System Design Project 2015—Course Guide*

Subject to revision at any time

Henry S. Thompson

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1 Introduction

The System Design Project (SDP) is a group-oriented practical for 3rd year students. For this year the task is to use Lego Mindstorms to play two-a-side football, based loosely on both foosball and the Robocup competition.

Week	Date			Item
1	9am	Wed	14 Jan	Lecture: Introductory briefing
2	11am	Tue	20 Jan	Workshop: Robot design
2	11am	Wed	21 Jan	Workshop: Robot hardware
2	11am	Fri	23 Jan	Lecture/tutorial: System architecture
3	2pm	Wed	28 Jan	Milestone 1: Move and kick
3	4pm	Thu	29 Jan	Performance Review 1
5	2pm	Wed	11 Feb	Milestone 2: Using vision
5	4pm	Thu	12 Feb	Performance Review 2
[6	*Mon–*	*–Fri*	*16–20*	*Innovative Learning Week]*
8	2pm	Wed	4 Mar	Milestone 3: Co-operate
8	4pm	Thu	5 Mar	Performance Review 3
9	2pm	Wed	11 Mar	First Friendly
11	2pm	Wed	25 Mar	Second Friendly, assessed
11	4pm	Thu	26 Mar	Performance Review 4
12	2pm	Tue	31 Mar	Seeding Friendly
12		Wed	1 Apr	Final Day presentation practice
12	9am	Thu	2 Apr	Final Day
–	4pm	Thu	23 Apr	Final reports

*A summary of this guide is available at the course home page, but in case of any accidental disagreement, this document is definitive.

The class is divided into groups of 6 or 7, supervised by a mentor, who is a senior student or a member of staff. The mentor offers advice, monitors progress, and marks reports; it is not the mentor's job to give technical advice, nor to lead or manage the group—identification of roles, as well as assignment to them, is up to the group.

Lab space is allocated for 9am–1pm on Wednesday mornings, and milestones and friendly matches are scheduled for 2–3.30pm Wednesday. The lab may be used at other times, depending on use by other groups. During the last two weeks of term, the lab is reserved exclusively for SDP.

Garry Ellard, the course technician, is available as follows:

11.30am–1pm, 2–3.30pm	Mon Tue Thu Fri.
9–11am, 11.30am–1pm, 2–3.30pm	Wed.

Assessment involves

- group marks and individual marks
- for *product*, that is, the performance of the robots in three milestone tests, in an assessed friendly match, and in a final tournament, along with various reports;
- for *process*, that is, how well the team members participated and contributed.

Complete details of assessment are given below in section 3.

Each group is responsible for the development of a single robot. Groups are paired up to form *teams*, with one group responsible for the defending robot and the other for the attacking robot.

The robot development process is driven by a series of *milestone tests*, which engage progressively more sophisticated sensing and action capabilities, and facilitated by three early workshops/lectures (see timetable above).

Milestone testing occurs 2–3.30pm Wednesday in weeks 3, 5, and actual[1] 8. The first friendly match will occur 2–3.30pm Wednesday in week 9, and friendlies will continue in most weeks thereafter. The friendly in week 11 will be assessed. The Final Day presentations and tournament take place Thursday of actual week 12, with presentation practice on the day before. The whole group should be present for these activities.

Each group will have a number of distinct tasks to work on including robot design, vision, planning, motion, strategy, comms and co-ordination. You may want to build a simulator for your system. As well as physical tests, you may wish to test parts of the system in simulation, or play your robots against themselves in simulation.

[1] That is, counting ILW as week 6

Before the first milestone, you should have an initial architecture of your system and a plan for the remaining work. By the first milestone, you should select a team name and logo; include these in your first performance review summary.

This year's students will have access to last year's projects, and similarly you will be asked to allow future years to build on your work. Groups are expected to make judicious use of previous years's work, and not to reinvent everything from scratch. Credit will be given for building on previous work; credit may be withdrawn for deciding to build from scratch, unless there is good justification.

Notifications about course activities from the course team will be sent by email, using the `sdp-students@inf.ed.ac.uk` mailing list. Questions can be raised on that list. Groups are free to use any other form of communication they wish to.

