**Compo**

**#1. Frame**

Partial-centralized / Centralized / Decentralized

Decentralized

실제 real-world에서는 3개의 ponds에서 유출된 물이 stream의 dynamic을 유발하는 요인이 되지만, Decentralized control 제도 하에서 각각의 pond는 다른 pond의 control decision에 영향을 받지 않고 독립적으로 각 pond의 control decision을 진행한다. 이 controller의 한계는, 실제 다른 ponds도 optimal controld을 하므로 static control을 했을 때와 실제 contro 사이에서 발생하는 간극이 생길 수 있다는 점이다. 예를 들면 stream의 dynamic이 적을 것이라고 생각하여 Pond1에서 outflow를 했는데, 실제로는 동시간대에 Pond2, Pond3에서도 동일하게 outflow를 진행한 경우가 있을 수 있다. 이 경우 stream이 받게 되는 inflow가 갑자기 커져 cost가 exponential하게 증가하게 되고, 그리고 overflow가 발생할 수 있다. 이런 경우가 생길지라도 decentral control의 경우는 이를 파악조차 하기 어렵다.

#모델

1개의 pond model과 pond에서 discharged 된 물이 유입되는stream model을 UPPAAL STRATEGO를 사용하여 디자인했다. 이 모델의 첫번째 목적은 stream의 수위 변화를 최소화하여 stream의 생태계를 보호하는 것이다 이에 stream의 cost는 stream의 water level dynamic이 증가할수록 증가한다. 이 모델의 두번째 목적은 pond에서 overflow가 일어나지 않는 한도에서 rain water가 pond에서 머무는 시간을 최대한으로 하여 pollutant sedimentation을 최대한으로 하는 것이다. 이 목적을 반영하여 pond의 cost는 pond내의 수위가 낮아질수록 cost를 증가하는 방향으로 진행하면서도 max 수위 부근에서는 penelized가중치를 크게 주어 cost가 급격하게 증가하도록 의도하였다.

#STOMPC

위에서 설명한 동일한 모델 3개를 online synthesis를 support하는 STOMPC framework에 각각 연결하였다. STOMPC에 연결된 각 model은 주어진 time horizon과 rain forecast를 고려하여optimal controller를 synthesized한다. 각 system model을 서로 연결되어 있지 않고, controller 결정 과정에서도 서로 영향을 주지 않는다. 각 system model은 1개의 pond와 1개의 stream의 interaction만을 고려하여 cost를 계산하고 그에 따른 optimal strategy를 계산한다.

#swmm

STOMPC는 UPPAAL STRATEGO 에서 control strategy 를 전달받아 이를 외부 simulator인 swmm으로 전달한다. swmm에도 uppaal stratego에 적용하였던 동일한 rain gauge를 적용하고 Swmm은 real-world의 physics를 반영하는 simulator로서 swmm을 이용해 UPPAAL STRATEGO 에서 생성한 strategy가 real-world에서 어떤 결과를 내는지 유추할 수 있다.

TO DO

각 Pond는 자신의 Decision 결정 그리고 다른 pond는 static outflow를 한다는 가정 하에 stream의 dynamics를 예측하고 그에 따라 decision을 한다.

Centralized

시스템 모델에서 일반적으로 사용하는 controller은 centralized-control이다. 이 controller은 모든 것이 통제 가능한 상황에서 모든 값을 예측할 수 있다는 가정 하에 유용하다.

보통은 시뮬레이션을 통해 model의 흐름을 예측할 수 있고, model을 통해 값을 계산하기 때문에 정확하게 값을 예측할 수 있다. 그리고 미래의 값을 정확하게 예측할 수 있으므로, controller가 정확한 값에 기반하여 decision을 한다. 하지만 이 controller은 모델에 적용할 경우 유용하지만, real-world와 같이 실제 상황에서는 ”정확한 값”을 예측할 수가 없고, ”정확하지 않은 값”에 기반하여 decision을 하는 controller가 필요하기에 real-world에 적용하기에는 언제나 무리가 있다. (한계)

Partial -control

Initial control status는 static setting으로 시작한다. Pond1은 Pond2, Pond3가 static control이라는 가정 하에 stream의 dynamic을 최소화 할 수 있는 optimal 결정을 내린다. 그리고 이 결정을 기반으로 stream의 dynamic이 계산되고 나면 Pond2의 controller가 결정을 내린다. 그리고 stream의 dynaimc은 Pond1의 decided control, Pond2의 optimal control, Pond3의 static control을 바탕으로 결정한다. 그 다음 Pond3는 controller 는 optimal control을 결정하고 Pond1,Pond2는 이전에 결정한 control을 그대로 유지한다. Stream의 dynamic이 계산된다. 이 방식의 control은 주어진 time period 동안 recursive하게 진행된다. 이 control은 Centralized control만큼 정확한 controller은 아니지만, stream의 dynamic을 매개체로 하여 Ponds간에 간접적인 상호 의사소통을 한다는 것에 있다.

