SE 2AA4, CS 2ME3 (Introduction to Software Development)

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28 Parnas Tables DRAFT

Dr. Spencer Smith

Faculty of Engineering, McMaster University

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28 Parnas Tables DRAFT

- Today's slide are partially based on slides by Dr. Wassyng
- Administrative details
- Translating English to Math exercise
- Motivating example: midterm question
- History of tables
- Example tables
- Semantics for tables
- Classification of tables
- Tables in practise
- Advantages of tables
- pointInRegion(p)

Administrative Details

TBD

Exercise

- For SE Section

Consider an array D with index values ranging from 1 to n. The subject of this example is part of a specification for a subprogram that will count how many times a particular given value occurs in the array D.

The goal of this exercise is to write a postcondition for the subprogram, relating the various relevant variables values when the search is complete.

Exercise Continued

Understand the task in the original language

- Identify objects referred to (look for nouns in the original English text)

- Identify missing information

Exercise Continued

Understand the task in the original language

- Identify objects referred to (look for nouns in the original English text)
- Array D, index value, times (count), particular given value, relevant variables's value
- Identify missing information

Exercise Continued

Understand the task in the original language

- Identify objects referred to (look for nouns in the original English text)
- Array D, index value, times (count), particular given value, relevant variables's value
- Identify missing information
- Names of variable for: index, times (count), particular given value

Exercise Continued

Understand the task in the original language

- Identify objects referred to (look for nouns in the original English text)
- Array D, index value, times (count), particular given value, relevant variables's value
- Identify missing information
- Names of variable for: index, times (count), particular given value
- Are there any other relevant variables?

Exercise

- Identify missing information
- Names of variable for
  - Index: assume *i*
  - Times (count): ask the author of the task, assume *count*
  - Particular given value: Ask the author of the task, assume *key*
  - Are there any other relevant variables? (no?)

Exercise Continued

- Close the gap between English text and mathematics
  - Reword the English text to be closer to mathematics
  - Use the English verb *count*

Exercise Continued

- The English verb *count* means, in programming language and in terms closer to mathematics, *add* 1
- But this is a dynamic (action) concept
- The corresponding static (state, relational) concept in mathematics is the function *addition with 1*, that is $+1$

Exercise Continued

- The occurrence of the particular given value in an array element in D
- $D[i] = key$
- A condition for the addition with 1
- The repetition over a variable number of index values suggests quantification with the function addition and with the argument 1
- $+(i :? | ... \wedge D[i] = key : 1)$

Exercise Continued

Identify relationships between essential objects

- Array D, index value, particular given value: $D[i] = key$
- Combine the above with count ($+$ conditionally with 1)
- $count = +(i : \mathbb{N} | ... \leq i \leq ... \wedge D[i] = key : 1)$
- Range of i missing
- Refer to original English text: 1 to n
- $count = +(i : \mathbb{N} | 1 \leq i \leq n \wedge D[i] = key : 1)$

Exercise: New Glossary Entry

Now we have a new entry for our glossary

- count: $+(i : \mathbb{N} | ... \leq i \leq ... \wedge ... : 1)$, where the ... defines the range of the quantified variable and the condition for counting

Summary

- Knowledge of English and Mathematics is necessary but not sufficient to translate into Mathematics
- Knowledge of subject area also needed
- Translating skills needed
- The three are different

Summary

- Compile your own glossary
- Make intermediate steps and expressions conscious
- Modularize
- Organize systematically
- KISSS

