



PRAVDA?



The Official(?) Newsletter of the KGB

Editor: Matthew Kehrt
(mkehr@andrew.cmu.edu)

Price: FREE
Volume 9, Issue 0 — December 13, 2004

I Rule the Universe

by mkehr

Once again I have published the glorious newsletter of the KGB. For some of you, this may be the first time you have seen such a thing. I ask that those of you for which this is true take a moment to step back and marvel at the beauty of the thing you hold. Notice how it sparkles and shines in the cold, winter light. Isn't it pretty?

As nice as that is, there are more pressing issues. One of these is the next issue of Pravda?. It is vitally important to the well-being of all humanity that such a thing exist, and exist soon. To make this dream a reality, I ask all you readers out there to think of the children and to

SUBMIT TO PRAVDA?!

Remember, I will personally glance at every submission before handing it off to my trained staff of monkeys.

PrAVda!!!

by Psyfe

Hrodulf Color suffering pulling Mark Deer (Generation English Sentence) Beginning Village Rudolph, it is cold Grassy plain vagrancy Line It is low, Hrodulf Color suffering pulling Mark The deer – that merely the field Didn'T possession unshiny nostril! Good nose child Bone Ryo harmony Light. Hoof holding vote human taunted other things from here Arrogant Mark ; Same mind wouldn' T permits Orphan painful Hrodulf joining Deer ratio . Nature empress, resident in Front evening area resident in Violence/exposing Old person Sumi Ryo that, giving Akiva <3s Mkehr¹ other proper form Ryo : ” Dear night suffering watching Mark friend, nose child discernment Akikazu! Hrodulf, military officer Our suffering equipment Mark quick wagon! ” Nature empress sky Line thing name Ryo other things Mark Deer – amount on hand Chord ; The possession angular part this inside one Broad area singing/stating Ryo ” Lo and Hrodulf Color suffering pulling Mark Deer Mark reputation Broadcasts Right renowned! ”

Pravda Submission #3

by arwong

And the first column 1. The Tartan is a good time. I was a good, % Page left the first crime the world. The Tartan, And a good for me and a AFC-25 Mark damages the Tartan doesn't have been here long space marine hottie film without the Tartan I was also, I had children they would have these men of the Technical Taurus: When we were sent to the Tartan. I have a different pace, I had children they would be

¹I hate you, Psyfe. –ed.

put to be so, What is damaged upper torso of the new York School. And I had to be a few of a date the Tartan.

And I was produced in a pervert.

I have run through UNIX what they have an actual budget is the other words,

- TiBooks

amazing creativity (that's the title)

by mtelgars

FORTY SEVEN! no, forty eight bumble bees. how could they know? The devious, many-horned nymphknocks, bizarre masochists extraordinaire, are known for vagrant hedonism, and no heed for others. But bumble bees?

SIXTEEN! no, SEVENTEEN mutants. Who sends mutants in these days of quantum defibrillated defecators, soup forks, and electromagnetically control fusion nail clippers? well they did, and the results were terrifying.

CAPITAL LETTERS! no, err, YES! They sent these diabolical devices.

Somehow they peered through the crevices of time, the portals of my soul—somehow they determined that these three things together are more irksome than they semmifrious glands of—

—oh, a memo. It was in my .plan.

In other news, I have perfected the design for my boulevard-wide lawnmower.

ahahahaha barbecued mutants.

La salle d'attente

by jcipa

Un jour froid, pluvieux, venteux au printemps, dans un bâtiment plat, dans la salle plate indéfinissable sans fenêtres peinte aux nuances de gris et de violet, sous la lueur de la lumière et du fredonnement durs des lumières fluorescentes reposait une femme d'âge mûr, dans une chaise en plastique générique. Ses cheveux blonds dérangés (et évidemment teints) et son maquillage enduit. était-elle désordonnée en raison de la pluie, ou pour une autre raison? Le logo sur son sac à main, grand, gauche, et d'or, le manteau beige de bon goût qui se semblait être de cachemire, les anneaux qui sont parvenus à miroiter dans la lumière plate; tout avait annoncé sa richesse. Ses vêtements étaient froissés, son visage rincé, ses yeux rougis. Sans horloge dans la chambre, il n'y avait aucune manière de savoir combien de temps elle avait été là. Silencieuse sauf pour ses sanglots occasionnels, les mains tordues dans des poings sur son recouvrement, elle attendait impatiemment.

