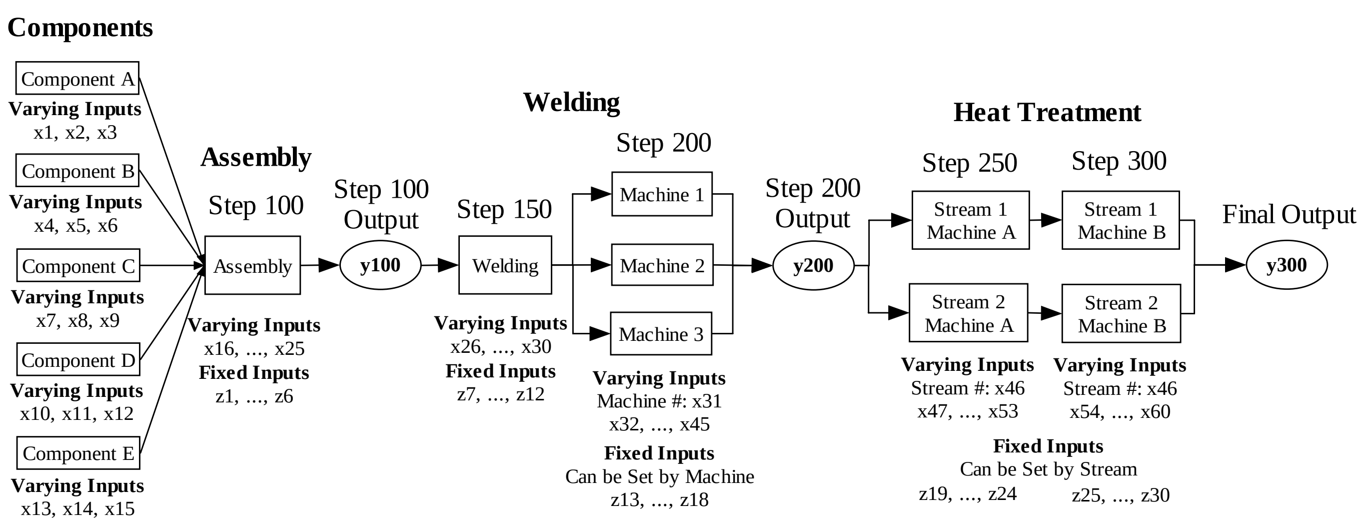
Watfactory Variation Reduction Game

Part I – Introduction

Process Description

The virtual process is loosely modeled on a manufacturing process that produces camshafts (see picture below) used to open and close valves in an automobile engine.

The virtual camshaft manufacturing process has three major processing steps as illustrated below. In Step 100, five components (purchased from suppliers), such as lobes, journals and a rod, are assembled together. In Step 200 the components are welded together. Due to volume, there are three welding machine operating in parallel. In Step 300 the camshafts are heat treated to harden them using two machines operating in parallel. We speak of Step 100 being upstream of Step 200, while Step 300 is downstream of Step 200.



The process produces 1440 parts (camshafts) per day (i.e. one per minute) in three eight hour shifts (midnight to 8am, 8am to 4pm and 4pm to midnight). The plant operates five days per week – there is no production on weekends. At the start it is Monday morning at the start of the first shift.

Output(s)

The critical (for this project) process output straightness, a continuous characteristic, can be measured, using the same automated (i.e. no operators) gauge, after processing steps 100 (y100), 200 (y200) and 300 (y300). The output straightness cannot be measured at other locations in the process. The output is measured as a deviation from a nominal (target) value. As such, the target *observed* output (i.e. y300) value is zero.

Varying Inputs

As shown on the process map, there are a total of 60 varying inputs, denoted x1, x2, …, x60, in the manufacturing process. Two inputs, x31 and x46, denote the machine number and stream used to process a particular part at Steps 200 and 300 respectively. The other inputs are a variety of other characteristics, such as: temperatures, fixture numbers, environment characteristics, operators, etc. Some inputs are continuous (e.g. temperature) while others are categorical (e.g. operator: Fred, Bob and Jane). [It will be important to take into account whether an input is continuous or categorical when you start investigating the process.]

All teams are given the following existing knowledge about the varying inputs (note that the continuous characteristics are measured as a deviation from nominal). You can, of course, learn more by observing or experimenting with the process.