**#2. 목적하는 바**

**Performance comparison**

**Centralized > partial centralized > decentralized**

**Partial decentralized의 성능을 centralized에 가깝게 할 수 있는 theory 찾기**

**#3. UPPAAL에 대한 이해 / 11 March (토)**

**#4. Experimental result / 13 March (월)**

1. **Partial observation control**
2. **Centralized control**
3. **Decentralized control**

**#5. Experimental result + overleaf / 14 March (화)**

**#6. Martijn feedback 요청 / 14 March (화)**

**#7. Thomas feedback 요청 / 14 March (화)**

In this paper a unified method is developed which enables one to design control systems of various types in the situation that the dynamic characteristics of the controlled process are not known perfectly.

The control system to be designed is to satisfy the following specifications:

(a) It has zero steady-state error.

(b) It has adequate damping characteristics.

(c) (a) and (b) satisfied, it has a shortest rise-time.

For the design, a sequence of parameters is found suitable to represent the dynamics of an element or a system. The sequence is equivalent to that of moments of the impulse response in the sense of I. F. S. (independency from the successors) which plays a fundamental role in the development.

The specifications above are also reorganized into a sequence of conditions on the parameters of the control system to be designed.

Owing to the I. F. S., any truncated sequences of conditions and parameters give rise to a formula to design a compensator and/or a controller based upon partial knowledge about the controlled process. The formula has a kind of matching property, so that the simpler control mode calls for as less the number of controlled process parameters known.

Formulas for the PID and the I-PD control schemes are derived, and some results are demonstrated in step response curves, which show the effectiveness of the method. For an overdamped process, the response speed increases as the number of controller parameters, whereas the damping characteristics remain unchanged. Even for an unstable process, a satisfactory control system is brought about when a sufficient number of controller parameters are employed.

// @ARTICLE{4982681,

author={Wang, Guangchen and Wu, Zhen},

journal={IEEE Transactions on Automatic Control},

title={The Maximum Principles for Stochastic Recursive Optimal Control Problems Under Partial Information},

year={2009},

volume={54},

number={6},

pages={1230-1242},

doi={10.1109/TAC.2009.2019794}}

UPPAAL STRATEGO analysis

#paper: UPPAAL STRATEGO

#Model checking

Model checking is a technique that can be used to make that a proposed controller operates in a way that is both desired and prevents unsafe circumstances from occurring in the environment.

#UPPAAL SMC

The simulation-based method of statistical model checking, which is allowing for highly scaleable analysis of fully stochastic Sliced Timed Automata with respect to a wide range of performance properties. For instance, expected waiting-time and cost, and time-bounded and cost-reachability probabilities, may be estimated (and tested) with an arbitrary precision and high degree of confidence. Combined with the symbolic model checking of UPPAAL this enables an adequate analysis of mixed critical systems, where certain (safety) properties must hold with absolute certainty, whereas for other quantitative (performance) properties a reasonably good estimation may sufficient.

#UPPAAL TIGA

An efficient on-the-fly algorithm for synthesis of reachability and safety objectives for timed games has been implemented, with a number of successful industrial applications.

Paper: on time with minimal expected cost

6 conclusion and future works

A new technique that combines classical controller synthesis with reinforcement learning to compute strategies that provide near optimal expected cost and time-bound guarantees.

DPA models and PTMDPs models

If a time-bound is not required then we can omit the TIGA step and apply

Compo

**#1 uppaal analysis**

File1. Model in uppaal stratego

File2. Query for synthesis / one horizon

**strategy opt = minE (2\*st\_c + c) [<=2\*60]: <> (t==120.0)**

simulate [<=60+1; 1] { t,rain,S\_UC,w,c,Open,o,Rain.rainLoc,st\_w,st\_o,st\_c,w2,c2,o2,w3,c3,o3,Open2,Open3 } under opt

**strategy opt = minE (2\*st\_c + c2) [<=2\*60]: <> (t==120.0)**

simulate [<=60+1; 1] { t,rain,S\_UC,w,c,Open,o,Rain.rainLoc,st\_w,st\_o,st\_c,w2,c2,o2,w3,c3,o3,Open2,Open3 } under opt

**strategy opt = minE (2\*st\_c + c3) [<=2\*60]: <> (t==120.0)**

simulate [<=60+1; 1] { t,rain,S\_UC,w,c,Open,o,Rain.rainLoc,st\_w,st\_o,st\_c,w2,c2,o2,w3,c3,o3,Open2,Open3 } under opt

File3. Model\_config path (.yaml)

File4. Learning\_config\_path (.yaml)

File5. Weather\_forecast\_path(.csv) // not clear

out\_file\_path = stream\_result.txt

goal: one controller for three ponds / each pond should aligned to each ponds.