Edelweiss

by epr

Try as I might, I find it difficult to explain to others what happened under the blood moon that October. My job at the Northern Valley Hydroponic Pumpkin Plant seemed perfect. The pay was decent, my coworkers were pleasant, and they made the most delicious pumpkin pie.

Something always seemed a little off though. The management had an air about them that was very... forced. They were always nice and always polite, but something about the way they held themselves when they spoke to you made it seem like they would like nothing more than to crush the life out of every man, creature, insect and plant they came across.

Being a hydroponic pumpkin farm, we produced delicious pumpkins year-round, but it was always during the traditional "harvest season" that we had the most business. As such, every year there was a large influx of temporary workers, hired to help meet that demand.

Last year, R&D was experimenting with a new product. It was an enormous, albino pumpkin called "Edelweiss". These pumpkins were genetically engineered to be stunningly delicious, and anyone who tasted a pumpkin product derived from the white giant felt compelled to eat more. It was to be a windfall for our company, but the researchers were having trouble producing them in any significant quantity.

Much to our relief, they solved the problem just as the busy season began. Business was booming, we were all looking forward to big Christmas bonuses, and we were eating pie made from the incredible Wonder Pumpkin every day. Everything seemed idyllic. The temporary workers were grumbling more than usual, but nobody cared about them. That is, until my curiosity got the better of me.

My job was in shipping. I oversaw the packaging of the pumpkins, making sure that nothing untoward would happen to them in transit. As such, I never really got the chance to look at the other areas. One day though I had a rare break in the work, and decided to look at the place the Edelweiss were grown. The beautiful, sensuous taste of them drew me.

Nobody paid me any heed as I walked among the enormous tanks, with the hulking, white forms floating inside. As I walked deeper into the genation chambers, the lights grew dimmer and dimmer. It became difficult to see where I was going. I kept going though, now curious about what the depths held.

Among the mechanical hums, I began to perceive a new sound. It grew stronger and became more distinct, and my mind made the connection: I was hearing the moaning of several people suffering. Panic filled me. I began to rush between the tanks, looking for the cause. That was a mistake.

I came upon a door. The moans came from behind it. I opened it expecting to find that some accident had occurred. Thoughts of heroism flashed through my head, as I contemplated single-handedly lifting a large machine from the crushed legs of some poor researcher.

I was disappointed. There was nothing I could have done for the poor souls behind that door. What I saw as I opened it were a series of medical tables. They were all inhabited, and their occupants alternated between people and pumpkins. The pumpkins varied between normal, orange pumpkins, and juvenile Edelweiss, as well as pumpkins that seemed to be somewhere inbetween. As I drew closer, I recognized one of the people as a temp worker who had joined the week before. His pumpkin was still quite orange, and he seemed to still have

hits wits about him. There were electrodes connected to his head, and they ran over to the pumpkin.

"Please you have to help me!" he begged as I came into his view.

"What on Earth is going on here?"

"They're killing us! Making pumpkins from us!"

"They're what? That doesn't make any sense." I tried to release his restraints, but they were securely locked to the table.

"They're taking our souls!"

Just then I heard a sound from behind another door. There were people approaching. I quickly made my way back toward the door I came from, and the man started to scream.

I closed the door behind me and stood for a moment, listening. Under the man's screams, I heard a voice singing,

"Edelweiss, Edelweiss

Every morning you greet me.

Small and white, clean and bright,

You look happy to meet me."

I ran. I ran out of the room, out of the building, and out of the town. I got as far away from North Valley as I could, as quickly as I could.

I'll never eat a pumpkin pie again.

Skolemization Rap

by guyg

Yo, make some heat dog, make it warm.
About to define the Skolemized form.
Of a well-formed formula, call it B ,
Say B 's a sentence, so no vars free.

You start by doin' a left to right traversal
To make a string that's universal.
A def for that can anyone give me?
cMeans each quantifier occurs positively.

And take a countable formulation:
That implies there exists an enumeration
Of F , let's call it B_1 through B_k ,
And bring a new n -ary constants to play

A role that will prove completely essential,
Let's nickname these guys the constants existential.
Now add them to F and I'll quickly mention
 F^* 's gonna give us a conservative extension.

