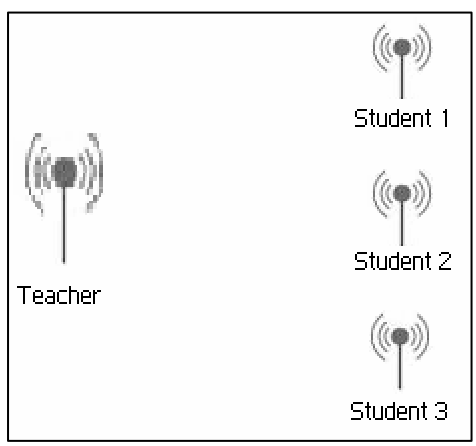
A Class as a Communications Problem

Gaining Pedagogical Insight via Communications Theory

The Analogy

This entire project is an expansion of a relatively simple analogy. The main premise is that one can build up a communications system that is analogous to a classroom. This is best understood by example. Suppose there was a classroom that had a single student and a single teacher. In this classroom, the only interaction between the teacher and the students is that the teacher lectures. The student does not respond; the teacher doesn't use any other teaching techniques. In terms of communications, one could describe this system as a single transmitter sending data to a single receiver. This is a very simplified situation, but it makes the idea fairly clear. The communications systems involved can get fairly complex very quickly. For example, a better model might include a noisy channel to represent the less than perfect data transmission due to a variety of reasons: maybe the student is tired or inattentive. One could also model the fact that different students have different learning styles (demodulating filters); perhaps the teacher is explaining things in a way that the student doesn't readily understand. The system can get far more complex as it gains some intercommunication. For example, the students could ask for clarifying questions (a checksum) or they could help each other outside of class (relays).

For the purposes of this paper, the classroom will be set up as follows. There is a single teacher who is lecturing to three students. Each of these students has a particular learning style; they are all generally similar (they have similar educational backgrounds), but differ in details. The classroom is very hard to concentrate in because it is a beautiful day (the channel is very noisy).



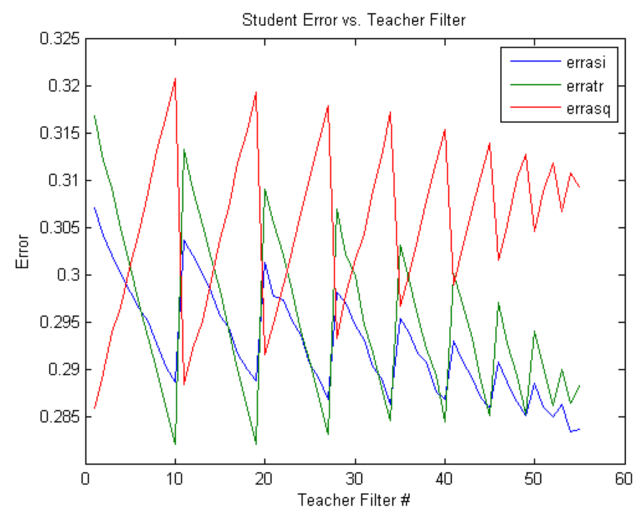
The Classroom

Simulating the Classroom

Several Matlab programs were implemented in order to simulate the classroom. First, three main filters were defined. These were a sinusoidal filter, a triangular filter and a square filter; each is a single period of the appropriate waveform. A random string of digital data (representing the information the teacher was attempting to convey), was created. Each bit was then encoded by having a one be represented by having the positive portion of the wave first and a zero be represented by having the negative portion of the wave come first. This waveform then had noise added to represent the channel. After all of this, the students/receivers attempted to extract the original data. By convolving the data with their demodulating filter (ideally a 1 signal flipped left to right) and looking at the sign of the n^{th} term (where n is the number of points that define the filter), one can easily tell what the original signal was meant to be.

