of-memory issue, clinical workflow using this software was not considered feasible. The manufacturer has acknowledged these problems and has now released another software product to replace SharePlan to generate TomoTherapy back-up plans.

4. Conclusion

SharePlan was commissioned with the intention of clinical use. SharePlan was shown to generate backup plans which are accurate and deliverable on a traditional Linac. During the use of SharePlan, however out-of-memory errors resulted in workflow issues resulting in SharePlan not being used clinically. The manufacturer has acknowledged the problem and new software will shortly be installed in our centre to replace SharePlan.

References

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