From left-to-right through each B
And use a function we've yet to see
To replace each instance of the x
That's bound by a quantifier of negative specs.

Apply the function to the free vars
That are in the scope the quantifier bears.
And in some model this new form's valid;
By the way that's why Skolem is solid.

Yo holla now, I gotta proof
 B^* implies B , yeah raise the roof.
It follows from subst. bf implication
That B is valid; if so's its Skolemization.

©Guy Goldstein

A Day in the Lounge

by csugl, submitted by mbk

This text is lonely. Will it date me?

No, but it will let you grep it.

A date with string? Kinky...

That's 'sed'icious.

What an 'awk'ward pun, Wes!

'fortune'-ately, it was grounds for better.

I hate you all, to a 'man'.

This one's truly a 'perl'

'la','la','la', I'm not 'ls'tening.

'cat'egorically bad puns.

Stop 'bash'ing my puns.

A 'mv'ing sequence, indeed.

Kinda a 'du'd, if you ask me.

(so bad, they're 'cp'-outs)

What a /regular expression/...

'this' is 'ps'ing me off

This 'make's me want to cry.

invocation_to_muse.h

by aleffert

```
/** @file invocation_to_muse.h
 * @brief An invocation to the muse
 *
 * Contains an Invocation to the muse.
 * So our OS is not eaten by grues.
 * Metrically, iambic pentameter
 * Though sometimes other types of feet occur.
 */

// To me O muse of countless lines of code
// sing and aid construction of my ode.
// And if Pan's call should interrupt my course
// May its cause be clearly found in my source.

// Segfaults, drivers, kernels, and interrupts
// Protect me from lassitude which corrupts.
// Oh blessed muse on this course help me stay
// and with your aid I hope to earn an A
```

Propositional Calculus Rap

by guyg

The syntax we start with has or's and not's,
Implicit brackets are shown as dots.
We also have propositional vars,
And the def. of well-formed formulas swears
That the meet of every single
In which the following rules are met
Creates the set of well formed strings
And elements are joined to make longer things.
Yo, holla now, the rules:
Ya gotta have prop. variables fools,
And if A is in then so is $\neg A$
If B 's also in there then $A \vee B$'s ok.
Next we consider the principle of induction:
If a property holds for every constuction
Then we know it's true for all forms legal;
If it's not for a string then that string's not regal.
Here's the axiom schemata, for P ,
 $A \rightarrow B \rightarrow C \vee A \rightarrow B \vee C$

We're not done, that's just the longest one.

What's next you say? $A \vee A \rightarrow A$

Another to obey is $A \rightarrow B \vee A$

But how you gonna make any other rules

Without *Modus Ponens* as an inference tool?

We have theorems and wff screebug,

But semantics are what still gives them meaning.

Every theorem's a tautology, hell yeah, we're sound,

And thus P must be consistent once that is found.

The question remaining is if P 's complete.

Every tautology's a theorem, prop calculus is sweet.

©Guy Goldstein

Meditations Upon the Nature of Human Existence

aleffert

When I was a much younger man, I set out to find the meaning of life. I packed myself some food, put on my best pair of adventuring socks, and started walking. I decided to head east in order to find the source of the sun, as I was once told that when trying to learn, one should always start at the beginning. I passed through hill and valley, learned much, and wore through many pairs of shoes. One day I saw myself in a stream and a stranger stared out. Who is this man staring back I wondered. Then I realized that rather I should be asking who is this man in my mind who once was me. I found much foolishness in the world and much wisdom. The two are not always distinct.

After many years of travelling, I came to a great valley, withered and barren. The decaying and dead trees dotted the landscape. I had come to the place where the sun rises. I started my descent into the intense heat. My skin began to char and bubble, but still I went on. I melted into the parched terrain and soon I was but a memory.

My spirit lay there watching as a fierce storm blew in, cloaking the sun in darkness. Rain poured down and life sprouted up. Flesh grew around my bare bones. I walked up out of that valley as the rain soaked my body.

When I stepped onto level ground, drenched and tired, a man appeared from behind a tree and came toward me. He moved in the manner of a madman, limbs lurching forward.