Tables Motivating Example: ptOn(c, s)

$$
\begin{aligned}
(x(c) = x(s) \Rightarrow & \begin{array}{r} (y(s) \leq y(f) \Rightarrow y(s) \leq y(c) \leq y(f) | \\ y(s) > y(f) \Rightarrow y(f) \leq y(c) \leq y(s)) \end{array} \\
|y(c) = y(s) \Rightarrow & \begin{array}{r} (x(s) \leq x(f) \Rightarrow x(s) \leq x(c) \leq x(f) | \\ x(s) > x(f) \Rightarrow x(f) \leq x(c) \leq x(s)) \end{array} \\
|N(c, s) \Rightarrow & \text{ False})
\end{aligned}
$$

$$N(c, s) \equiv x(c) \neq x(s) \wedge y(c) \neq y(s)$$

In Tabular Form

		out
$x(c) = x(s)$	$y(s) \leq y(f)$	$y(s) \leq y(c) \leq y(f)$
	$y(s) > y(f)$	$y(f) \leq y(c) \leq y(s)$
$y(c) = y(s)$	$x(s) \leq x(f)$	$x(s) \leq x(c) \leq x(f)$
	$x(s) > x(f)$	$x(f) \leq x(c) \leq x(s)$
$x(c) \neq x(s) \wedge y(c) \neq y(s)$		False

A Brief History of Tables

- Similar work, such as decision tables, have been around for a while (1950s?)
- The intuitive use of tables proliferated on the A-7E Aircraft US Naval Research Lab (NRL) project (Parnas)
- The US NRL continues to work on the SCR (Software Cost Reduction) method
- Ontario Hydro - Darlington Shutdown Systems
- Work began on the semantics of tables - Parnas, Janicki, Zucker, Abraham
- Ontario Power Generation (OPG) methods for Safety Critical Software
- More semantics - Janicki, Khedri, Kahl, Wassyng
- Dave Parnas has championed the use of tabular expressions (tables) in documenting software requirements and designs

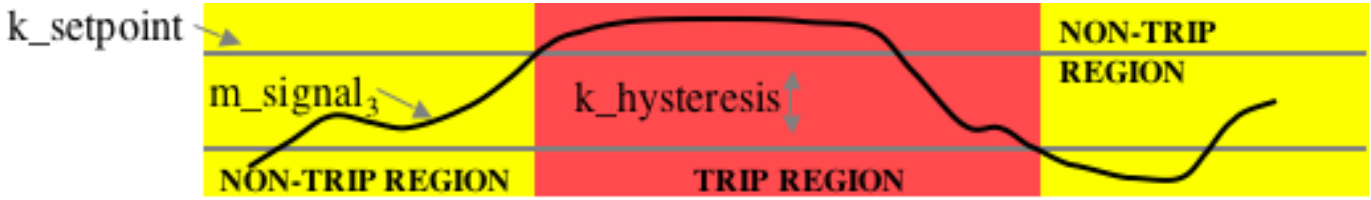
Example Table from A-7E Project

SCR/A7-E

Inmode(*High*) ∨ *Inmode*(*Permitted*)	$TRUE$	$FALSE$
Inmode(*TooLow*)	!Overridden!	¬!Overridden!
%%Safety_Injection%% =	OFF	ON

Example Table from OPG Project

OPG



$f_sensortrip_i$, i=1,..,4

{For each i = 1,..,4}

Condition	*Result* **$f_sensortrip_i$**
$k_setpoint \leq m_signal_i$ *{i^{th} signal is now in the trip region}*	e_Trip
$k_setpoint - k_hysteresis < m_signal_i < k_setpoint$ *{i^{th} signal is now in the deadband region}*	No Change
$m_signal_i \leq k_setpoint - k_hysteresis$ *{i^{th} signal is now in the non-trip region}*	e_NotTrip

Example for Input Checking

Composition rule	$\cup_{i=1}^{4} H_2[i] \cap (\cap_{j=1}^{2} H_1[j]\ ;\ G[i,j])$

H_1

$S'_{GET} \cup =$	$ErrorMsg' + =$

H_2	G
$x_1 < 0$	$\emptyset$ $\quad$ $InvalidInput_x_1$
$0 \leq x_1 < min_d$	$\emptyset$ $\quad$ $x_1_TooSmall$
$x_1 > max_d$	$\emptyset$ $\quad$ $x_1_TooLarge$
$min_d \leq x_1 \leq max_d$	$\{@x_1\}$ $\quad$ $NULL$