MPC:

Within industry, model predictive control (MPC) is a widely adopted method for designing controllers. MPC schemes are popular as they yield high-performing control systems without expert intervention over long periods of time. **This is achieved by periodically using a model to predict the system’s future behavior and calculate an optimal control strategy for the next time bounded period. Therefore, MPC schemes are also called online control, as they can adapt control strategies while the system is running.**

Framework overview

MPC captures a particular way of designing controllers for a broad range of systems and processes. **It has the following three characteristics: a model, which is used to predict the future of the system within a certain horizon, the calculation of a control sequence (strategy) that optimizes some objective, and a receding approach, where all calculations are repeated after executing the first control action from the sequence and observing the true state as a consequence of that.**

Figure1.

It provides a conceptual overview of the key ingredients of MPC that are implemented by STOMPC.

Up to time t=k, we have observed the true state of the system x and provided control input u to it. Using a model of the system, we can predict the future state x\_k within the control horizon. The evolution of the state depends on the control sequence being applied uk, where the applied control action can be switched after each control period. To determine which control sequence to choose, the objective is optimized.

Once the optimal control sequence is obtained, the first control action of this sequence is applied. When the end of the control period is reached, the process mentioned above is repeated. At time t=k+p, where p is the duration of the control period, the true value of the state of the system x(x+k)

# on time with minimal expected cost!

Motivation

Assuming a randomized environment where the duration of tasks are stochastic –

The priced timed game essentially defines an infinite-state Markov reward decision process, here named priced timed Markov decision processes (PTMDP). In this setting the objective is to find a strategy that will minimize the expected reachability cost, but with no guarantees on worst-case behavior.

In this paper, we provide efficient methods for synthesizing reachability strategies for PTMDPs that subject to guaranteeing a given worst case time-bound, will provide (near-) minimal expected reachability cost.

Conclusion

It combines classical controller synthesis with reinforcement learning to compute **strategies that provide near optimal expected cost and time-bound guarantees**. Our experiments show very good results on the class of DPA models.

The framework presented is general and not limited to neither DPAs or PTMDPs**. In particular, if a time-bound is not required then we can omit the TIGA step and apply our technique to hybrid MDPs by utilizing SMC support for stochastic hybrid systems.**

#1

After the death of Moses the servant of the LORD, the LORD said to Joshua son of Nun, Moses’ aide: Moses my servant is dead. Now then, you and all these people, get ready to cross the Jordan River into the land I am about to give to them-to the Israelites. I will give you every place where you set your foot, as I promised Moses. Your territory will extend from the desert to Lebanon, and from the great river, the Eupharates-all the Hittite country-to the Great Sea on the west. No one will be able to stand up against you all the days of your life. As I was with Moses, so I will be with you; I will never leave you nor forsake you.

Be strong and courageous, because you will lead these people to inherit the land I swore to their forefathers to give them. Be strong and very courageous. Be careful to obey all the law my servant Moses gave you; do not turn from it to the right or to the left, that you may be successful wherever you go. Do not let this Book of the Law depart from your mouth. Meditate on it day and night. So that you may be careful to do everything written in it. Then you will be prosperous and successful. Have I not commanded you? Be strong and courageous. Do not be terrified; do not be discouraged, for the Lord your God will be with you wherever you go. So Joshua ordered the officers of the people.

Go through the camp and tell the people, Get your supplies ready. Three days from now you will cross the Jorden here to go in and take possession of the land the LORD your God is giving you for your own. But to the Reubenites, the Gadites and the half-tribe of Manasseh, Joshua said, Remember the command that Moses the servant of the LORD gave you. The LORD your God is giving you rest and has granted you this land. Your wives, your children and your livestock may stay in the land that Moses gave you east of the Jordan, but all your fighting men, fully armed, must cross over ahead of your brothers. You are to help your brothers until the LORD gives them rest, as he has done for you, and until they too have taken possession of the land that the LORD your God is giving them. After that, you may go back and occupy your own land, which Moses the servant of the LORD gave you east of the Jordan toward the sunrise.

Then they answered Joshua, Whatever you have commanded us we will do, and wherever you send us we will go. Just as we fully obeyed Moses, se we will obey you. Only may the LORD your God be with you as he was with Moses. Whoever rebels against your word and does not obey your words, whatever you may command them, will be put to death. Only be strong and courageous!

#2

Then Joshua son of Nun secretly sent two spies from Shittim. Go, look over the land, he said, especially Jericho. So they went and entered the house of a prostitute named Rahab and stayed there. The king of Jerico was told, Look! Some of the Israelites have come here tonight to spy out the land. So the king of Jerico sent this message to Rahab. Bring out the men who came to you and entered your house, because they have come to spy out the whole land. But the woman had taken the two men and hidden them. She said, Yes, the men came to me, but I did not know where they had come from. At dusk, when it was time to close the city gate. The men left. I don’t know which way they went. Go after them quickly. You may catch up with them.