"Hello there." I yelled out to him.

"Gah. Greetings!" He shouted back, continuing his halting approach.

"Who are you?"

"What? Oh. I'm me. How about you?"

"I seem to have lost my name in the valley."

"You've come back from the valley?"

I waved my arm behind me at the pit behind me.

"Where else could I have come from?"

"Thought you might've grown out of the ground. It happens."

"I see. You wouldn't happen to know the meaning of life would you?"

"Look up."

I looked up, and there was the sun. It shone through a cloud. I followed its rays and where they fell the valley vanished and all that remained in that whole expanse was a single tree. It rose high into the sky. A serpent was twined around each branch. I smiled at the man and then began to walk west.

October Rain

by *mam5*

It was past midnight, but not much past. I had been waiting for a long rain. I did not have to wait long. Thank you, October. Thank you, Pittsburgh. My plan was full of holes that would only be filled by hours of trial and error, so speed and stealth were not my weapons tonight. On a rainy night, no one wants to lift up their head. Then again, no one has reason to. Since the Wean freight elevator was rewired to go no further than 8th floor without a key, the space above had not seen an unsolicited footstep for half a decade. And besides, I hadn't even made a single friend among our fine Campus Police yet. In a few years I would have many. In a few weeks I would have my first. And in a few hours, some dusty nooks of the Wean roof would make their first new friend in years. But for now I was focused on my task. The year was 2000, and I was 17.

The Doherty addition had not yet been built. In its place was a much less inviting fire escape winding up the Wean-side wing. In Wean itself, the lock on any door that might lead to the sky was still in its original un-raped condition. Some elders had claimed that the freight elevator could be hacked. Now a sophomore, I was no longer naïve enough to trust a rumor that many believed yet no one could prove. The fire escape was the only way. Problem was, the roof gutter overhung it by a bit. Not only would a small ladder have to be dragged up the escape, it would have to be secured to the top railing and thus unavailable for the further climb.

So after borrowing a ladder of the appropriate size from a place far lower, after much metal clanking and relief for the cover of darkness and rain, after realizing that there was no easy way from the wing onto the main Doherty roof, there I was. Cold, wet, slipping, and yet childishly excited. An image more fitting of these lands than any to have ever graced the cover of our student handbook. My choice was between figuring out how to either get 10 feet higher without a ladder, or a little over 4 feet across from one gutter to another with only bare wall to hold on to. After an hour of battle, the empty air between those two gutters conspired with the nine stories beneath it to defeat my resolve. Right foot on the wing roof and left on the main, one hand holding a gutter and the other fruitlessly searching the brickwork for something to clutch, my still existent spirit of self preservation forbade me from casually pushing off with my back foot and hoping for the best. Horizontal option ruled out I was left with the vertical. The highest thing for me to stand on was a vent curving into Doherty. From it, I could at least put my hands on the part of the roof I wanted to be on. But getting my feet on this wet, angled sheet of metal was another matter.

With nothing better to support me, I had tied some twine around this vent. Several minutes of calculated wiggling allowed me to straddle its top part. The twine now acted like reins around my metal horse. But now I had to stand up, of course, of course. I'd wiggle my way into one position or another, start slipping, and slump back down into my saddle. Wiggle, wiggle, slip, slump. Wiggle, wiggle, slip, slump. Wiggle, wiggle, slip, slide, slide, air.

Some time later, I would actually manage to stand up on the vent, only to discover the uselessness of my new position. I would figure out a way to half-tie down my little ladder so that I could use it for the next part. I would even manage to execute all of this without onset of the seemingly inevitable death side effect of my plan. Yet when I think back on that

drenching night, the most vivid thing in my memory is air. Or to be more specific, the surprise of feeling air rather than the vent beneath me.

For some reason, I had thought that my twine would support me. Half way through my slip, I felt it give way with a light snap. Though the realization of what just happened raced through my mind, I actually remember rationalizing that it must have just slipped a bit rather than snapping, and would still break my fall. But a moment later, technicality gave way to surreal freedom as I felt the air. Refreshing as it may have felt, air failed utterly at providing the type Normal force a vent could. Gravity having not been turned off, the inevitable soon followed. Thud.