$\wedge ChangeOnly(S_{GET}, ErrorMsg)$

Solving Real Roots of $ax^2 + bx + c = 0$

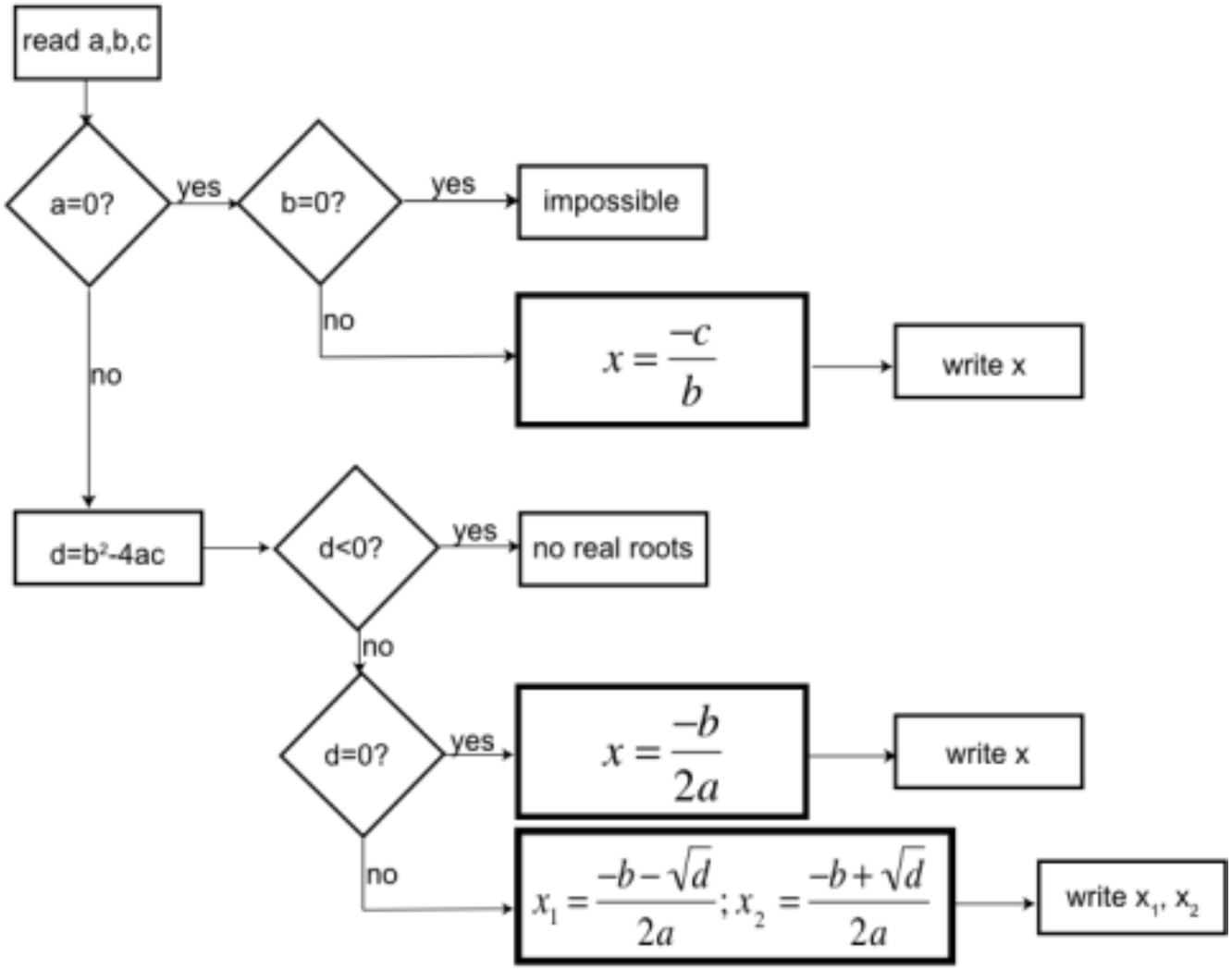


Table for Solving the Quadratic Equation

			Solution caption	x_1	x_2
$a = 0$	$b = 0$		Ill defined	—	—
	$b \neq 0$		One root	$-\frac{c}{b}$	—
$a \neq 0$	$b^2 - 4ac < 0$		No real roots	—	—
	$b^2 - 4ac = 0$		One root	$-\frac{b}{2a}$	—
	$b^2 - 4ac > 0$	$b \geq 0$	Two roots	$\frac{-b-\sqrt{b^2-4ac}}{2a}$	$\frac{c}{ax_1}$
		$b < 0$	Two roots	$\frac{-b+\sqrt{b^2-4ac}}{2a}$	$\frac{c}{ax_1}$

What are the advantages of the tabular specification?

Table for Solving the Quadratic Equation

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$a \neq 0$	$b^2 - 4ac < 0$		No real roots	—	—
	$b^2 - 4ac = 0$		One root	$-\frac{b}{2a}$	—
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		$b < 0$	Two roots	$\frac{-b+\sqrt{b^2-4ac}}{2a}$	$\frac{c}{ax_1}$

What are the advantages of the tabular specification?

- Understandable
- Unambiguous
- Check for completeness and disjointness
- Test cases

Why We Need Precise Semantics

- To promote an unambiguous understanding for both writers and readers
- To understand the meaning of tables that look similar, but have different semantics
- To be able to link tables of different types
- To know what notation we can use in the tables
- To be able to build software tools that create, edit, transform and print tables

Early Semantics

	f_name
Condition 1	Result 1
