Synthetic aperture imaging radar signal simulation of urban environments

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MEng interim individual project report part A

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Part 1

Project Plan

1.1 Scope and Aims

This project is to create a simulator that can show the transformation between a 3 dimensional model and a 2 dimensional image using synthetic aperture imaging radar mostly for use as a demonstration tool. This is a method of radar that generally uses the movement of the platform that the radar transceiver is mounted on to build up an image based on the range that the radar signal travels and the reflection characteristics of the surface it is reflected off of. This form of radar imaging has a higher resolution than a conventional radar transceiver as the aperture size is based on how far the platform travels during the time it is imaging a target, and so the aperture is far larger than could be physically constructed.

The main aim of this project is to create a very basic simulator that can take a cube as an input and output an accurate SAR image. This will require a few steps to achieve. The first will be to create a scene in the chosen programming platform, which as of writing this document is MATLAB and Simulink, created by MathWorks. The radar pulse signal will need to be simulated as well as effects of multipath reflection, and finally the response received by the simulated radar will need to be transformed to an image by use of backscattering or an Omega-K algorithm. A secondary aim is to simulate the inclusion of speckle within the image, which is a SAR image artefact created by the sum of contributions from a large number of scatterers, thereby increasing the realism of the output image.

More advanced aims of this project are to be able to simulate the more advanced scenes such as actual urban environments and to simulate the multipath reflection effects of the radar signal in this area. This will end up requiring a more efficient implementation so the final major aim is to implement either a ray tracing or rasterisation approach, which are common methods of transforming a 3 dimensional space to a 2 dimensional image, most commonly used in animation and video games. While in other SAR simulation implementations efficiency is something that is considered, this is not necessarily something that is within the scope of this project. Improvements in efficiency are desirable up to a point however accuracy and functionality are more important. This is especially true as some of the literature (as covered later) focuses on a real-time implementation which is desirable for some applications, especially in practical applications such as determining SAR platform flight paths. It is not so applicable here in a demonstration application.

1.2 Project Plan

1.2.1 Workplan

A series of steps have been defined to help meet the overall aims as defined previously. The exit criteria for each of these packages are major milestones and will be defined appropriately.

Step 1 - Basic 3D Modelling

The purpose of this step is to create a 3 dimensional model of a cube using a modelling package. This step will have more time built in than is required as it also includes some research on the best technology to use, above the research that has already been performed. This step will also require some time to learn the tool chosen. The exit criteria for this step is being able to display a 3 dimensional model on screen and view it from different directions using the tools provided by the software package.

Step 2 - Antenna Beam Simulating

This step will overlap somewhat with step 1 as they can be performed in two separate environments. A basic definition of the platform that the radar is mounted on will be created as well as a basic definition of the characteristics of the radar's beam with the characteristics of the propagation medium. The exit criteria for this step of the project is to have a model of the environmental parameters and the radar parameters.

Step 3 - First Order Contributions

Having created the 3 dimensional model, this step will have the purpose of defining the reflection characteristics of the environment. This step is only to simulate the first reflections off of the target structure or the ground, and not the results from the radar signal reflecting off of the wall and then the ground or vice versa. This only really requires the completion of step 1, as all reflections can be tested using an emitter at a single point and does not need to have accurate responses, only to prove that the radar signals will reflect off of the model in a coherent and predictable way. The exit criteria for this is to have a reflection based on the dielectric constant of the model building and a different dielectric of the model ground, to be defined and hard coded into the program for different materials.

Step 4 - Create Output Image

This is the first step that will actually produce a visible result, using a matched filtering algorithm yet to be determined but most likely time-domain Backprojection, due to its flexibility. The technique uses the difference between what the radar is expecting and what it actually receives in order to construct an image. The exit criteria for this step is to be able to produce an image based on the raw SAR data that is generated from the simulated platform.

Step 5 - Simulate Second Order Contributions

This is the final necessary step for completion of this project, and is an extension to step 3. The purpose of this step is to add in the effects of the antenna beam reflecting off both the ground and the wall, in either permutation, before returning to the receiver. This will complicate the final image somewhat but also more accurately simulate its effects.