Up to this point, I had been very careful on the wet, slanting roof of Doherty. My assumption was that if I did not have conscious control, I would slide straight off. Thankfully, this proved no more true than my faith in the twine. Surrounded by darkness, I felt the rain gently tap my head. Slowly, I woke up to the realization that I was lying face down and prostrate on the roof. Ten feet above me, a torn end of my twine dangled from the vent. But most importantly, to my relieved surprise, I was not sliding. Content with this state of affairs, my brain turned the adrenaline knob off and let the pain flow in.

I learned that failure, when it does not result in death, will only get you closer to success. Eventually, full of bugs and smooth as sand paper, the plan did go off. And perhaps on any of the occasions when I let shoelace knot in the same weak twine hold down an angled ladder that was the only thing between me and the ground, I was actually in much more danger. But my clearest memory, epitomizing both the art of fuckup and the eventual victory, is that empty air. And a lot has changed it three years, but every time it rains hard in October, I still look up out of habit.

Bonus Game: Hey kids! Now you too can play along and be like Misha. Just follow these simple instructions to the Moiseyev play at home game:

Step 1: Climb something that's a little taller than you.

Step 2: Spread your arms, and pretend you're the ruggedly handsome Misha soaring high in the darkness of night.

Step 3: Fall face down.

And as always, remember to send any life-altering metaphysical realizations to Pravda?

A Fairy Tale in Not English

by *epr*

Einmal gab es einen Jungen, der Hans genannt war. Hans wohnte bei seinem Vater und und seiner bsen Stiefrobotin. Der Vater Hans hat die Robotin gebaut, als seine Frau von Tuberkulose gestorben war. Sie wurde von Eisen gemacht und ihr Herz war eine Dampfmaschine. Der Vater war der grsste Erfinder der Welt, aber er konnte nicht die Seele des Seelgerts whlen, und sie wurde von einer schwarzen, dunklen Seele besitzt.

Die drei wohnten in einer Hausmaschine. Das Kind versuchte seine Mutter zu gefallen, aber sie hasste ihn und er musste immer mehr Hausarbeit machen. Jeder Tag putzte er die Ventile und er schaufelte die Kohle. Er lte die Getriebe und er polierte die Nieten. Er versuchte das Problem zu seinem Vater zu erklen aber der Mann liebte seine Metalle Frau und sagte, dass Hans musste sich sie eigentlich angewhnen.

Continued on Page 5

Aber ein Junge kann nur Schrauben so viele Male sortieren, bevor er wegläuft will. Hans packte seinen Koffer und spürte in der Nacht schlief er vom Haus.

Er ging in die dunkle Stadt. Die Strassenbeleuchtung war schwach, und jenseits der Kanten des Lichts konnte er die kratzenden, schliefenden Töne der alten, kaputten Maschinen hören. Hans hatte Angst. Sein Vater hatte ihm oftmals gesagt, dass er nie einer fremden Maschine sprechen sollte. Seine Sorgen wuchsen, als er weiter ging, bis schliesslich kam er zu einer Lampe, die ausstarb, als er unterging.

Plötzlich wurde alles ruhig. Hans zitterte von Angst. Seine Augen passten das schwache Licht an, und er bemerkte die kolossalen, eisernen Körper der arbeitslosen Maschinen. Er drehte sich um und wieder um, aber er war ganz umfassen von den ruhigen Gestalten. Manchmal konnte er sehen, als ein schweres Glied sich bewegte. Hans fiel zum Grund, und er fing an zu weinen.

Hans erwartete, dass er jeden Augenblick gefangen würde, aber es passierte nicht. Die Tränen halteten, und er sah auf. Die Maschinen blieben sitzen. Langsam tritt eine Maschine vor. Es trug ein kleines Box in seinem verbeulten Stielglied. Das Box hatte ein komplizierter Schloss. Es gab das Box dem Kind, und dann nahm es Hans und stellte ihn auf seinen Rücken. Hans klammerte zur dunklen Gestalt, als es langsam die Strasse entlang ging.

Sie kamen zu Hause, und Hans kletterte vom Rücken des metallenen Ungeheuers. Er drehte sich um, um Tschüss zu sagen, aber die Maschine kehrte schon in die Dunkelheit zurück. Das Kind schlief ins Haus und ging ins Bett. Er versteckte das kleine Box unter seinem Kissen und dann schlief er.