But she had taken them up to the roof and hidden them under the stalks of flax she had laid out on the roof. So the men set out in pursuit of the spies on the road that leads to the fords of the Jordan, and as soon as the pursuers had gone out, the gate was shut. Before the spies lay down for the night, she went up on the roof and said to them, I know that the LORD has given this land to you and that a great fear of you has fallen on us, so that all who live in this country are melting in fear because of you. We have heard how the LORD dried up the water of the Red Sea for you when you came out of Egypt, and what you did to Sihon and Og, the two kings of the Amorites east of the Jordan. Whom you completely destroyed.

When we heard of it, our hearts melted and everyone’s courage failed because of you, for the LORD your God is God in heaven above and on the earth below. Now then, please swear to me by the LORD that you will show kindness to my family. Because I have shown kindness to you. Give me a sure sign that you will spare the lives of my father and mother, my brothers and sisters, and all who belong to them, and that you will save us from death. Our lives for your lives! The men assured her. If you don’t tell what we are doing, we will treat you kindly and faithfully when the LORD gives us the land. So she let them down by a rope through the window, for the house she lived in was part of the city wall.

Now she had said to them, Go to the hills so the pursuers will not find you, Hide yourselves there three days until they return, and then go on your way. The men said to her, This oath you made us swear will not be binding on us unless, when we enter the land, you have tied this scarlet cord in the window through which you let us down, and unless you have brought your father and mother, your brothers and all your family into your house. If anyone goes outside your house into the street, his blood will be on his own head; we will not be responsible. As for anyone who is in the house with you, his blood will be on our head if a hand is laid on him. But if you tell what we are doing, we will be released from the oath you made us swear.

Agreed, she replied. Let it be as you say. So she sent them away and they departed. And she tied the scarlet cord in the window. When they left, they went into the hills and stayed there three days, until the pursuers had searched all along the road and returned without finding them. Then the two men started back. They went down out of the hills, forded the river and came to Joshua son of Nun and told him everything that had happened to them. They said to Joshua, The LORD has surely given the whole land into out hands; all the people are melting in fear because of us.

#3

Early in the morning Joshua and all the Israelites set out from Shittim and went to the Jordan, where they camped before crossing over. After three days the officers went throughout the camp, giving orders to the people: when you see the ark of the covenant of the LORD your God, and the priests, who are Levites, carrying it, you are to move out from your positions and follow it. Then you will know which way to go, since you have never been this way before. But keep a distance of about a thousand yards between you and the ark; do not go near it. Joshua told the people, Consecrate yourselves, for tomorrow the LORD will do amazing things among you.

Joshua said to the priests, Take up the ark of the covenant and pass on ahead of the people. So they took it up and went ahead of them. And the LORD said to Joshua, Today I will begin to exalt you in the eyes of all Israel, so they may know that I am with you as I was with Moses. Tell the priests who carry the ark of the covenant: When you reach the edge of the Jordan’s waters, go and stand in the river. Joshua said to the Israelites, Come here and listen to the words of the LORD your God. This is how you will know that the living God is among you and that he will certainly drive out before you the Canaanites, Hittites, Hivites, Perizzites, Girgashites, Amorites and Jebusites.

See the ark of the covenant of the Lord of all the earth will go into the Jordan of Israel, one from each tribe. And as soon as the priests who carry the ark of the LORD – the Lord of all the earth – set foot in the Jordan, its water flowing downstream will be cut off and stand up in a heap. So when the people broke camp to cross the Jordan, the priests carrying the ark of the covenant went ahead of them. Now the Jordan is at flood stage all during harvest. Yet as soon as the priests who carried the ark reached the Jordan and their feet touched the water’s edge,

The water from upstream stopped flowing. It piled up in a heap a great distance away, at a town called Adam in the vicinity of Zarethan, while the water flowing down to the Sea of the Arabah (the Salt Sea) was completely cut off. So the people crossed over opposite Jericho. The priests who carried the ark of the covenant of the LORD stood firm on dry ground in the middle of the Jordan, while all Israel passed by until the whole nation had completed the crossing on dry ground.

여호수아 4장

1

When the whole nation had finished crossing the Jordan, the LORD said to Joshua, Choose twelve men from among the people, one from each tribe. And tell them to take up twelve stones from the middle of the Jordan from right where the priests stood and to carry them over with you and put them down at the place where you stay tonight. So Joshua called together the twelve men he had appointed from the Israelites, one from each tribe, and said to them, Go over before the ark of the Lord your God into the middle of the Jordan