The exit criteria for this step is to include the effects of second order contributions in the output image.

Step 6 - Complicate Scene and Increase Order Contributions ***(Optional)***

This step will involve increasing the number of structures in the simulated scene as well as simulating third order contributions and above. This is when the signal reflects off of objects three or more times before returning to the receiver. The contributions from this are exceedingly small however it is still worth implementing as it will contribute something. The scene complications will also involve a more accurate dielectric modelling, with an attempt at windows and other non-stone aspects of a building. The final aspect of this is to be able to extract a scene from a mapping tool such as OpenStreetMap or Google Earth and import it into the program before using that to generate an image. The exit criteria for this step is to produce an image of a more complicated scene and be able to import a section of a Google Earth or OpenStreetMaps 3D model as the complexity of this will likely require the next step to image correctly.

Step 7 - Implement Hybrid Method ***(Optional)***

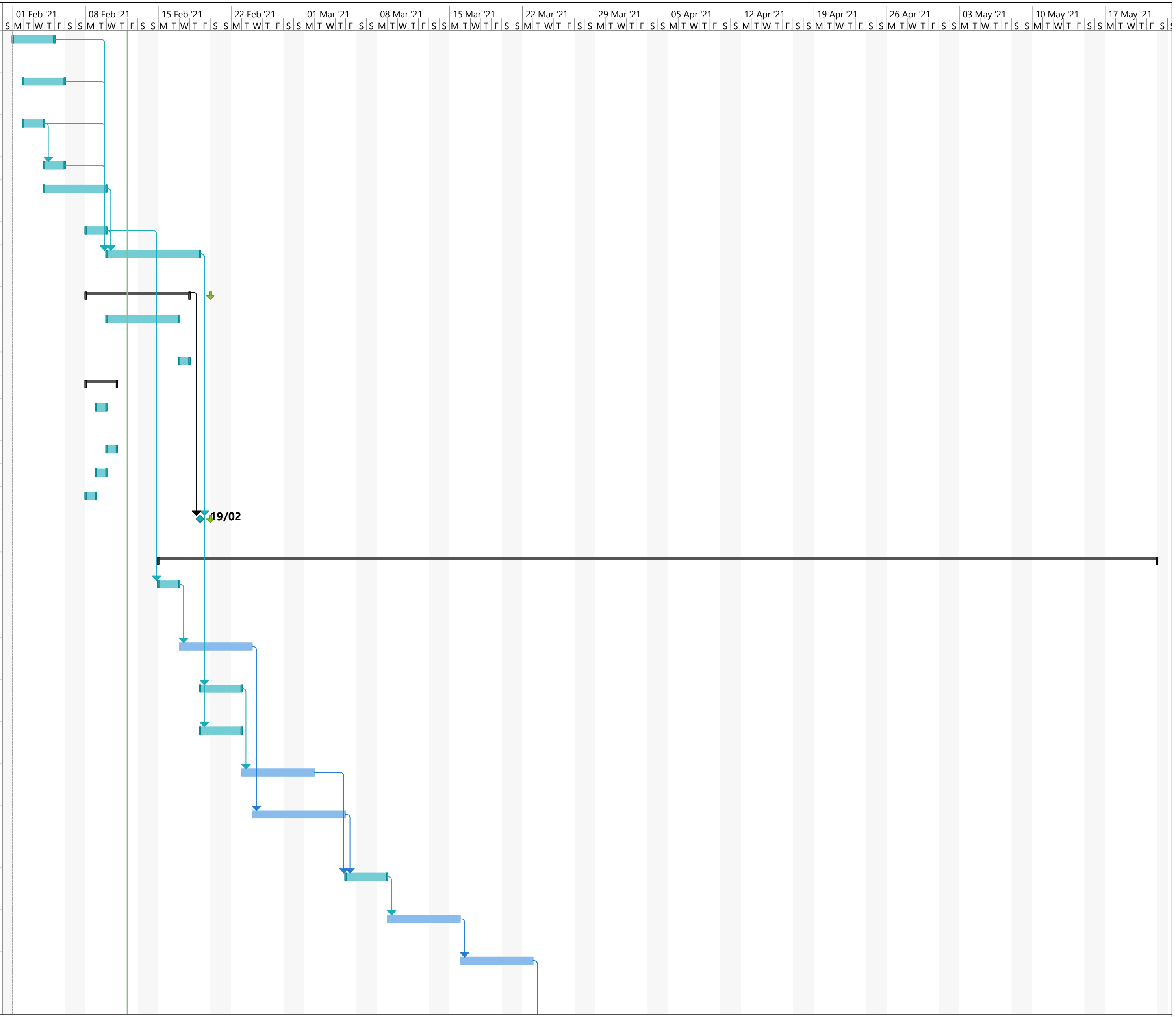
This step is to use a secondary method to reduce the computational complexity of creating the raw SAR image. There are a few approaches to this that have been investigated in the literature and are explored in more depth in part B. The actual method used is currently undecided as is the approach taken towards its implementation however the goal is to improve the efficiency of the simulator while maintaining a high level of accuracy in the output SAR image. The exit criteria for this milestone is to have an implementation of a hybrid method that improves the calculation efficiency.