Condition 2	Result 2
...	...
Condition n	Result n

If Condition 1 then f_name = Result 1
Elseif Condition 2 then f_name = Result 2
Elseif ...
Elseif Condition n then f_name = Result n

Early Semantics

	f_name
Condition 1	Result 1
Condition 2	Result 2
...	...
Condition n	Result n

If Condition 1 then f_name = Result 1
Elseif Condition 2 then f_name = Result 2
Elseif ...
Elseif Condition n then f_name = Result n

Disjointedness $\equiv \forall(i, j : \mathbb{N} | 1 \leq i \leq n \wedge 1 \leq j \leq n \wedge i \neq j :$
Condition $i \wedge$ Condition $j \Leftrightarrow$ false$)$

Completeness $\equiv \vee(i : \mathbb{N} | 1 \leq i \leq n :$ Condition $i)$

Semantics

Example of a table describing f(x,y):

Guards(H_1,H_2)

$P = H_1 \wedge H_2$

r = G

C: $R = \bigcup_i \bigcup_j R_{i,j}$

H_2 \ H_1	$y = 10$	$y > 10$	$y < 10$
$x \geq 0$	0	y^2	$-y^2$
$x < 0$	x	$x + y$	$x - y$

G Values(G)

Information flow

Cell Connection Graph
CCG

Corresponding to:

$$f(x,y) = \begin{cases} 0 & \text{if } x \geq 0 \wedge y = 10 \\ x & \text{if } x < 0 \wedge y = 10 \\ y^2 & \text{if } x \geq 0 \wedge y > 10 \\ -y^2 & \text{if } x \geq 0 \wedge y < 10 \\ x + y & \text{if } x < 0 \wedge y > 10 \\ x - y & \text{if } x < 0 \wedge y < 10 \end{cases}$$

Semantics Continued

- Disjointedness and Completness are not part of the semantics of tables
- We impose these conditions to make tables more useful in practise