2 Milestones

Milestone testing will take place on the main pitch in the Level 3 lab. Each milestone consists of two or three tasks, with each task to be attempted three times. For milestone 1, each group will be tested separately. For milestones 2 and 3, the two groups of each *team* will be tested together, but will be marked separately. Points are awarded per task as follows:

- 2 or 3 points: Perform the task reliably (all trials).
- 1 or 2 points: Perform the task unreliably (on some trials).
- 0 points: Fail to perform the task at all.

A typical group will earn 4 points out of a possible 6 for each milestone.

The milestone tasks are as follows (subject to revision up to a week before the test date):

- *Milestone 1: Robot construction, ball handling and mobility* [This milestone applies to each robot in a team independently] Demonstrate basic control of movement and kicking
  - The robot must be able to move in a straight line
  - It must be able to do a placed kick
  - You must be able to start and stop the robot from a remote computer
- *Milestone 2: Vision integration* Demonstrate a vision system controlling the robot in real-time:

(A) The attacking group's robot must be able to get control of a stationary ball, positioned so as to make it impossible to kick towards the goal from its starting position, and then manouevre so as to be able to kick towards an undefended goal

(D) The defending group's robot must be able to intercept a ball moving from opposition's attacking zone, control it, and kick it back towards the attacking zone

- *Milestone 3: Cooperation* Demonstrate co-operative play

(D) The defending group's robot must be able to get control of a stationary ball and pass it across an unoccupied adjacent zone to its (stationary) attacking teammate

(A) The attacking group's robot must be able to move so as to give a clear line for a pass from its (stationary) defending teammate when their initial positions and that of a (stationary) robot in the intervening zone mean no straight-line pass can get through

– The two robots, in the presence of a scanning robot in the intervening zone, must be capable of organising and achieving transfer of the ball from defender to attacker

3 Assessment

3.1 Performance reviews

After each milestone, and one of the friendlies, each group will conduct a performance review of its members. The group's mentor and a mentor from another group will be present and conduct the review, so as to come to a consensus view of the contribution made by each group member.

Each student brings to the performance review an individual report, describing her or his contribution in the previous fortnight. You should email your group mentor or group leader to submit the report (or the first four of the five points below) by e-mail by midnight before the day of the performance review itself, which will happen after the milestone itself, in the same week if at all possible.

The report should be in the following format:

- One to three sentences summarising your contribution to the group over the review period.
- One to three bullet points emphasizing the high points of your contribution.

- One to three bullet points indicating areas you feel need improvement.
- The points you believe you have earned for this performance review (**0**–**10**), and your suggestions of anyone who made an exceptional contribution, that is, one meriting an **8** or above.
- Any other relevant information: detail to back up the points above, measurements to quantify your achievement, justification for design decisions, or points important to record for yourself or the group.

The report should be one-half page to one page in length; often a briefer report is better.

At the performance review, the group considers the individual reports and agrees the points to be awarded to each student. Those marks are then forwarded to course organisers for recording, along with any information about missing individual reports.

Individual reports are mandatory: they form an important input to the performance review, and provide documentation that may be reviewed by the external examiner. Repeated failure to submit an individual report on time may lead to loss of credit.

Points are awarded for work during the period since the previous milestone (or the beginning of the course, for Milestone 1). The 10-point scale corresponds to CMS1, the university standard UG 0–100 marking scale. Some *suggestions* about various points on the scale are given below.

- **0** points == 0%

  0 is for the student who has not participated at all

  - Absolutely nothing

  For example:

  - Not turning up
  - No contribution whatsoever

- **2** points == 20%

  2 is for the student who has made some effort, but to no very great effect

  - Turning up at all
  - Contributing in any way

  For example:

  - Turning up to several meetings, but not saying anything
  - Beginning a piece of code, but not getting it working or handing it off successfully

Note that **2** and **3** are still failing grades and should be awarded when the student has turned up to some group meetings and/or done some work but made no contribution of any value.

- **4** points == 40%

  A **4** is a barely passing grade but shows that the student has put some time and effort into the project.