Am nächsten Morgen war alles normal. Der Vater ging in seine Werkstatt, und die Stiefrobotin wurde dem armen Hans wieder bese. Er musste sechs Stunden arbeiten, bevor er sich ausruhen konnte. Er ging Germanisch, eine lustige Sprache im Schlafzimmer, und er nahm das Box raus. Im vollen Licht war es gar wunderschön. Es trug Bilder von schönen Robotern, die Flügel hatten. Der kleine Hans versuchte über eine Stunde das Schloss zu lösen, aber es steht nicht in seiner Macht. Schliesslich nahm er das Box zu seinem Vater. Er war sehr vorsichtig, dass seine Stiefrobotin ihn nicht bemerkte.

Als er in die Werkstatt kam, sah sein Vater ihm. "Ach, was ist, Kind? Ich habe viel zu machen."

Hans hob das Box hoch. "Ich habe dieses Box gefunden, aber ich kann es nicht öffnen. Kannst du es machen?"

Der Vater nahm das Box und sah es verwirrt an. Er benutzte seine Werkzeuge und sehr schnell öffnete er das Box. Als er so tat, kam ein helles Licht hervor. Innen sass eine Robotenseele. "Eine Seele? Mein Kind, das ist ein sehr wertvolles Ding, das du gefunden hast. Hast du es gestohlen?"

"Nein Vater! Ich habe es draussen gefunden. Es war neben der Strasse, als ich spielte," sagte er.

"Hm. Interessant. Danke, Kind. Du kannst gehen." Der Vater stellte das Box auf einen hohen Einlegeboden und nahm wieder seine Arbeit auf.

Hans ging in sein Zimmer zurück, und er weinte. Die neue Seele konnte seine Stiefrobotin reparieren, aber es war jetzt ausser Reichweite. Er weinte, bis es Nacht wurde und dann ging er wieder zur Strasse.

Hans erklärte, was passierte mit Tränen in seinen Augen. Er wartete, aber er hörte nichts und sah nichts. Schliesslich wollte

er sich umdrehen, aber genau in diesem Augenblick kam eine neue Maschine hervor, die einen langen Arm hatte. Hans freute sich und er fuhr den kleinen Roboter nach Hause.

Die zwei kroch so ruhig wie möglich zur Werkstatt des Vaters. Der Arm des Roboters erweiterte sich und erreichte den Einlegeboden, auf dem sass die Seele. Hans nahm die glühende Objekt in seinen Händen und sah es an.

Als er so stand, kam seine Stiefrobotin wütend durch die Tür. Zuerst sah sie die kleine Maschine mit dem langen Arm, und sie griff es an. Als ihr Rücken zu Hans war, sprang er auf sie mit der Seele. Blitzschnell riss er ihre Gehirnrinde offen, zog die rostige und schwarze Seele heraus, und steckte die neue, helle Seele ein.

Die Umformung war sofort. Die Stiefrobotin hielt inne, und blickte herum. Plötzlich war sie nicht böse, sondern wurde sie nett und freundlich. Sie sah Hans und kietete vor ihm. Sie sagte, "Hans, verzeihe mich! Ich kann jetzt sehen, wie grausam ich zu dir war." Sie umarmte ihn, und er sie.

Am nächsten Tag war alles ganz anders für Hans. Seine Stiefmutter liebte ihn und gab ihm Torten und Süßigkeiten. Sie säuberte die Werkstatt, bevor der Vater aufstand, und er wusste nie, was passierte. Er war aber froh, dass sein Sohn endlich seine mechanische Frau mochte.

Quantum Computation

by Creidieki

1 Classical symbol – 0

Consider a classical bit with value 0. We know exactly the state of this bit. It has 0 entropy.

2 Classical ensemble

Now, consider a classical symbol, chosen to be 0 with probability $\frac{1}{2}$ and 1 with probability $\frac{1}{2}$. The state of this symbol is "maximally unknown"; we say that it has "one bit" of entropy.

3 Quantum State

Now, we will define a quantum bit. We write the quantum equivalent of the "0" bit as $|0\rangle$, and the quantum equivalent of "1" as $|1\rangle$. We call these quantum bits "qbits". We call this notation a "ket", by the way, for reasons apparent later.