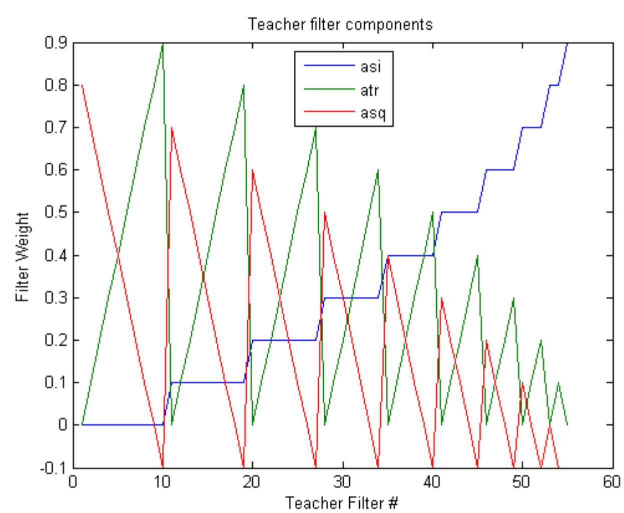
The Simulation in Action

This paper examines the effects of changing the teacher's choice of modulating filter. Pedagogically, this corresponds to the teacher adopting a new style of teaching. Using the three original filters many (55) of intermediate filters were created from linear combinations of the original three. These were then simply put into the simulation. The following graph represents the errors that each of the three students saw for each different filter.



Error for each Student

The next plot displays the particular linear combination of each of the three original filters that gave rise to the new filters. It is worthwhile to note that everything is consistent with what would be expected. For example, the high-frequency trade-off between square and triangular signals, leads to the opposite effect in their respective errors.



Components of each Filter

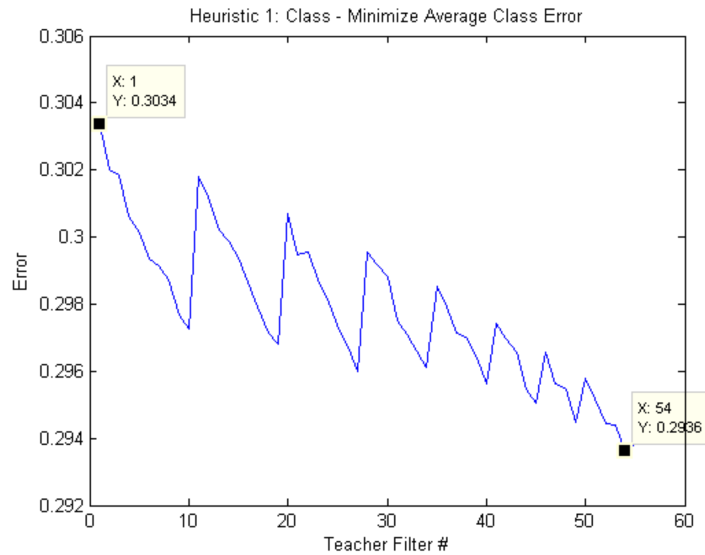
The Heuristics

In order to test the model, several heuristics were generated that fulfilled specific goals in pedagogy. These heuristics chosen were: teaching the most to the class as a whole (minimizing total data loss), teaching *everyone* as much as possible (minimizing maximum individual error), and a more balanced approach between the other two heuristics.

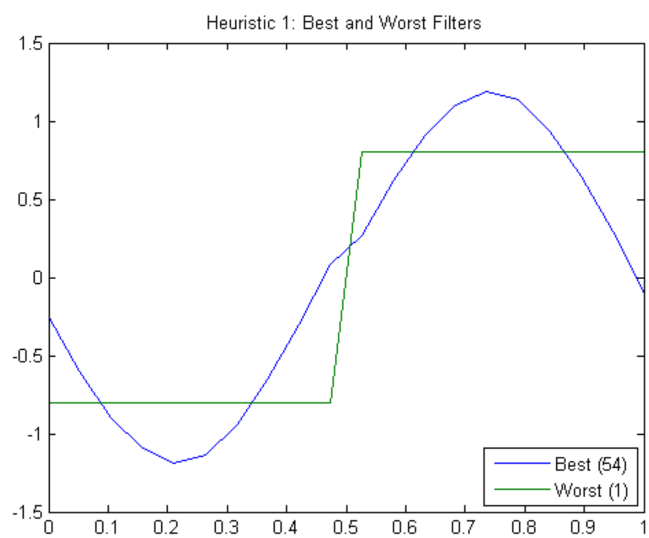
Heuristic 1

This heuristic is perhaps the simplest of all. The idea is simply to maximize the data transfer rate to the class as a whole. For this heuristic, filter 54 yields the lowest error and filter 1 had the greatest error.