  - A small contribution to a single aspect of the project providing effort was put in to it

  For example:

  - Volunteered to write a simulator and disappeared for two weeks. At the end of the time s/he provided a simulator that didn't integrate well with the rest of the system.
  - Spent the milestone watching matches from previous years, producing a document outlining a high-level strategy at the end.
  - A team leader who scheduled meetings but lacked preparation for them.
  - Took satisfactory minutes in multiple meetings and provided the team with them.

- **6** points == 60%

  6 is for the average student who has put time and effort into the project.

  - A good contribution to a single aspect of the project

  For example:

  - Helped in getting the A* algorithm running and added blacklisting of nodes to it.
  - Built a large part of a robot e.g. Kicker assembly, Chassis
  - A team leader who scheduled, prepared for, and chaired team meetings
  - Researched and implemented barrel correction for the vision system.
  - Wrote a wide range unit tests for a variety of systems and reported the bugs found to the team
  - Constructing a new kicker assembly that keeps control of the ball by using spinning wheels
  - Hacked together something for the final milestone without consulting with the rest of the team whether this was the best thing to do

Note that **3** is the maximum grade that can be awarded for a member of the team that does not work within the team. Teamwork is an important part of SDP and failure of an student to work with the team, by not communicating with regard to what s/he is doing, and not discussing new ideas with the team before proceeding with them, should be noted.

- **7** points == 70%

  7 or above is for the student who has done work beyond what is required of a good team member.

  - A majority contribution to a single aspect of the project or several smaller aspects of the project

  For example:

  - Hacked together something for the milestone with the agreement of the team that worked
  - Wrote a wide range of unit tests for a variety of system, reported the bugs back to the team, and fixed a vast majority of the bugs.
  - Switched to a system from the system s/he was working on, learned it and got up to speed on how it works, then did the equivalent of **3**-point work on it.
  - A team leader who scheduled, prepared for and chaired meetings, did some work towards an aspect of a project, and mediated and resolved issues and disagreements within the team. The team has agreed that those conflicts were resolved
  - A justified, that is the team agreed it should happen, complete rebuild of a robot late in the development stage which solved a major design flaw.

- **8–10** points == 80–100%

  Marks above **7** are for the rare cases where someone has gone far above and beyond the call of duty for the team

  - Substantial and unprecedented innovation
  - Truly heroic effort (not *just* effort, but *successful* with it)

  For example:

  - Achieve a design breakthrough with an approach which no-one ever has used before, such as integration of holomonic wheels for the first time
  - Replace an entire subsystem from scratch, over one weekend, while keeping the team in the loop. This has to be exceptional work, covering for example the entire vision system

A typical student will get a **5** or **6** for each milestone. It would be unusual for more than three students in a group to be awarded **7** or above, or for more than one to be awarded **8** or above, and mentors will be particularly careful to review any such award pattern. Fractional values may *not* be awarded. Using them would be an example of misplaced precision.

3.2 Submission

Group final reports and individual final reports are due 4pm Thursday the first week after spring break. All reports must be submitted online using `submit sdp` on DICE—do `man submit` for detailed documentation. Always keep an untouched copy, preferably in a repository (git, mercurial, svn, cvs, . . .), of every report you submit.

Submit as follows:
`> submit sdp final [your filename]`
Where `[your filename]` is the name of your report file. The report filename *must* be `group-[g]-individual-report.{html,pdf}` if it is your individual report or `group-[g]-group-repor` if is is a group report. All reports *must* be in either (X)HTML or PDF.

Group reports should be submitted by a group member nominated for this purpose, and notified to the group mentor and to `sdp-demonstrators@inf.ed.ac.uk` before each report submission.

3.3 Marks

The overall relation of individual assessed items to final mark is:

Individual: 50%
- performance reviews: 40%
- final individual report: 10%

Group: 50%
- three milestones at 6% each: 18%
- one assessed friendly: 8%
- Final Day presentation: 8%
- Final Day team performance: 8%
- final group report: 8%

This mark scheme reflects that it is important to build something, important to go create a group which does the work *as* a group and important to communicate your achievements well.