There is an important difference between quantum and classical bits. We will allow any sum of qbits to be a valid qbit. That is, we want to allow states like

$$|0\rangle + |1\rangle$$

$$3|0\rangle - 4|1\rangle$$

There are two mild complications to this method. First, we have some sense that we don't want any qbits to be "bigger" than $|0\rangle$ and $|1\rangle$. If we think of qbits as vectors, with $|0\rangle$ and $|1\rangle$ as a basis, we want all of the vectors to be the same length. We "normalize" the vectors by dividing them by their absolute value; that is, we consider the states

$$\frac{1}{\sqrt{2}}(|0\rangle + |1\rangle)$$

$$\frac{1}{5}(3|0\rangle - 4|1\rangle)$$

Continued on Page 6

The second complication is that quantum mechanics typically requires us to use complex numbers. This paper will avoid introducing complex numbers whenever possible; however, it may be unavoidable in some of the later examples. Example states involving complex numbers are

$$\frac{1}{\sqrt{2}}(|0\rangle + i|1\rangle)$$

$$\frac{1}{\sqrt{3}}(|0\rangle + (1+i)|1\rangle)$$

4 Interpretations

The interpretation of these superpositions of quantum states is not immediately obvious. In particular, consider two states, which we will call $|+\rangle$ and $|-\rangle$:

$$|+\rangle \equiv \frac{1}{\sqrt{2}}(|0\rangle + |1\rangle)$$

$$|-\rangle \equiv \frac{1}{\sqrt{2}}(|0\rangle - |1\rangle)$$

These states seem to be “halfway” between $|0\rangle$ and $|1\rangle$. We plan to use quantum states as inputs to channels, much as with classical states; how is $|+\rangle$ different from sending $|0\rangle$ and $|1\rangle$ with probability $\frac{1}{2}$ each? And how are $|+\rangle$ and $|-\rangle$ different from each other?

It turns out that $|+\rangle$ is very different from simply sending $|0\rangle$ half of the time and $|1\rangle$ half of the time. $|+\rangle$ and $|-\rangle$ represent *quantum* superpositions of $|0\rangle$ and $|1\rangle$, while alternating between $|0\rangle$ and $|1\rangle$ would leave us with a *classical* distribution. We can express both of these ideas with our notation, and we will need them both to study the ability of quantum channels to send classical and quantum information. Before we can deal with these problems, however, we have to develop our ideas somewhat further, by turning to what we want quantum bits to *do*.

5 Measurements

At first glance, it seems like our qbits carry an infinite amount of information. If we wanted to store one bit of information, we choose $|0\rangle$ or $|1\rangle$. If we wanted to store two bits in the same qbit, we could choose from $|0\rangle$, $|1\rangle$, $|+\rangle$, and $|-\rangle$. There wouldn't seem to be any reason why we couldn't choose our state from some extremely large set, corresponding to a huge amount of classical information.

We can certainly make this choice, when we are encoding information. However, the uncertainty principles of quantum mechanics prevent us from *retrieving* infinite information. When we make a measurement, we have to choose two orthogonal states to measure along; once we have made this measurement, our qbit will be left in whichever state is measured.

That is, given a qbit $|\Psi\rangle$, we can measure whether $|\Psi\rangle$ is $|0\rangle$ or $|1\rangle$; this measurement will produce one classical bit. Even if $|\Psi\rangle$ is in a superposition of $|0\rangle$ and $|1\rangle$, our measurement will tell us only “ $|0\rangle$ ” or “ $|1\rangle$ ”. Furthermore, *after* the measurement, $|\Psi\rangle$ will *actually be* $|0\rangle$ or $|1\rangle$, as measured – we will be unable to “go back” to the original state.

We could equally well choose to measure $|\Psi\rangle$ in the $\{|+\rangle, |-\rangle\}$ basis. We receive a result of either $|+\rangle$ or $|-\rangle$, and afterwards we have $\Psi = |+\rangle$ or $\Psi = |-\rangle$, as appropriate.

But since these measurements are destructive, we can get no new information about the original state with any second, or subsequent, measurements. Imagine if we measure $|\Psi\rangle$ in the $\{|0\rangle, |1\rangle\}$ basis, and receive $|0\rangle$, and then measure again, in some other basis. We are measuring a known state ($|0\rangle$); we can learn nothing more about $|\Psi\rangle$.