Because triangular and sinusoidal are somewhat similar, a mostly sinusoidal filter does best. The square wave on the other hand serves only one of the students, so it leads to greater overall error.



Heuristic 1 Error

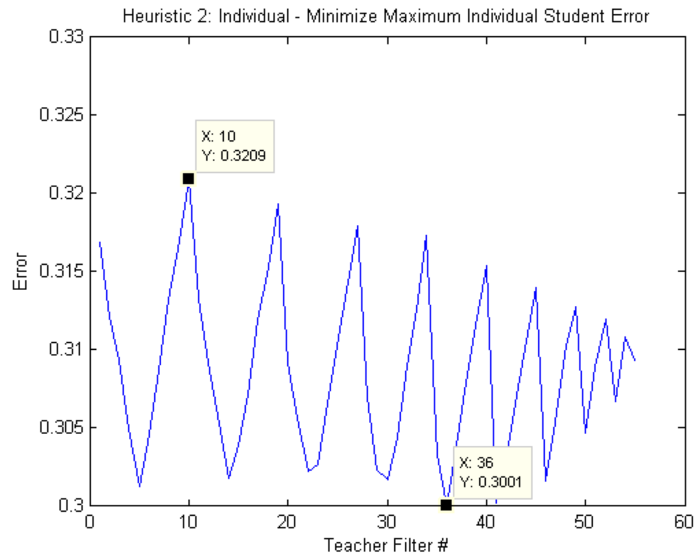


Best/Worst Heuristic 1 Filters

Heuristic 2

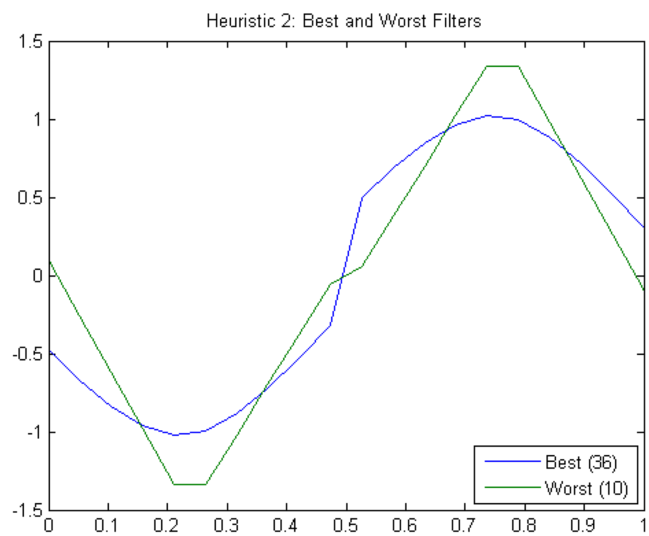
This heuristic is also very simple. In this one, the goal is to minimize the maximum error of any student. When looking to achieve this goal, filter 36 yields the lowest error and filter 1 has the greatest error.

In this case, a mixed wave composed primarily of sinusoidal and square filters did best while a predominantly triangular wave failed spectacularly



Heuristic 2 Error

Something interesting to note is the fact that the success of this heuristic correlated extremely well with reducing the standard deviation of the errors of each student. In other words, minimizing the maximum student error was almost exactly the same as minimizing the differences between student errors. Pedagogically, this could correspond to gifted students suffering by being in a system that attempts to move all students along at the same pace.