Varying Input	Description	Type (# levels)	Observed Range	Varying Input	Description	Type (# levels)	Observed Range
x1	dimension A	continuous	unknown	x31	machine #	categorical (3)	1, 2, 3
x2	diameter A	continuous	unknown	x32	squeeze time	continuous	unknown
x3	hardness A	continuous	-2.2, 7.2	x33	feed rate	continuous	unknown
x4	dimension B	continuous	unknown	x34	temperature	continuous	-17, 29.6
x5	diameter B	continuous	-17.1, 22.2	x35	dimension 1	continuous	unknown
x6	hardness B	continuous	-14.3, 18.5	x36	electrode force	continuous	unknown
x7	dimension C	continuous	unknown	x37	humidity	continuous	unknown
x8	diameter C	continuous	-20, 26.6	x38	dimension 2	continuous	0.2, 10.4
x9	hardness C	continuous	unknown	x39	mandrel position	continuous	-1.5, 12.1
x10	dimension D	continuous	unknown	x40	weld time	continuous	unknown
x11	diameter D	continuous	unknown	x41	load time	continuous	-1.6, 9.4
x12	hardness D	continuous	-7.5, 19.6	x42	cooling temp.	continuous	unknown
x13	dimension E	continuous	unknown	x43	spacing	continuous	unknown
x14	diameter E	continuous	unknown	x44	operator	categorical (5)	1, 2, …, 5
x15	hardness E	continuous	-12.6, 21.2	x45	fixture	categorical (12)	1, …, 12
x16	temperature	continuous	unknown	x46	stream #	categorical (2)	1, 2
x17	fixture	categorical (5)	1, 2, …, 5	x47	power density	continuous	unknown
x18	humidity	continuous	-3.0, 12.2	x48	induction level	continuous	-20, 26.2
x19	ball size	continuous	unknown	x49	frequency	continuous	-14.5, 29.5
x20	orientation	categorical (3)	1, 2, 3	x50	heating time	continuous	0.9, 8.4
x21	position	continuous	unknown	x51	operator	categorical (4)	1, 2, 3, 4
x22	pressure	continuous	-10.3, 22.4	x52	depth	continuous	unknown
x23	force	continuous	unknown	x53	coupling degree	continuous	unknown
x24	offset	continuous	-2.5, 6.9	x54	surface area	continuous	-14, 21
x25	operator	categorical (3)	1, 2, 3	x55	coil	categorical (8)	1, …, 8
x26	temperature	continuous	-10.6, 15	x56	current	continuous	unknown
x27	fixture	categorical (5)	1, 2, …, 5	x57	hold time	continuous	unknown
x28	operator	categorical (4)	1, 2, 3, 4	x58	air gap	continuous	unknown
x29	power	continuous	unknown	x59	inductance	continuous	-8.8, 13.4
x30	static	continuous	unknown	x60	quench temp.	continuous	-4.3, 8.8

Each of the varying inputs is associated with only one process step. This means, for example, that you know that varying inputs in Step 100 can influence the final output only through y100. These restrictions and information can be thought of as your engineering process knowledge from your prior experience with the process.

Fixed Inputs
The process also has 30 fixed inputs, denoted z1, z2, …, z30. Just like the varying inputs, each process step has associated fixed inputs that you can assume have a possible effect only on the output directly downstream. As the name suggests, these inputs are normally held constant while running the process. In a search for a dominant cause of output variation the fixed inputs can be ignored (i.e. not changed). When you start to think about remedies (i.e. solutions) that will reduce the output variation you can plan and

conduct investigations that change any of the fixed inputs. More information on the fixed inputs is provided in the description of the remedial journey provided in Part III.

Rules and Logistics

Each team starts with the same brief description of a process (as given above). With the current process there is excessive variation in the final output. Each team is given the desired specification limits (i.e. smallest and largest acceptable values) for the final output.

Goal

Your team's goal is to find a way to reduce variation in the final output (y300) so that all parts produced will be within the given specification limits, while minimizing investigation cost (in dollars) and time and also the cost of the proposed solution. To achieve the goal you should plan to apply the Statistical Engineering Algorithm and conduct a series of investigation to learn about how and why your process behaves as it does. More details are provided in Parts II and III of the simulator description.

Each team will work on a different version of the process. That means that for each team the important varying and fixed inputs will likely be different.

Playing the Game

At the start of term, you will form a team and be assigned a particular process to improve. To keep track of things, you will be given a team number that you must use throughout the term. To conduct investigations you will access the process game through the Watfactory login page www.student.math.uwaterloo.ca/~stat435/login.htm.

You can cut and paste the data generated by the virtual process into Minitab (or other statistical software of your choice). An example of what the results may look like is given below

daycount	shift	partnum	y300
1	2	481	7.5
1	2	482	-8.5
…	…	…	…

Here, daycount gives the consecutive count of elapsed days (in virtual time) since the start of the game. Shift equals 1, 2 or 3 depending on whether the parts are produced in the morning, afternoon, or evening shifts, and partnum corresponds to the minute of production for the selected part.

Costs

Your team starts with a budget of $10,000 that management has authorized for you to use to investigate the process. Remember that since you plan to conduct a series of investigations it is best not to spend too much money on any single investigation. If you decide you need more money, you must petition management and explain your reasoning. Investigation costs are discussed later.

Since each team has a different version of the process, teams will not be compared in terms of the amount of money they spend searching for a dominant cause or a solution, the simulated time taken, or the cost of the solution. Each team's process is different and requires different process investigations and variation reduction approaches.

Assignments/Reports

When you plan and submit the plan for an investigation you will receive the resulting data. You then analyze the results, draw appropriate conclusions and think about your next investigation, if necessary. A summary of the plan, analysis and conclusions for each investigation must be handed in for assessment. Your rationale should include a brief discussion of alternative (reasonable) investigations you considered.

Management Review Meetings

Throughout the term each team will be required to both conduct and be the subject of management review meetings. In a management review meeting, your progress to date is formally reviewed. The purpose is to ensure you are on track, have considered all relevant issues and have a good plan for what to do next. The team whose progress is to be reviewed will make a short presentation outlining what they have done/learnt so far and what they plan to do next and why. The team assigned to act as the corresponding managers will critic the presentation and decisions made, and try to provide guidance. See the course outline for more information on timing of the management review meetings.