Classification of Tables

Tabular expressions can be classified according to the orientation of the tables

Vertical condition tables

	c1	c2
res	v1	v2

Horizontal condition tables

	res
c1	v1
c2	v2

Types of Tables

Normal

	$y = 10$	$y > 10$	$y < 10$
$x \geq 0$	0	y^2	$-y^2$
$x < 0$	x	$x + y$	$x - y$

value cells

Inverted

value cells

$x + y$	$x - y$	$y - x$

$y \geq 0$	$x < 0$	$0 \leq x < y$	$x \geq y$
$y < 0$	$x < y$	$y \leq x < 0$	$x \geq 0$

Decision

value cells

gs	gb	gb	pb	g

Tem $\in \{h, c\}$	$*$	$*$	h	$*$	c
Wt $\in \{s, cl, r\}$	$s \vee cl$	s	cl	r	cl
Wn $\in \{T, F\}$	T	F	F	$*$	F

$* = don't\ care,\ T = true,\ F = false$
$h = hot,\ c = cool,\ s = sunny,\ cl = cloudy,$
$r = rain$
$Tem = Temperature,\ Wt = Weather,$
$Wn = Windy$
$gs = go\ sailing,\ gb = go\ to\ the\ beach$
$pb = play\ bridge,\ g = garden$

Vector

	$x_2 \leq 0$	$x_2 > 0$
$y_1 =$		
y_2	$y_2 x_1 - x_2 = y_2^2$	$x_1 + x_2 y_2 = \lvert y_2 \rvert$
y_3	$y_3 + x_1 x_2 = \lvert y_3 \rvert^3$	$y_3 = x_1$

value cells

Generalized Decision

value cells

$x_1 + x_2$	$x_1 - x_2$	$x_1 x_2$

$x_1 x_2$	$\# < 20$	$\# \geq 20$	$true$
$x_1 \div x_2$	$\# > 30$	$\# < 30$	$\# = 30$

World View of Tables

- Do tables take a dynamic or a static world view?
- Can you write an algorithm with a table?

Tables in Practise

- According to Dr. Wassyng projects typically define a small set of types of tables to be used in that project
- Tables at Ontario Power Generation, Darlington Nuclear Generating Station - Shutdown System One (SDS1)
  - Horizontal condition tables for requirements - read from left to right, fit on the page well
  - Vertical condition tables for the software design - better suited to multiple outputs
  - Sometimes also state transition tables
- Use table structure to visually aid readers so that they can discern nested conditions (see the quadratic equation example)
- Tables enable production of formal requirements that are readable by domain experts
- Use natural language expressions to enhance readability

Advantages of Tables

- Tabular expressions describe relations through pre and post conditions - ideal for describing behaviour without sequences of operations
- They make it easy to ensure input domain coverage
- They are easy to read and understand (you need just a little practise to write them)
- Coding from tables results in extremely well structured code
- They facilitate identification of test cases
- Extremely good for real-time/embedded systems

A Table for pointInRegion(p)

- Consider all of the cases
- Draw a picture
- Short form notation
  - $px = p.\text{xcoord}()$
  - $py = p.\text{ycoord}()$
  - $llx = lower_left.\text{xcoord}()$
  - $lly = lower_left.\text{ycoord}()$
  - $llxw = lower_left.\text{xcoord}() + width$
  - $llyh = lower_left.\text{ycoord}() + height$
  - T = Constants.TOLERANCE

		out

		out
$px < llx$		
$llx \leq px \leq llxw$		
$px > llxw$		

		out
$px < llx$	$py < lly$	
	$lly \leq py \leq llyh$	
	$py > llyh$	
$llx \leq px \leq llxw$	$py < lly$	
	$lly \leq py \leq llyh$	
	$py > llyh$	
$px > llxw$	$py < lly$	
	$lly \leq py \leq llyh$	
	$py > llyh$	

		out
$px < llx$	$py < lly$	$p.\mathsf{dist}(\mathsf{PointT}(llx, lly)) \leq \mathsf{T}$
	$lly \leq py \leq llyh$	
	$py > llyh$	
$llx \leq px \leq llxw$	$py < lly$	
	$lly \leq py \leq llyh$	
	$py > llyh$	
$px > llxw$	$py < lly$	
	$lly \leq py \leq llyh$	
	$py > llyh$	