4 Friendlies

Friendly games are your opportunity to assess the behaviour of your robot working with the other robot in your team and competing against opponents in a real game. Friendly games consist of a tournament, similar to the final day tournament. Both pitches will be used, and you will only find out which on the day. Performance (as judged by two judges, *not* on finishing position) in one of the friendlies will count toward your mark, as follows:

- 8 points: Play creatively, demonstrate impressive ball skills, coordinate between attacker and defender
- 6 points: Play well, pass and receive the ball to some extent
- 4 points: At least some signs of differentiation between attacker and defender
- 2 points: Better than nothing, but not by much
- 0 points: Play very badly, or not at all

Performance in the final friendly will determine your position in the final day tournament ladder.

5 Final Day

The final day consists of presentations, a tournament, and an prizegiving ceremony. The panel of judges consists of visitors from industry plus the course organiser (Henry), the course technician (Garry) and the course TA (Paul). In previous years we have had industrial visitors from Accenture, Amazon, Cisco, Citi, Freescale, Google, IBM, and Kal. Edinburgh's honour is a stake, and we expect you to make a good impression!

Presentations. Details forthcoming.

Tournament. The tournament will take place in the lab, and have the same form as the friendlies. Initial placement in the competition will depend on performance at the seeding friendly. Time will be allocated on the Final Day for any required calibration.

Prizegiving. The judges will award a prize for the best overall team. The award is based on performance in the tournament, quality of design, and excellence of execution—it is likely to go to the winner of the tournament, but may go elsewhere. Additional prizes may also be awarded. Awards include a cash prize donated by industry.

6 Reports

In addition to the input to the milestone review meetings, two sorts of reports are required:

- Individual final report, two pages. Due 4pm Thursday the first week after spring break. Submit online. Worth 10 points.
- Group final report, five pages. Due 4pm Thursday the first week after spring break. Submit online. Worth 8 points.

Individual reports describe the work of an individual student. Group reports describe the work of the group as a whole; and may, in part, be assembled from material in individual reports.

There are strict length limits on reports, as given above. Reports must use a 12pt font. (This document is in a 12pt font.) The font size is a serious requirement; use of a smaller font makes the report harder to read, and violates the intention of the page limit.

Reports have three purposes: to provide sufficient information to assess your work; to document for the group and yourself your design and what you have done; and to provide useful information for anyone who wants to build on what you have done in future. Reports may contain detailed appendices beyond the page limit, particularly in aid of the last two goals; but markers are not required to read these appendices. A common mistake is to overuse the appendices— figures, tables, or other material that explains your work belongs in the main report, not an appendix.

Individual final reports should be biased somewhat to activities *after* the final assessed milestone.

The final reports combined, group and individual, should contain enough detail for someone to take what you've done and build on your work. Code listings are not required (code will be archived), but you may quote and explain significant code fragments. Your group report *must* include a URI for a publically accessible repository of your code, or otherwise explain how to access whatever repository you used, and it *should* include pointers and/or documentation for any other publically visible material you used, such as issue trackers, task management support, hashtags, etc., all in an appendix titled "Online resources".

Final reports should cover both technical and management issues. Each report should list goals (What did you want (your part of) the robots to do?) and achievements (What can the robots do?), and distinguish clearly between the two (Which of your goals have been achieved?). Describe the current state of the design (How does it work?), outline alternatives considered (How else could it work?), and justify choices made (Is there a logical reason why your method is better? Did you find an article that said it was better? Did you perform an experiment comparing two approaches?). Pay particular attention to reusing previous work (What was done last year? Could you reuse it? If you chose

to rebuild from scratch, what were your reasons?). Include a section focussing on lessons learned (What would you do differently given the chance? What worked well?).

A poor report will simply present a design. A good report will motivate the design, consider alternatives, and justify the design chosen.

Don't just say "The vision system worked well." Specify what was achieved: "Our vision system determined the position of the ball, and the position and orientation of both robots." Test, measure, and quantify the results: "The system analyses 30 frames per second, and determines the ball location to an accuracy of 0.5cm."

Similarly, don't just say "We used two threads" or "We hand optimised the byte codes". Explain why the change was considered important, and quantify the speed up from the change. Don't just say "The code was thoroughly tested." Better: "The code was run on a regression test suite." Better still: "The test suite contains 75 unit tests and has a code coverage of 100%."

