Manufacturing data: SEMI tool level fault isolation

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background

In semiconductor manufacturing process the basic manufacturing unit is a silicon disk called wafer. During the fabrication process each wafer goes through a product (chip type) specific sequence of operations (hundreds). Each operation in the sequence is identified by its operation number. Some of these operations include adding a layer to the wafer, drawing a pattern on the wafer, covering the pattern with a photo layer, etching the pattern, etc. Wafers travel through manufacturing line in batches or lots. Every lot goes through each operation in the sequence. At each operation a lot could go through only one of many tools performing the same function. Maximum number of tools ~ 25, and the number of tools could be different from operation to operation. At the end of the manufacturing line many performance metrics are measured to monitor deviations from the desired target specifications. Often observed variation of a performance metric is caused by a subset of tools with effects of the problematic tools potentially changing in time.

1. problem statement

The simulated dataset closely reproduces the nature and complexity of the tool level fault isolation problem engineers face in the semiconductor manufacturing. It records every tool and time stamp at every operation every lot went through (predictors), and the corresponding numeric performance measure (target). The goal is to recover a small subset of influential/probelmatic operations/tools and the corresponding contributions in time (if the effect is not constant) to the variation of the numeric performance metric. Examples of problematic tools generating non-constant offsets are shown on the figures 1, 2.

1.1 data generative model - regression

$$ObservedPerformanceMetric(t) = TargetedPerformance + \sum_{i_j \in I} OFFSET_{i_j}(t) +$$

$$\sum_{k_l, r_s \in M} OFFSET_{k_l, r_s} + \epsilon$$

where ObservedPerformanceMetric(t) is observed at the end of line performance metric; TargetedPerformance is targeted by the process specification performance metric; I is a subset of operations where tool j at operation i causes $OFFSET_{i_j}(t)$ from the performance target; M is a subset of operations (different from I) where tools l and s from operations k and r produce a constant $OFFSET_{k_l,r_s}$ (pure interactions). The noise ϵ was generated from the normal ditribution with zero mean and variance adjusted to give a 1/1 signal-to-noise ratio for a tool (or combination of tools) with the weakest signal.

$$E|\epsilon| = \min_i E_t|OFFSET_i(t) - median_t OFFSET_i(t)|$$

1.2 data description and desirable results

Commonalityx4000 dataset has 602 variables and 4000 observations (lots); RES is the target - the performance metric measured at the end of line; LOT coded as LOTID (to be ignored); the rest are predictors: $LOCN_i$ and $TDATE_i$. Every lot goes through each of 300 operations: $LOCN_i$ (operation ID) at time $TDATE_i$, i=1-300. At each operation it could go through only one of the tools. Hence $LOCN_i$ are categorical predictors with number of levels= number of tools used, $TDATE_i$ are numeric variables (coded times through operation-tool). Approximately 25% of the data is missing.

The desirable result of the study is to identify problematic operations/tools and the corresponding offset patterns in time. The performance metrics for the evaluation of submissions will include the number of correctly identified operations/tools and number of false positives. Furthermore, to quantify the accuracy of offset pattern predictions the following metric will be used

$$\sum_{i=1:300} \sum_{j=1:4000} |(PredictedOffset_i(tool_j, time_j) - ActualOffset_i(tool_j, time_j))|$$

It is expected that submission would have at most 50 identified influential operations (the actual number is smaller), the rest of the operations will be assumed having no effect ($OFFSET(tool, time) \equiv 0$). The submitted prediction matrix would have at most 50 columns corresponding to $OFFSETS_i(tool, time)$ caused by a subset of tools at operation i calculated for 4000 observations (lots) from the provided dataset. Thus the metric above will be evaluated over union of actual $OFFSETS_a$ and predicted $OFFSETS_p$. Finally, submissions would include identified pairs of pure operation/tools interactions (no time effect).

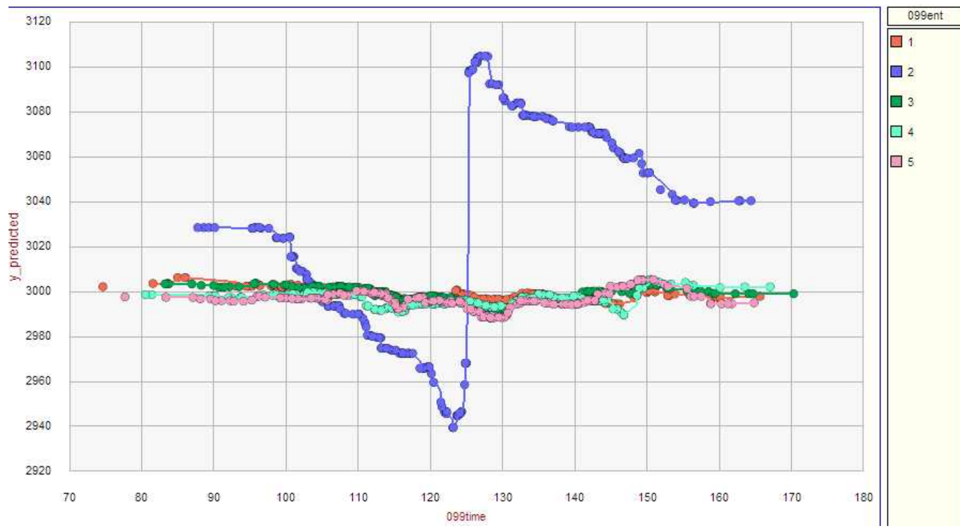

Figure 1: Sawtooth offset pattern caused by the tool=2 at operation=099. The rest of the tools stayed on target

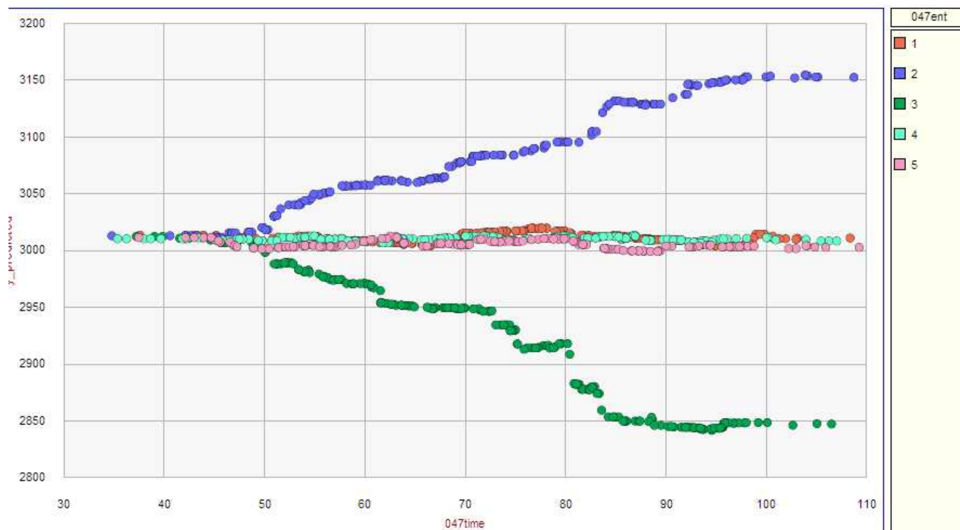

Figure 2: Trend offset patterns caused by the tools=2,3 at operation=047. The rest of the tools stayed on target