		out
$px < llx$	$py < lly$	$p.\text{dist}(\text{PointT}(llx, lly)) \leq \text{T}$
	$lly \leq py \leq llyh$	$(llx - px) \leq \text{T}$
	$py > llyh$	
$llx \leq px \leq llxw$	$py < lly$	
	$lly \leq py \leq llyh$	
	$py > llyh$	
$px > llxw$	$py < lly$	
	$lly \leq py \leq llyh$	
	$py > llyh$	

		out
$px < llx$	$py < lly$	$p.\text{dist}(\text{PointT}(llx, lly)) \leq \text{T}$
	$lly \leq py \leq llyh$	$(llx - px) \leq \text{T}$
	$py > llyh$	$p.\text{dist}(\text{PointT}(llx, llyh)) \leq \text{T}$
$llx \leq px \leq llxw$	$py < lly$	
	$lly \leq py \leq llyh$	
	$py > llyh$	
$px > llxw$	$py < lly$	
	$lly \leq py \leq llyh$	
	$py > llyh$	

		out
$px < llx$	$py < lly$	$p.\text{dist}(\text{PointT}(llx, lly)) \leq \text{T}$
	$lly \leq py \leq llyh$	$(llx - px) \leq \text{T}$
	$py > llyh$	$p.\text{dist}(\text{PointT}(llx, llyh)) \leq \text{T}$
$llx \leq px \leq llxw$	$py < lly$	$(lly - py) \leq \text{T}$
	$lly \leq py \leq llyh$	
	$py > llyh$	
$px > llxw$	$py < lly$	
	$lly \leq py \leq llyh$	
	$py > llyh$	

		out
$px < llx$	$py < lly$	$p.\text{dist}(\text{PointT}(llx, lly)) \leq \text{T}$
	$lly \leq py \leq llyh$	$(llx - px) \leq \text{T}$
	$py > llyh$	$p.\text{dist}(\text{PointT}(llx, llyh)) \leq \text{T}$
$llx \leq px \leq llxw$	$py < lly$	$(lly - py) \leq \text{T}$
	$lly \leq py \leq llyh$	True
	$py > llyh$	
$px > llxw$	$py < lly$	
	$lly \leq py \leq llyh$	
	$py > llyh$	

		out
$px < llx$	$py < lly$	$p.\text{dist}(\text{PointT}(llx, lly)) \leq \text{T}$
	$lly \leq py \leq llyh$	$(llx - px) \leq \text{T}$
	$py > llyh$	$p.\text{dist}(\text{PointT}(llx, llyh)) \leq \text{T}$
$llx \leq px \leq llxw$	$py < lly$	$(lly - py) \leq \text{T}$
	$lly \leq py \leq llyh$	True
	$py > llyh$	$(py - llyh) \leq \text{T}$
$px > llxw$	$py < lly$	
	$lly \leq py \leq llyh$	
	$py > llyh$	

		out
$px < llx$	$py < lly$	$p.\text{dist}(\text{PointT}(llx, lly)) \leq \text{T}$
	$lly \leq py \leq llyh$	$(llx - px) \leq \text{T}$
	$py > llyh$	$p.\text{dist}(\text{PointT}(llx, llyh)) \leq \text{T}$
$llx \leq px \leq llxw$	$py < lly$	$(lly - py) \leq \text{T}$
	$lly \leq py \leq llyh$	True
	$py > llyh$	$(py - llyh) \leq \text{T}$
$px > llxw$	$py < lly$	$p.\text{dist}(\text{PointT}(llxw, lly)) \leq \text{T}$
	$lly \leq py \leq llyh$	$(px - llxw) \leq \text{T}$
	$py > llyh$	$p.\text{dist}(\text{PointT}(llxw, llyh)) \leq \text{T}$