You are encouraged to develop and compare alternative approaches. "We prepared two different strategy modules, and ran them against each other in simulation. The heuristic strategy beat the potential field strategy in 7 out of 10 trials. We also compared the heuristic strategy with the module developed by Team 5 last year, and our heuristic outperformed Team 5's in 8 out of 10 trials."

7 Organisation

Successful completion of the project depends on effective management of the group's effort. One of the joys of SDP is watching individuals fuse together into an effective group, and this is something people remember long after the exercise has finished.

To ensure that your group remains cohesive, the entire group should meet formally with your mentor about once per week. Meetings without the mentor, and of subgroups concerned with individual components, may be needed at other times as well. During the final period, this may mean daily. Co-ordination meetings with the other group in your team will become increasingly important as the term progresses.

You should appoint a group coordinator or group leader. One responsibility of this person will be liaison with the mentor. You may wish to make this person responsible for strategic decisions, or you make wish to make decisions by consensus. Early tasks for the group will be deciding on an architecture of the system and appointing areas of responsibility. Evidence that good project management techniques have been employed will contribute to a good assessment.

Take steps to ensure that everyone has an assigned task. If each person decides separately what to do, there may be unproductive duplication of work. Build resiliency into the organisation; you don't want the robots to perform poorly because a single individual was

unable to complete a task.

Given the long timescale, it is tempting to push SDP down in priority relative to other assignments with immediate deadlines, but this is a recipe for a poor outcome. We recommend that from the outset you diarise time regularly for SDP (and for other activities, come to that). Be sure to allow adequate time and effort for systems integration. Many projects have foundered during the final assembly phase—making subsystems work individually is much easier than making them all work together.

Groups have great flexibility in how they set their goals. A group that sets high goals and achieves them will earn high marks. A group that sets lower goals and achieves them may earn better marks than a group that sets high goals and achieves little.

8 Fair play

We expect all teams to compete in a spirit of fair play. Ingenious solutions are encouraged; unfair ones are not. For example, deliberately confusing the another robot's sensors is not allowed, nor is remote manual control of your robots. If you are unsure, please consult with your mentor. In unanticipated situations the verdict of the course organiser is final.

9 Problems

In rare cases an individual may be seen as failing to participate fully in the work of the group. In this case, please discuss the situation with your mentor early. Please be sensitive; there may be factors affecting the performance of group members that are not obvious.

In extreme cases where a student has not participated well in the work of a group (as indicated by repeated marks of 0 or 1 in the performance reviews) the contribution of the group mark to the student's mark may be reduced by an amount depending on the severity of the problem, possibly up to receiving no credit for the group work. In past, non-participating students have seen their proportion of the group mark reduced to 0% or 25% of the mark received by other group members.

Problems are best dealt with if brought to the attention of your mentor or the course organiser early. If there appear to be problems with the group dynamics or with an individual, please bring this to the attention of your mentor.

Mentors should meet with their groups weekly, and be available throughout the term. If you have an issue with your mentor, please bring this to the attention of the TA or the course organiser. The TA and course organiser are happy to speak with anyone, anytime.

10 Communication Skills

No matter what career you pursue, communicating well—in print and in person—is a key skill. Many people are poor communicators, and even excellent communicators can sharpen their abilities. The biweekly progress reviews, the Final Day presentations, and the final reports comprise the majority of the assessment for SDP, and your marks for these in part depend on your ability to communicate well.

Here are four books that may prove useful. The first of these is particularly recommended, as it is short and inexpensive. (Less than £6—it could be the best investment you make in your undergraduate career!)

- William Strunk, Jr., and E. B. White, *The Elements of Style*, Longman, 1999 (Fourth edition). (First edition 1959.)
- Sir Ernest Gowers, *The Complete Plain Words*, Penguin, 2004 (Third revised edition).
- Edward Tufte, *The Visual Display of Information*, Graphics Press, 2001 (Second edition).
- Max Atkinson, *Lend Me Your Ears: All you need to know about making speeches and presentations*, Vermilion, 2004.