Step 8 - Extra Time

This step is a catch-all step if other steps take longer than was previously expected or to implement other features that are decided upon during the implementation of previous steps. This is to avoid feature creep during the process as unless it is absolutely necessary it can be deferred to this step. This step has no exit criteria, however will result in the program being finished and after this stage no more features will be added.

1.3 Gantt Chart

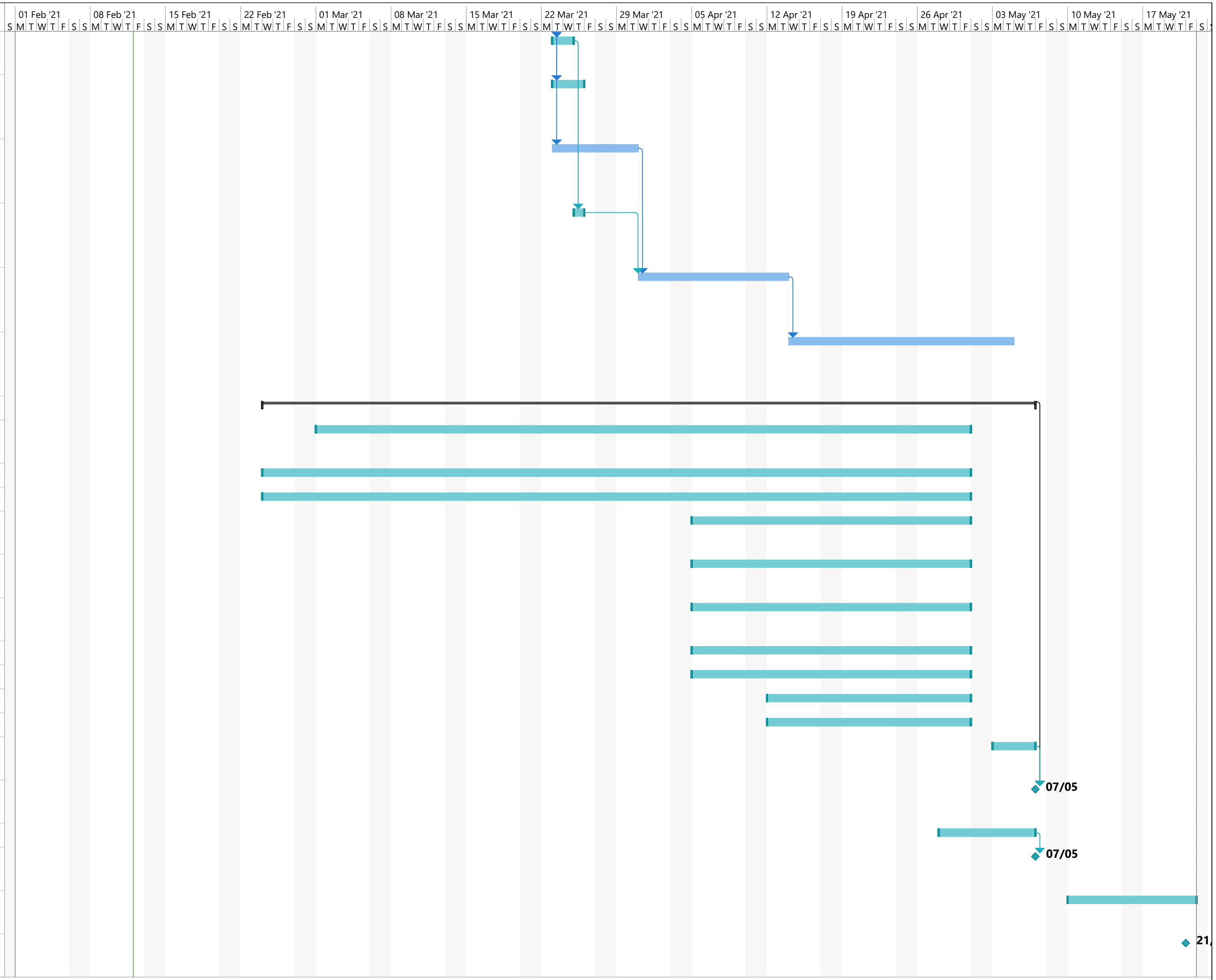
ID	Task Name	Duration	Start	Finish	Predecessors
1	Research Previous Appproaches	4 days	Mon 01/02/21	Thu 04/02/21	
2	Research Possible Solutions	4 days	Tue 02/02/21	Fri 05/02/21	
3	Decide on tasks and steps	2 days	Tue 02/02/21	Wed 03/02/21	
4	Create Gantt Chart	2 days	Thu 04/02/21	Fri 05/02/21	3
5	Define Scope and Aims	4 days	Thu 04/02/21	Tue 09/02/21	
6	Define Project Plan	2 days	Mon 08/02/2	Tue 09/02/21	
7	Write Interim Report	7 days	Wed 10/02/21	Thu 18/02/21	1,2,3,4,5,6
8	**Interim Report**	**8 days**	**Mon 08/02/2**	**Wed 17/02/2**	
9	Project Background	5 days	Wed 10/02/21	Tue 16/02/21	