Seven Cases

		out
$px < llx$	$py < lly$	$p.\text{dist}(\text{PointT}(llx, lly)) \leq \text{T}$
	$lly \leq py \leq llyh$	$(llx - px) \leq \text{T}$
	$py > llyh$	$p.\text{dist}(\text{PointT}(llx, llyh)) \leq \text{T}$
$llx \leq px \leq llxw$		
$px > llxw$	$py < lly$	$p.\text{dist}(\text{PointT}(llxw, lly)) \leq \text{T}$
	$lly \leq py \leq llyh$	$(px - llxw) \leq \text{T}$
	$py > llyh$	$p.\text{dist}(\text{PointT}(llxw, llyh)) \leq \text{T}$

Seven Cases

		out
$px < llx$	$py < lly$	$p.\text{dist}(\text{PointT}(llx, lly)) \leq \text{T}$
	$lly \leq py \leq llyh$	$(llx - px) \leq \text{T}$
	$py > llyh$	$p.\text{dist}(\text{PointT}(llx, llyh)) \leq \text{T}$
$llx \leq px \leq llxw$		$(lly - \text{T}) \leq py \leq (llyh + \text{T})$
$px > llxw$	$py < lly$	$p.\text{dist}(\text{PointT}(llxw, lly)) \leq \text{T}$
	$lly \leq py \leq llyh$	$(px - llxw) \leq \text{T}$
	$py > llyh$	$p.\text{dist}(\text{PointT}(llxw, llyh)) \leq \text{T}$

Six Cases

		out
$px < llx$	$py < lly$	$p.\text{dist}(\text{PointT}(llx, lly)) \leq \text{T}$
	$py > llyh$	$p.\text{dist}(\text{PointT}(llx, llyh)) \leq \text{T}$
$llx \leq px \leq llxw$		$(lly - \text{T}) \leq py \leq (llyh + \text{T})$
$px > llxw$	$py < lly$	$p.\text{dist}(\text{PointT}(llxw, lly)) \leq \text{T}$
	$py > llyh$	$p.\text{dist}(\text{PointT}(llxw, llyh)) \leq \text{T}$
$lly \leq py \leq llyh$		

Six Cases

		out
$px < llx$	$py < lly$	$p.\text{dist}(\text{PointT}(llx, lly)) \leq \text{T}$
	$py > llyh$	$p.\text{dist}(\text{PointT}(llx, llyh)) \leq \text{T}$
$llx \leq px \leq llxw$		$(lly - \text{T}) \leq py \leq (llyh + \text{T})$
$px > llxw$	$py < lly$	$p.\text{dist}(\text{PointT}(llxw, lly)) \leq \text{T}$
	$py > llyh$	$p.\text{dist}(\text{PointT}(llxw, llyh)) \leq \text{T}$
$lly \leq py \leq llyh$		$(llx - \text{T}) \leq px \leq (llxw + \text{T})$

Three Cases

	out
$llx \leq px \leq llxw$	$(lly - \mathrm{T}) \leq py \leq (llyh + \mathrm{T})$
$lly \leq py \leq llyh$	$(llx - \mathrm{T}) \leq px \leq (llxw + \mathrm{T})$
$\neg(llx \leq px \leq llxw) \wedge \neg(lly \leq py \leq llyh)$	

Three Cases

	out
$llx \leq px \leq llxw$	$(lly - \mathrm{T}) \leq py \leq (llyh + \mathrm{T})$
$lly \leq py \leq llyh$	$(llx - \mathrm{T}) \leq px \leq (llxw + \mathrm{T})$
$\neg(llx \leq px \leq llxw) \wedge \neg(lly \leq py \leq llyh)$	$\min[p.\mathrm{dist}(\mathrm{PointT}(llx, lly)), p.\mathrm{dist}(\mathrm{PointT}(llxw, lly)), p.\mathrm{dist}(\mathrm{PointT}(llx, llyh)), p.\mathrm{dist}(\mathrm{PointT}(llxw, llyh))] \leq \mathrm{T}$