6 Measurement Results

If a quantum system is in some state $|\Psi\rangle$, and a measurement is made on some basis $\{|a_1\rangle, |a_2\rangle\}$, the chance that $|\Psi\rangle$ will be measured as being $|a_1\rangle$ depends on how close the the states $|\Psi\rangle$ and

$|a_1\rangle$ are; in terms of vectors, it depends on their *inner product*. If we have, for example, a state

$$|\Psi\rangle = |0\rangle + 300|1\rangle$$

and we measure this state on the $\{|0\rangle, |1\rangle\}$ basis, we expect to “almost always” measure $|1\rangle$.

We will formalize the results of measurement in a later section; so far, we do not have the notation for it. For now, we will use the qualitative result to study the behavior of $|0\rangle$, $|1\rangle$, $|+\rangle$, and $|-\rangle$, which will shed light on the difference between classical and quantum superpositions.

7 Measuring $|+\rangle$ and $|-\rangle$

Consider the state $|0\rangle$. If we measure this state on the $\{|0\rangle, |1\rangle\}$ basis, we always obtain $|0\rangle$. Classically speaking, the output has an entropy of 0 bits. If we measure it on the $\{|+\rangle, |-\rangle\}$ basis, we obtain each of $|+\rangle$ and $|-\rangle$ with probability $\frac{1}{2}$. This output has a classical entropy of 1 bit.

Similarly, consider the state $|+\rangle$. If we measure $|+\rangle$ on the $\{|0\rangle, |1\rangle\}$ basis, we find each of $|0\rangle$ and $|1\rangle$ with probability $\frac{1}{2}$, for a classical entropy of one bit. If we instead measure on the $\{|+\rangle, |-\rangle\}$ basis, we always obtain $|+\rangle$; this has a classical entropy of 0 bits.

The states $|0\rangle$ and $|+\rangle$ are very similar. Because of quantum uncertainty, we can always find a basis where a measurement is completely unpredictable. But, in their own bases, they are perfectly known. They are as certain as quantum states can be; and so, we assign to them a “entropy” of zero bits. States like this are called “pure states”.

8 Quantum Ensembles

We are finally in a position to ask how quantum superpositions are different from classical uncertainty. Consider a classical device, perhaps a graduate student, which generates the qbits $|0\rangle$ and $|1\rangle$, each with probability one-half. We call the resulting output ρ , in anticipation of future notation.

If we measure ρ in the $\{|0\rangle, |1\rangle\}$ basis, we obtain $|0\rangle$ and $|1\rangle$ with equal probability; this output has classical entropy 1 bit.

Consider, however, if we measure ρ in the $\{|+\rangle, |-\rangle\}$ basis. If our graduate student has sent $|0\rangle$, we will obtain $|+\rangle$ and $|-\rangle$ with equal probability. If our graduate student has sent $|1\rangle$, we will measure the same thing. In this basis, our classical output *still* has entropy 1 bit.

In fact, the entropy will be 1 bit in any basis we choose to measure. No amount of quantum cleverness or superposition will eliminate the fact that we *do not know* the state of the system.

We say that the entropy of the quantum state ρ is one bit. We will call quantum states with entropy above zero “mixed states”, to indicate that they can be viewed as classical “mixtures” or “ensembles” of multiple pure states.

9 Notation and Formalism

At this point we have hopefully built up some amount of intuition for some of the basic concepts of quantum information. However, if we plan to continue studying quantum information theory, we will need to be able to write about it in more formal and mathematical terms. It is time to develop some notation.

I will mince no words on what we now introduce – our most fundamental, and perhaps only, piece of new notation is the state vector $|\Psi\rangle$, written *backwards*: $\langle\Psi|$. Since we called $|\Psi\rangle$ a “ket”, we will call $\langle\Psi|$ a “bra”; the total is thus rendered “bra-ket notation”, in an unfortunate pun which has survived to this day.

In formal terms, the kets $|\Psi\rangle$ live in what is called a “Hilbert” space, which is a vector space that includes complex numbers and has an inner product. The bras $\langle\Psi|$ live in the “dual” space.