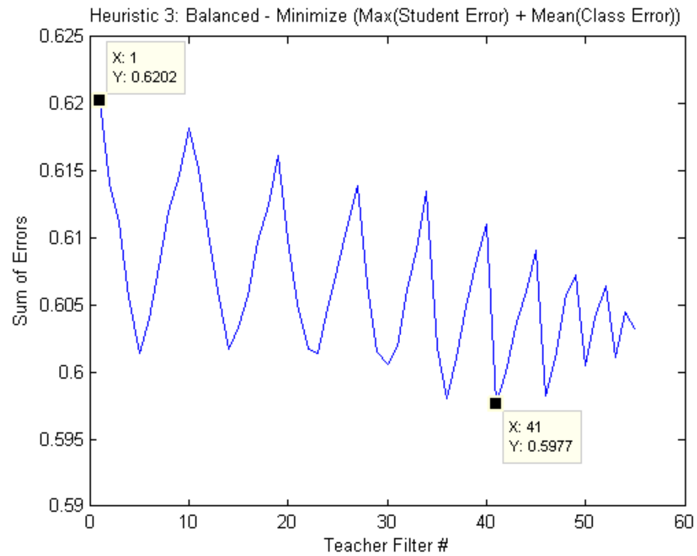


Best/Worst Heuristic 2 Filters

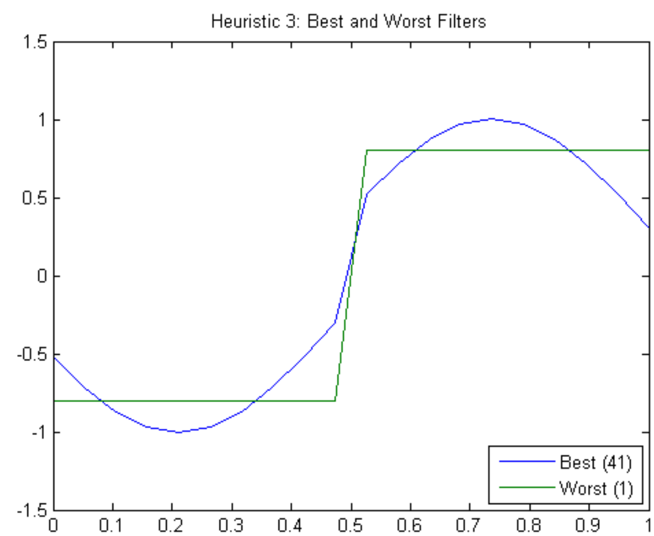
Heuristic 3

The final heuristic that is examined in this paper is a combination of the previous two heuristics. The hope is that a balanced system will allow everyone in the class to learn a substantial amount while mitigating the issue of forcing every student to perform at the same level.

The simulation shows that the best filter to achieve this goal is a mix of the sinusoidal and square filters. There is a little bit more of a sinusoidal characteristic in the best filter because the 3rd student has a triangular filter that is more similar to the sinusoidal filter than to the square filter. This is also the reason that a pure square wave does the worst in this scenario. Teaching towards a student who learns very differently carries a cost of teaching all the other students less effectively.



Heuristic 3 Error



Best/Worst Heuristic 3 Filters

Conclusions

Modeling the classroom using communications theory seems to effectively describe many of the situations that are seen in pedagogy. It remains to be seen if a model of this kind could allow someone to get quantitative data regarding a classroom learning situation instead of merely qualitative data. Unfortunately, all of the quantitative data is based upon subjective constants. How can a researcher translate inattention to a solid number that can be input as Gaussian noise in the channel? Despite the limitations of the model with respect to gaining quantitative knowledge, we feel that it can allow people to think about teaching a new way and lead to insights that would remain otherwise unfound.

Far more can be done with this model than is in this paper. One interesting direction might be using only two types of students and taking more data points. By limiting it to two students, it would become possible to display all of the data for a given noise level on a single 3d surface plot. Ideally, this would lead to some way of understanding what filter (teaching style) would be effective in relation to the students' filters (learning styles) without having to run simulations on all possible options (as this is unfeasible in the classroom). In short, we believe this is a powerful model and that pedagogy stands much to gain from its liberal application to current classroom problems.

-Boris Dieseldorff and Allison Weis

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