10	Title Page	1 day	Wed 17/02/2	Wed 17/02/2	
11	**Project Plan**	**3 days**	**Mon 08/02/2**	**Wed 10/02/2**	
12	Scope and Aims	1 day	Tue 09/02/21	Tue 09/02/21	
13	Project Plan	1 day	Wed 10/02/2	Wed 10/02/2	
14	Gantt Chart	1 day	Tue 09/02/21	Tue 09/02/21	
15	Risk Table	1 day	Mon 08/02/2	Mon 08/02/2	
16	Interim Report Submission	0 days	Fri 19/02/21	Fri 19/02/21	7,8
17	**Final Report**	**70 days?**	**Mon 15/02/2**	**Fri 21/05/21**	
18	Research 3D Modelling Environment	2 days	Mon 15/02/21	Tue 16/02/21	6FS+3 days
19	Create a basic 3D environment	5 days	Wed 17/02/21	Tue 23/02/21	18
20	Define Platform characteristics	2 days?	Fri 19/02/21	Mon 22/02/21	7
21	Define medium characteristics	2 days	Fri 19/02/21	Mon 22/02/21	7
22	Simulate Antenna beam	5 days	Tue 23/02/21	Mon 01/03/21	20
23	Simulate first order contributions	7 days	Wed 24/02/21	Thu 04/03/21	19
24	Implement Matched Filtering	2 days	Fri 05/03/21	Mon 08/03/21	23,22
25	Create output image	5 days	Tue 09/03/21	Mon 15/03/21	24
26	Simulate second order contributions	5 days	Tue 16/03/21	Mon 22/03/21	25



Project: fyp
Date: Fri 12/02/21

Task | Summary | Inactive Milestone | Duration-only | Start-only | External Milestone | Manual Progress
Split | Project Summary | Inactive Summary | Manual Summary Rollup | Finish-only | Deadline
Milestone | Inactive Task | Manual Task | Manual Summary | External Tasks | Progress

ID	Task Name	Duration	Start	Finish	Predecessors
27	Increase to higher orders	2 days	Tue 23/03/21	Wed 24/03/21	26
28	Model a scene with multiple buildings	3 days	Tue 23/03/21	Thu 25/03/21	26
29	Extract scene from external mapping tool	6 days	Tue 23/03/21	Tue 30/03/21	26
30	Decide on secondary method	1 day	Thu 25/03/21	Thu 25/03/21	27
31	Implement secondary more efficient method	10 days	Wed 31/03/21	Tue 13/04/21	29,30
32	Extra time for overspill or extra features	15 days	Wed 14/04/21	Tue 04/05/21	31
33	**Report Writing**	**52 days**	**Wed 24/02/2**	**Thu 06/05/2**	
34	Create Background	45 days	Mon 01/03/21	Fri 30/04/21	
35	Methods	48 days	Wed 24/02/2	Fri 30/04/21	
36	Documentation	48 days	Wed 24/02/2	Fri 30/04/21	
37	Milestones review	20 days	Mon 05/04/21	Fri 30/04/21	
38	Deliverables description	20 days	Mon 05/04/21	Fri 30/04/21	
39	Results exploration	20 days	Mon 05/04/21	Fri 30/04/21	
40	Uncertainty	20 days	Mon 05/04/2	Fri 30/04/21	
41	Conclusion	20 days	Mon 05/04/2	Fri 30/04/21	
42	Further work	15 days	Mon 12/04/2	Fri 30/04/21	
43	Extra parts	15 days	Mon 12/04/2	Fri 30/04/21	
44	Review and revise	4 days	Mon 03/05/21	Thu 06/05/21	
45	Final Report Submission	0 days	Fri 07/05/21	Fri 07/05/21	33,44
46	Design Poster	7 days	Wed 28/04/2	Thu 06/05/2	
47	Poster Submission	0 days	Fri 07/05/21	Fri 07/05/21	46
48	Presentation and Viva Voce	10 days	Mon 10/05/21	Fri 21/05/21	
49	Poster Exhibition (Interim)	0 days	Fri 21/05/21	Fri 21/05/21	



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Task, Split, Milestone, Summary, Project Summary, Inactive Task, Inactive Milestone, Inactive Summary, Manual Task, Duration-only, Manual Summary Rollup, Manual Summary, Start-only, Finish-only, External Tasks, External Milestone, Deadline, Progress, Manual Progress

1.4 Risk Table

Risk	Impact	Mitigation
Computer dies and can't be used	Delay project, some data may be lost	Data backed up automatically to iCloud and three weeks extra are built into the project to account for major delays, if there are more delays then non-key milestones can be removed
Discover chosen tools can't perform required functions	Delays project while new tools have to be found and existing work is ported over	Three week grace period as mentioned previously, spend more time initially to ensure chosen tools can perform required functions
Feature creep during design and implementation phase	Important features are delayed while unimportant features are added	Once the plan is finished stop adding features until all of the planned features are added then revisit the planned features, extra time is added into the project plan in order to facilitate this
Eye strain	Work will be slowed down due to having to recover	Ensure workspace is set up properly initially following the University of Bath Health and Safety Standard provided, follow 20-20-20 rule
Bug in program that makes the program unusable	Delay project due to debugging and re-writing	Extra time built in to project plan to deal with this
Progress grinds to a halt due to the difficulty of implementation	Delay project	Fallbacks methods have been identified within MATLAB which can be used as a platform for more advanced implementation